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Fertility Transition in India: Development and Diffusion

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ABSTRACT

Fertility trends in India exhibit much spatial variation, with some regions reaching total fertility rates below 2.0 even as others lag far behind with levels above 4.0. The relevant literature is replete with references to the conditions that have promoted or retarded declines in fertility. There is, however, a tendency to regard development and diffusion as exclusive hypotheses in explaining the differential trends. This may be due to the fact that studies generally focus on economic and social development and treat diffusion as an inherent process. This paper is an attempt to enlarge the focus to look at the pace of fertility change in terms of combinations of both development and diffusion factors as explanations for regional variations. It is an exploratory exercise.

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1. Introduction

Fertility decline has emerged as a worldwide phenomenon towards the end of the last century. This has not prevented the periodic reappearance of pessimistic forecasts about population growth and its consequences. However, slowing population growth is at the same time leading to some balanced reviews of the global fertility transition seen to be surely under way. Such reviews avoid doomsday visions and attempt to describe how social structures relevant to fertility are changing in the different parts of the world and at what pace population growth rates are shrinking. They thus seem to be concerned not only with facts, but-as we read them - also with the contrasting conditions that drive the underlying processes across communities and nations.

One such review has a foreword (Sinding, 2001) saying that no paradigmatic theory of demographic transition has emerged from half a century of research, and goes on to explain:

> "As development occurs in a society through industrialization, urbanization, vocational specialization - and reduced child mortality - and as the value of children declines relative to the cost of rearing them, fertility, too, will decline.This proposition appeared for many years to fit the historical experience of most of today's industrialized countries, although the influential Princeton study of demographic transition in Europe cast serious doubts on how well it actually conformed to patterns of demographic change in eighteenth- and nineteenth-century Europe.

> In any case, classical "structuralist" propositions about the demographic transition - propositions that posit the necessity of fundamental changes in the structure of a society and economy - have come to seem less and less useful in explaining the extraordinarily rapid fertility transition being experienced by many developing countries today. Two features of classical theory, in particular, appear increasingly questionable: that basic changes in social and economic relationships must occur before fertility will change, and that the process is a gradual one that requires many decades to complete. There are simply too many examples of countries that have passed rapidly through the transition, and without many of the structural transformations assumed to be necessary, for the structural model to remain credible. Yet, for many people, scholars and policymakers alike, this model remains a central tenet of population theory and policy."

Reviewing several general theories of fertility, Bulatao (2001:2) lists eight basic factors that are supposed to explain fertility transition. These are: mortality declines - especially among infants and children; reduced economic contribution from children; increasing opportunity costs of childbearing; family transformation from joint to nuclear ones; vanishing cultural props for childbearing - for example by religious injunctions; improved access to effective fertility regulation; postponement of marriage beyond traditional norms; and finally, "diffusion". Except for diffusion, these may be seen as changes in the socio-economic conditions, many of them readily identified with falling fertility regimes in well-documented studies; besides, other frequently mentioned causal variables such as education obviously work as intermediate ones manifesting themselves through those in the list above. The list is fairly exhaustive, but, no doubt, other similar factors could be added to it to illumine specific regional histories. We may regard such an enlarged set as one of "substantive conditions" associated with fertility change, as distinct from diffusion factors to be discussed further below. It must be emphasised however that the difficulty in formulating a general theory lies precisely in extracting a set of conditions, covering both substantive factors and those aiding diffusion, as necessary and (or) sufficient to promote and sustain fertility decline - conditions that can, moreover, explain the historical panorama of fertility change in both the developed and the developing world, from the mid-nineteenth century Europe to Africa of our times. The variety in the past as well as in the present defies simple description and generalisation.

Turning now to diffusion, let us refer again to Bulatao (2001:3):

> "Diffusion refers to the spread of ideas and practices that lead to lower fertility. In a sense, it is not an independent explanation. What diffuses [sic] must be ideas or practices connected with one or more of the preceding explanations, or with some other substantive explanation that may have been overlooked. The diffusion explanation appears to address only the process of, rather than a fundamental reason for, fertility change. Nevertheless, it directs our attention to the fact that individuals and couples do not act in isolation: they interact and influence each other, giving the process of fertility change its particular dynamics".

We may certainly question this line of thinking about diffusion as an explanation that overlooks something else, but let us pursue it with the enlarged view of the diffusion process as one relating not merely to the spread of ideas as such (for example: "we know, small families mean a better life") but also to their acceptance under powerful resistance to change (expressed in sentiments such as: "but we need a son" or "we accept children as divine gifts", and so on) that comes from long-held traditional views of family formation and life. To explain: If fertility has declined substantially in a given region, it is clear that diffusion has indeed taken place there, and that contraception has been emerging as an accepted practice among the poorer and the lower middle classes. The upper middle classes and the rich constitute an island in many countries including India: fertility rates in the aggregate decline significantly in such countries only when contraception spreads to the poor and the lower middle classes. The question to ask then is how diffusion - as perception of the small family advantage, leading further on to the practice of contraception - has been taking place among the poor and the lower middle classes and by what means. At the other extreme there may be regions - and indeed there are such regions in India - where fertility remains high despite the gradual improvement in the substantive conditions that favour small families. In such cases, surely there must be deep-rooted cultural factors that impede the acceptance of contraception. To give an example, the strong preference for sons can slow down fertility transition even as other conditions - such as a significant improvement in education, a rise in living standards, declines in child mortality, and so on - that promote fertility reduction gain momentum. When we consider the working of the diffusion process, it is thus necessary to pay attention not only to the development of education, the content and reach of the mass media, propaganda by the State and by other agencies, etc., but also to widely-accepted cultural norms that lie behind high fertility rates and to social forces that actively support them. In any case the role of diffusion factors - irrespective of whether or not they are independent of theoretically postulated substantive conditions - needs to be analysed for insights into the processes governing fertility reduction.

There are numerous studies of the Indian fertility transition, which attempt to identify the underlying substantive conditions and to elaborate the nature of the diffusion of contraceptive practice. Many of them deal with regional disparities within the country, across the states and the districts within states, some of them looking at all districts in India, very large in number and culturally diverse. We may refer in this context to Dreze and Murthi (2001), Guilmoto and Irudaya Rajan (2005), and to the many studies cited therein, all concerned with what has been driving a decline in fertility rates in India. Most of the identified factors in these studies correspond in some fashion to those in the Bulatao review referred to earlier, but, understandably for the Indian case, they include other variables such as caste, religion and female empowerment (and agency) defined in different ways, all of them important for explaining regional disparities in India. In this paper, however, we approach regional and temporal variations by a different route, by first focusing on the relative speeds with which fertility has been declining in the different parts of the country since the 1970s. This procedure, combined with some analysis of what lies behind variations in speed, is of course logically equivalent to the analysis of spatial variations in levels of fertility at several points of time; but, as we shall see, analysing trends by region as a first step provides some interesting insights into transition as a dynamic process. This study is largely exploratory, aimed at gaining some knowledge into development and diffusion not as exclusive hypotheses but as essential and interacting elements in explanations of fertility change. The mapping of the complex interactions of this type across states is a formidable task, but many clues are available even from a cursory analysis of differential trends.

2. Data and Method

To study variations in the pace of decline we need first to answer the question: when did fertility begin to decline? Even with data over a long period it is not easy to answer the question since pre-transitional levels tend to fluctuate, exhibiting declines over some periods, so that a starting point for the declining trend cannot be determined unambiguously. The influential Princeton European study solved the problem by assuming fertility transition to be under way when a decline of ten per cent or more occurs from a peak (Coale and Treadway, 1986). Ignoring the arbitrariness behind this definition, it still does not lead to an operational concept of the starting point from the available Indian data. Let us see why. The Sample Registration System (SRS) provides annual estimates of the total fertility rate (TFR) for all states in India, and for their rural and urban parts, from 1971 onwards. Since fertility levels have begun to decline demonstrably during the 1960s and possibly earlier in some urban areas, these data do not help us to answer the question about the starting points; but they do allow us to make interregional comparisons in the speed of decline since 1971. Alternatively, the data enable us to look at the time points at which specific TFR levels, such as 5 or 4 or 3, were attained in the different regions in which such levels have actually been observed in the post-1971 period. However, fluctuations arising from sampling and non-sampling errors still pose a problem. For example, the SRS estimates of TFR values for rural Andhra Pradesh for the nine-year period 1979-1987 are in succession: 4.2, 4.0, 4.2, 4.2, 4.1, 4.1, 3.8, 4.1 and 3.8. Such a trend does not enable us to determine through simple inspection (by the naked eye or by graphs) the year when a level of 4.0 was reached from earlier higher rates - a task otherwise easily and unambiguously done by fitted curves. It is clear that we need to smooth the data through an appropriate model so as to uniquely determine (or, to estimate, to be more precise) a time point corresponding to a specified TFR level, say 5 or 4. A caveat about smoothing: it is risky to use a fitted curve to extrapolate TFR outside the observed range: for example, to estimate when a replacement level of 2.1 would be reached or when a TFR of 6.5 or 7.0 prevailed in the past. This is because the Indian states and regions are observed in the available data from 1971 to be in different phases of the transition process; a pure time trend is unlikely to yield sensible predictions of the future or projections into the past, in all cases. However, smoothing does help us to interpolate values within the observed ranges. All this is made more explicit in the model discussed below.

Let us write

(1) $f_{jt} = M_j\,(1 - p_{jt})$,

where $f(.)$ refers to the total fertility rate (TFR) and $p(.)$ to the proportion of women in the reproductive ages (say, 15-49) preventing births (that is, not choosing to have a child, in the given region and the year); the suffix j refers to the region/state (for example, rural Andhra Pradesh) and the suffix t to the time period (year),. Here M_j is the hypothetical maximal (or natural) fertility rate that would obtain when no woman prevents birth (p = 0).

Equation (1)) holds strictly within age groups of women and can be valid only as an approximation when aggregated over age groups: this is because while the left hand side is independent of the age distribution of women (TFR being defined simply as the sum of age-specific fertility rates), the aggregation of the right hand side involves the age distribution of women - which however may be expected to change but slowly under transitional regimes. Note also that women preventing births are different from "acceptors" in family planning statistics, as reflected, for example, in couple protection rates (CPRs) - referring to practitioners of modern surgical, chemical and barrier methods - because only some and not all acceptors choose birth prevention in a given year. (Of course, sterilisation leaves no choice.)

A word about the natural fertility rate: conceptualised in different ways, it refers to the maximum under given traditions and cultural conditions that limit fertility to some extent such as age at marriage, periods of non-cohabitation, duration of breastfeeding, pre-modern practices of contraception, and so on. What matters thus is not a physiological or biological maximum but a culturally regulated one- specific to communities and regions.

In this paper, we posit a logistic time path for pjt, with an upper asymptote at p^*_j. For any given region, dropping the suffix j, we assume

(2) $dp/dt = bp\,[1-(p/p^*)]$.

This means that the increments in p will be bell-shaped, increasing from zero, attaining a maximum at $p^*/2$, and tapering off thereafter. A heuristic argument and some data in support of the logistic curve follow later in this section. The solution to (2) (as well as to its alternative as a difference equation for discrete time sequences) is a 3-parameter logistic of the form

(3) $p_{jt} = p^*_j / [1+exp(- a - bt)] = g_j(t \mid p^*, a, b)$.

Rewriting (1) as

(4) $[1 - (f_{jt} / M_j)] = p_{jt}$

and combining (3) and (4), we get a time path for the observed TFRs, a 4-parameter logistic of the form

(5) $f_{jt} = M_{\mathrm{j}} [1 + g_j(t \mid p^*, a, b)]$.

A little reflection shows that an efficient estimation of the parameters in (5), namely *M, p**, a and *b* is possible - and makes sense - only when the observed range of TFR values (in any given Indian region) includes all the phases, from the pre-transitional *M* levels to the ultimate low values. In this exploratory exercise, we circumvent this by trying values for *M* in each case within a plausible range and estimating the remaining three parameters, the final choice made and given here on the basis of the R^2 criterion and plausible values for other parameters. To elaborate: if the 1971 TFR value is 5.0, we assume the relevant *M* to be in the range, say, of 6 to 7.5, and work with values in that range by increments of 0.25, and pick the one that yields the best by the above criteria, In practice we have used (dropping suffixes) the function

(6) $[1 - (f / M)] = b_1 / [1 + \exp(b_2 b_3 - b_2 t)]$,

computing the left hand side values from the *f* (TFR) data and the assumed *M* values (derived by the procedure explained above); *t* refers to the year and b_1, b_2, and b_3 to the parameters, b_1 being the upper asymptote p^*. The estimated equation (6) enables us to work out the *t* values that correspond to specified TFR levels. We however use this procedure for estimating times taken (speeds) for declines from levels of 5 to 4 or from 4 to 3 mostly in cases when these values are in the observed ranges. In other words, the smoothing is used mostly for interpolation; extrapolation is done cautiously, when, for example, a value such as 3.9 is in the observed range, to derive a time point corresponding to 4.0 that is close to a value in the range.

Before we present the data and analysis, a word about the appropriateness of the logistic model in the present context is in order, The logistic growth curve fits well to many types of observed time-series associated with dynamic population processes such as the undesirable spread of rumours and epidemics but also to the expansion of innovative knowledge and practices of many kinds supporting human progress. What is common to all these processes is that the outcome is the result of interactions among members of large populations. Indeed in many such processes the incremental growth tends to bell-shaped as in equation (2), yielding an S-shaped time series with possible lower and upper asymptotes. (Rumours and contagious diseases begin slowly, gain momentum and die down ultimately- with varying durations in the different phases.) The versatility of the logistic in this respect has led to models of "cultural transmission" that seek to integrate the effects of biological and cultural factors in the process of change (see, for example, Cavalli-Sforza and Feldman, 1981). We should however listen in this context to the words of caution by the celebrated probability theorist William Feller (1966:52) " [A]n unbelievably huge literature tried to establish a transcendental "law of logistic growth"; measured in appropriate units, practically all growth processes were supposed to be represented by a [logistic] function ...Lengthy tables, complete with chi-square tests, supported this thesis for human populations, for bacterial colonies, development of railroads, etc... Theories of this nature are short-lived because they open no new ways" He goes on to say that naïve reasoning as such must be supported by common sense. The warning suggests that for credibility a plausible model, fully supported by empirical data, appropriate to any given situation, must back up the use of a logistic curve. Equations (1) and (2) together with some actual data on contraceptive users discussed below constitute such a model for fertility transition.

Despite the simplicity and the general applicability of the cultural transmission model, there is without doubt a need to identify and to understand the working of specific factors relevant to fertility change. While we do not attempt to meet this need in full measure here given the exploratory nature of this study, we list a few obvious features of factors that govern the diffusion of contraceptive practice. For example, education is expected to play a major role in this respect, but even under unimpressive development of formal education - as judged for example by literacy rates in census statistics - diffusion can take place by other means: propaganda by the organs of the State backed by incentives to limit family size, the content and reach of the mass media such as television and cinema, and so on. On the other hand, diffusion may be slow in the face of cultural resistance to the idea of contraception and family limitation. Another set of factors in this context relates to what is sometimes described as "infrastructure", in particular to facilitate means of communication: we may refer here to the fact that many villages in India are poorly connected by road and rail, with negligible schooling facilities, and so on.

To see how well the logistic explains the spread of contraceptive practices we present in Table A1 (in the Appendix) trends in the couple protection rates (CPRs, referring to couples practising contraception) for the period 1970 to 1998 in Tamil Nadu and India as a whole. The data show that this rate increased during that period from 12.5 per cent to 50.8 per cent in Tamil Nadu, and from 9.4 per cent to 45.4 per cent in India. Table 1 gives the corresponding logistic fits to these figures.

Table 1: Estimated Parameters of a Logistic Curve Fitted to Data on Couple Protection Rates

Region	b_1	b_2	b_3	R^2
Tamil Nadu	62.85 (5.02)	0.138 (0.023)	11.62 (1.52)	0.987
India	53.82 (2.91)	0.130 (0.012)	12.77 (1.06)	0.996

Note: The logistic is of the form: Couple Protection Rate = b_1 /[1 + exp (b_2b_3 - b_2t)], where t refers to time (year). The numbers in parentheses are standard errors.

It can be seen that the 3-parameter logistic fits extremely well to the CPR data, with all the parameters statistically significant at the 1 per cent level. The estimated ceiling rates are 62.85 per cent and 53.82 per cent for Tamil Nadu and India respectively. But as we have suggested earlier, empirical fits based on a limited observed range of data (not covering all the three phases of transition) may not provide reliable estimates for the upper asymptote. The logistic can however be safely used as a device for describing trends in the observed data and hence for smoothing and interpolation in the corresponding time range.

3. Results

Annual estimates of the total fertility rate (TFR) for all regions in India with a few gaps are available from 1971 onwards from the Sample Registration System (SRS). Some less-detailed estimates based on census data have however been worked out for the 1960s in some studies. For the pre-Independence period, we have some reviews of fertility based on crude birth rates (CBRs) as in Visaria and Visaria (1984:463-532). These studies do not tell us much about the levels of pre-transitional fertility and how they had been changing before the 1970s, particularly for capturing interregional differences. The estimates for 1961-71 by Mari Bhat et al. (1984) show a range of interstate variation in TFR from 4.66 in Tamil Nadu to 6.9 in Haryana. Similarly, Rele (1987) provides estimates for the period 1961-66, ranging from 4.8 in Tamil Nadu to 7.2 in Haryana. Thus natural fertility, or the maximal one as we have postulated in equation (1) above, could have been as high as 7 or higher in some regions; at the lower end of the range - particularly in the urban areas - it was possibly 6 or less.

Table 2: Total Fertility Rate: India, 1971 - 2005

Year	Total	Rural	Urban
1971	5.2	5.4	4.1
1981	4.4	4.8	3.3
1991	3.6	3.9	2.7
2001	3.1	3.4	2.3
2005	2.9	3.2	2.1

Source: Sample Registration Bulletin, various issues.

We are on a firmer ground for the years after 1971. Table 2 sets out the TFR estimates for the country as a whole for specified years. In urban India TFR declined from 4.1 in 1971 to the rough replacement level of 2.1 in 2005; this means that on average it has taken 17 years to achieve a reduction of 1 birth per woman in TFR terms. In rural areas the reduction in TFR was from 5.4 (1971) to 3.2 (2005), with a speed of decline of about 15.5 years per birth. Given sampling errors, any suggestion of a learning process - usually associated with late starters - at work in rural areas by the observed, slightly faster pace of transition must remain in abeyance,

To examine interregional variations we begin by looking at trends in the urban areas of 15 major Indian states (Table 3). The data show that levels of fertility at or below replacement level (2.1) have been reached by as early as 1991 in Tamil Nadu, Kerala, West Bengal and Assam; by 2005 many other states have joined these ranks: the exceptions are, apart from Gujarat and Haryana (regions that have been advancing in economic terms but are perhaps bogged by traditionally high fertility rates), the so-called BIMARU states, Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh. What is notable is that declining trends from 1971 are clearly seen to have been at work all over urban India, even among the poorer and the backward states; however, the initial levels would continue to influence variations across states until replacement levels are attained everywhere. Moreover, urban cultural and living conditions that promote small families, expected to have been at work in Maharashtra, Tamil Nadu and West Bengal, states with large cities, have perhaps been developing in other, less industrialised states with growing populations in medium-sized cities and big towns. On the other hand, cultural resistance to diffusion of the small family norm even in urban areas may account or the unimpressive declines in fertility in Gujarat and Haryana, not to speak of the BIMARU states, backward in all respects.

Rural rates (Table 4) exhibit similar interregional contrasts. Replacement levels of TFR or those below them have been attained by 1991 in Kerala, surely where it all started. Tamil Nadu's progress in this respect has been only slightly less impressive, with a lower speed of transition. Andhra Pradesh and Punjab have been coming close to the goal of replacement levels. The most striking, but not unexpected, aspect of the rural data is the persistence of high fertility in the BIMARU states. Some states such as Punjab and Gujarat, where traditional levels were high, have been experiencing accelerated declines from 1981.

Let us now refer in passing to the much-discussed Kerala experience. In urban areas both Tamil Nadu and Karnataka were ahead of Kerala in the course of transition, readily seen from the changes in the TFR between 1971 and 2005: in Tamil Nadu from 3.3 to 1.6, in Karnataka from 3.4 to 1.8 and in Kerala from 3.8 to 1.7. Kerala's true achievement is in the reduction of fertility in its rural parts; rural Kerala is at the top (in Table 4), in terms of both low levels and the speed of decrease to replacement levels. But then, rural Kerala is distinctly different from the rest of rural India in many respects (more on this theme later).

Table 3: Total Fertility Rates, Urban Areas, 1971-2005

State	1971	1981	1991	2001	2005
Tamilnadu	3.3	2.7	2.0	1.8	1.6
Karnataka	3.4	3.0	2.5	1.9	1.8
Kerala	3.8	2.4	1.7	1.7	1.7
Andhra Pradesh	3.8	3.0	2.5	2.0	1.7
West Bengal		2.4	2.1	1.6	1.4
Maharastra	3.9	3.0	2.5	2.2	1.9
Orissa	4.3	3.7	2.3	2.1	1.7
Assam	4.3	2.6	2.1	1.8	1.6
Punjab	4.4	3.4	2.8	2.1	1.9
Haryana	4.6	3.5	3.0	2.5	2.3
Gujarat	4.6	3.5	3.0	2.5	2.3
Madhya Pradesh	4.7	3.9	3.4	2.5	2.5
Uttar Pradesh	4.9	4.1	3.7	3.4	3.3
Rajasthan		4.2	3.7	2.8	2.7
Bihar		4.8	3.5	3.1	3.2

Note: Blank spaces indicate non-availability of data. States are arranged in increasing order of the 1971 rates.
Source: As for Table 2.

Table 4: Total Fertility Rates, Rural Areas, 1971-2005

State	1971	1981	1991	2001	2005
Kerala	4.2	2.9	1.8	1.8	1.7
Tamilnadu	4.2	3.7	2.3	2.1	1.8
Andhra Pradesh	4.8	4.2	3.1	2.4	2.2
Karnataka	4.8	3.8	3.3	2.6	2.5
Orissa	4.8	4.3	3.4	2.7	2.7
Maharastra	4.9	4.0	3.4	2.6	2.4
Punjab	5.5	4.1	3.2	2.5	2.2
Assam	5.8	4.2	3.6	3.2	3.1
Gujarat	5.9	4.6	3.2	3.2	3.1
West Bengal		4.8	3.6	2.7	2.4
Rajasthan		5.5	4.9	4.3	4.0
Madhya Pradesh	6.1	5.5	4.9	4.3	4.0
Bihar		5.8	4.5	4.6	4.4
Uttar Pradesh	6.9	6.1	5.4	4.8	4.5
Haryana	7.3	5.3	4.3	3.3	3.0

Notes and Sources: As for Table 2 and 3.

Statistics of the three-parameter logistic curve fits for the different regions, urban and rural, in the major Indian states are given in Tables A2 and A3 in the Appendix. The fits are based on the SRS annual data for the 35-year period 1971-2005. In estimating these logistic curves we have used equation (6), following the procedure outlined earlier for choosing the M values, experimenting with values in plausible ranges. Barring a very few exceptions, the logistic fits extremely well to data in all regions, urban and rural.

Estimates of times taken in the different regions to achieve reductions of a unit (one birth per woman) in TFR levels (from 5 to 4, 4 to 3, etc.) derived from the estimated logistic curves are given in the Appendix (Tables A4 and A5). These refer to the urban and the rural parts respectively of the 15 major Indian states. Consider first the urban areas. The TFR levels in the BIMARU states, Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh, have still (by 2005) to reach replacement levels. At the top are the four southern states, Tamil Nadu, Karnataka, Kerala and Andhra Pradesh, the early starters in the transition process judged by the 1971 levels. Seven states, namely, West Bengal, Maharashtra, Orissa, Assam, Punjab, Haryana and Gujarat, fall in the intermediate range. Leaving aside the BIMARU laggards, it is only for Orissa and Punjab that we find somewhat faster rates of change in TFR from 4 to 2 than among the southern states, barring incomparable Kerala, A notable feature of this variation in speeds in urban areas is that Maharashtra and West Bengal have lagged behind the southern states arguably less endowed with urban cultures and ways of living: a puzzle worth pursuing. Turn next to the rural areas. Table A5 tells us that in the transition from 5 to 4 in the TFR levels a number of states in the intermediate range (by the 1971 TFR values), namely Punjab, Gujarat, West Bengal and Haryana, have done it faster (in around 8 years) than did the leaders, Andhra Pradesh and Karnataka (in 12 years or so), implying thereby a learning process of some kind at work among the latecomers. On the other hand, the laggards Rajasthan, Madhya Pradesh and Uttar Pradesh have taken about 18 years to achieve a reduction in the TFR from 5 to 4, exhibiting perhaps backwardness and resistance to change of many dimensions.

Looking at speeds at given levels of TFR across regions thus provides some clues as to whether late starters perform better by virtue of a learning process associated with the transmission of knowledge. There is however a different way of analysing spatial variations in the pace of decline. We show below that with a few simplifying assumptions equation (1) leads to such a procedure. Assuming that pjt is a function of a set of independent variables, the equation can be rewritten as

$$(7) \qquad [1 - (f_{jt} / M_j)] = p_{jt} = g_j(X_{jt}),$$

where X_{jt} is a matrix of development and diffusion variables and $g_j(.)$ are region specific functions of some unknown form. Note that since the p_j have an upper asymptote pj^*, the functional form should be a mapping into the open interval (0,1), i.e., yielding values below unity. It would then be possible to use (7) to study cross-sectional data. Indeed, a variant of this is the grist to the mill of fertility variation studies. Many of these refer to large data sets - covering, for example, in the Indian case, TFR and its many presumed correlates at the district level. The largeness of data enables the inclusion of numerous relevant factors on the right hand side of (7). However, such studies hardly - if ever - discuss the role of pre-transitional, culturally determined, high levels of fertility and their continuing influence on regional variations during transitional regimes. In other words, TFR values are in such studies directly regressed on a set of independent variables, without reference to maximal or natural fertility (*M* values that we have introduced here). The use of dummy variables in these regressions for specific regions, caste compositions, etc, redresses this defect to some extent. But we need a coherent model of the type we are pursuing here for understanding persistent differences across space.

We make the further simplifying assumption that the g_j are linear, with two additive components, a region-specific factor that remains roughly constant over time and the other determined by development and diffusion factors, captured in combination by some index that can be used for empirical experiments. The assumption here is that the effects of cultural resistance factors such as a strong preference for sons changes slowly, if at all. This means that across regions fertility change (rather than absolute level of TFR) is determined by the substantive and diffusion factors referred to earlier. More precisely, we write

$$(8) \qquad p_{jt} = \alpha_j + \beta \; G(X_{jt})$$

where the j are state-specific effects, β a constant, and *G* an index of development and diffusion based on *X*. If we then consider fertility change between two time points, say f_2 and f_1 corresponding to times t_2 and t_1, combining (7) and (8), and taking the differences between the two time points we get a relationship

$$(9) \quad (f_{1j} - f_{2j})/Mj = \beta \; (G_{2j} - G_{1j})$$

valid across the regions, in which the *j* as they appear in (8) are eliminated via the differencing over time periods. In other words, the change in fertility between two periods as a ratio of the maximal fertility is proportional to the change in the index *G*. Note that the left hand side in (9) is a measure of the speed of transition.

Indeed that such a relationship makes sense is demonstrated by regressions of interstate differences in TFR declines between 1981 and 1991 on changes in the Human Development Index (HDI) during that period (Table 5; HDI data are in Table A6). In rural areas, variations in fertility reductions as a proportion of (estimated) pre-transitional levels among the states are explained to the extent of 92 per cent by improvements in the HDI. In urban areas the R^2 is lower at 0.75, obviously because of factors in urban living that drive fertility down irrespective of development and also because urban areas all over India are well endowed with the means for communication. Since the variations in the true *M* values (as against the experimental ones we used here) among regions are not expected to be large, we also tried these regressions dropping the *M* values in (9). The last two rows of Table 5 exhibit good fits of these modified regression, with slightly lower R^2 values: nevertheless, they are useful because they express rough proportionality between changes in fertility rates and those in an index that combines development and diffusion, as observed among the different regions in India, and further classified by rural or urban residence.

Table 5: Linear Regressions of Fertility Change on Changes in the Human Development Index Across 15 Major Indian States: 1981-1991

Dependent Variable	Residence	Estimated	Standard Error	R^2
$(f_{81} - f_{91})/M$	Rural	1.636	0.126	0.92
$(f_{81} - f_{91})/M$	Urban	1.098	0.171	0.75
$(f_{81} - f_{91})$	Rural	11.31	0.99	0.90
$(f_{81} - f_{91})$	Urban	6.57	1.03	0.74

Notes: *f(.)* refers to TFR and *M* to maximal fertility as explained in the text. Note also that the regressions are estimated without a constant term, in accordance with equation (9) in the text.

A word about the choice of the Human Development Index in this empirical experiment is in order. No doubt, the index must be replaced, in more probing and substantial work than is being reported here, by one based on a larger set of the relevant development and diffusion variables. However, we should note that the three components of HDI, income, education and health (captured by proxies), are all relevant to fertility change. In particular, education may be regarded as a diffusion-enabling variable. Low speeds of transition in the rural parts of the BIMARU states are thus explained to a large extent by poor development of education, health etc; low speeds also lead to the persistence of high fertility. What is striking about this preliminary quantitative exercise is that a crude first approximation to our approach via the HDI seems to work well. However, it is only changes - or speeds - in fertility decline that are explained by improvements in a composite development index, so that the influence of pre-transitional variations remain over time, and interregional convergence can come about only through faster rates of development and diffusion in the backward regions. This is no doubt a trite observation, but the methodology here, employed in further research, can throw light on aspects of backwardness of kinds not adequately discussed in the literature. In this context we may refer to the fact that villages large in (population) size tend to have better facilities for education and health, better roads etc than do small and geographically isolated villages. Statistics of mean village size and the proportion of villages linked to roads (Table A7) show for example that the BIMARU states are handicapped by large percentages of unlinked villages, and barring in the case of Bihar the average village size in these states is relatively small.

4. Discussion

Pending a further elaboration of the diffusion process, we now refer to a few examples that suggest its importance.

Rural-urban differences in the several dimensions of economic and social development in India have been sharp and are persistent. Differences in services for education, maternity and child care, transport and communication - among those relevant to the spread of contraception, whether by perception or by persuasive propaganda - have no doubt played a crucial role in keeping rural India far behind urban areas in the processes of fertility decline. Kerala is an exception in this respect because of its unique pattern of human habitat, a continuous one over space with no clearly defined village boundaries, and with well-developed road connectivity and transportation. The extraordinary average village size of over 15000 people in Kerala (Table A7) is the result of artificially designed boundaries for administrative purposes in that continuum .

Kerala is exemplary for other reasons as well. The early onset of mortality and fertility declines in this region has understandably led to a revision of the classical theory of demographic transition, bringing to the foreground questions about the necessary and sufficient conditions that can be postulated for transitional processes. The Kerala experience showed that rapid demographic changes are possible even under conditions of poor economic and industrial expansion; and that "urbanisation" viewed as a motor for cultural change has other vital components. Studies demonstrated that "public action" - as it is called in recent literature - encompassing multiple agencies, has played an important role in the social transformation of the region. While leaving the issue of necessary and sufficient conditions for a theory of fertility transition somewhat open, the Kerala social development model nevertheless became a common referent in discussions of the dynamics of population in India.

The rapid fertility declines in Tamil Nadu and Andhra Pradesh that followed during the 1980s and the 1990s led to further doubts about generalisations since they could not be associated neatly with either a model of the classical type or of a Kerala type of social development. Indeed, a comprehensive study of the Tamil Nadu experience by Nagaraj (2000) draws our attention to the fact that the state's achievement in raising female literacy, lowering infant mortality, etc (presumed pre-conditions for a rapid decline in fertility) has by no means been as impressive as in Kerala. Analysing the socio-economic changes responsible for the birth rate in Tamil Nadu dipping to levels as low as in Kerala, he refers, inter alia, to several diffusion factors such as the strong rural-urban linkages that have been emerging, the changing patterns of mobility, the spread of mass media, all of which playing an important role in the transition process. Summarising the process as a phenomenon of "social capillarity", he suggests that it represents the dynamics of a large section of the population, mainly poor, adopting family limitation as a means of bridging the gap between increasing aspirations and resources to meet them, A similar suggestion has been made earlier by Kishor (1994).

The course of fertility decline in Andhra Pradesh (AP) is yet another example that does not conform to a model derived from the Kerala experience. Indeed an early study of the transition in AP has the suggestive subtitle; "A Search for Alternative Hypotheses" (James, 1999). The latest data from different sources show that the TFR in this state has declined to 1.8 by 2005; moreover, the rural-urban differences have all but disappeared, along with a considerable narrowing of differentials across social groups and among categories of women with varying levels of education, and so on. A large part of the decline took place during 1987-96, a period of improvement in the components of the HDI, the levels of which however are still far short of the Kerala values (for details see CESS, 2008: 79). An amazing aspect of this decline is that Srikakulam, one of the poorest districts in the state - with a high infant mortality rate and a very low female literacy rate - has by 1996 recorded a TFR below replacement level (Ramachandran and Ramesh, 2005:123). Because of its backwardness and poverty the district has a highly migrant rural population; and migration no doubt leads to contact with urban life and aids the transmission of knowledge through informal channels. Nagaraj's analysis of Tamil Nadu is valuable in this context for it points to rural-urban integration as an important vehicle for change, and to the different routes by which such integration strengthens.

These examples of the southern region illustrate how different combinations of development and diffusion factors can drive fertility down to replacement levels at a fast rate. Backwardness that is responsible for a slow pace of change as in the BIMARU states, likewise, reflects features of both sets of factors.

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APPENDIX

Table A1: Couple Protection Rates: Tamil Nadu and India, 1970-1998

Year	India	Tamil Nadu	Year	India	Tamil Nadu
1970	9.4	12.5	1985	32.1	36.1
1971	10.4	13.3	1986	34.9	41.1
1972	12.2	16.1	1987	32.5	46.3
1973	14.5	18.8	1988	39.9	52.6
1974	14.7	19.1	1989	41.9	55
1975	14.8	20.7	1990	43.3	57.1
1976	17	22.7	1991	44.1	57.3
1977	23.5	28.5	1992	43.6	57.3
1978	22.5	27.7	1993	43.5	54.5
1979	22.4	28.3	1994	45.4	54.5
1980	22.3	27.8	1995	45.8	54.8
1981	22.8	27.8	1996	46.5	53.5
1982	23.7	27.7	1997	45.4	51.7
1983	25.9	28.4	1998	45.4	50.8
1984	29.2	32.1			

Source: Rajna et al. (2005)

Table A2: Trends in Total Fertility Rates: Logistic Fits, Urban Areas, 1971-2005

State	*M*	b_1	b_2	b_3	R^2
Tamilnadu	5.25	0.88	0.052	6.80	0.993
		(0.16)	(0.017)	(7.30)	
Karnataka	5.25	-	-	-	-
Kerala	5.50	0.70	0.133	0.16	0.998
		(0.01)	(0.012)	0.46)	
Andhra Pradesh	5.75	1.96	0.051	14.05	0.996
		(0.17)	(0.012)	(7.37)	
West Bengal	5.25	1.09	0.036	15.97	0.999
		(0.37)	(0.015)	(18.76)	
Maharastra	5.50	0.85	0.046	10.42	0.996
		(0.16)	(0.012)	(8.31)	
Orissa	5.50	0.82	0.075	13.43	0.995
		(0.08)	(0.011)	(2.90)	
Assam	6.00	0.72	0.092	-1.48	0.997
		(0.03)	(0.018)	(1.04)	
Punjab	5.50	0.86	0.062	14.22	0.998
		(0.08)	(0.008)	(3.25)	
Haryana	6.75	0.81	0.050	5.47	0.997
		(0.12)	(0.014)	(6.17)	
Madhya Pradesh	6.50	0.86	0.052	12.74	0.996
		(0.16)	(0.012)	(7.51)	
Uttar Pradesh	6.50	-	-	-	-
Rajasthan	6.50	-	-	-	-
Gujarat	7.00	0.81	0.060	4.10	0.998
		(0.05)	(0.009)	(2.04)	
Bihar	7.50	0.60	0.151	8.36	0.998
		(0.02)	(0.027)	(0.73)	

Note: The logistic is of the form: $[(1\text{-}ft)/M] = b_1 /[1 + exp\ (b_2 b_3 - b_2 t)]$, where t refers to time (year), fitted to the 35-year period annual data on total fertility rates *ft* from the *Sample Registration Bulletin*. The numbers in parentheses are standard errors. See text for further details on the estimation procedure. Blank spaces indicate poor logistic fits by specified criteria.

Table A3: Trends in Total Fertility Rates: Logistic Fits, Rural Areas, 1971-2005

State	*M*	b_1	b_2	b_3	R^2
Kerala	6.25	0.74	0.132	1.49	0.998
		(0.12)	(0.012)	0.43)	
Tamilnadu	6.25	0.76	0.089	6.34	0.997
		(0.03)	(0.010)	(0.98)	
Andhra Pradesh	5.75	1.96	0.051	14.05	0.996
		(0.11)	(0.009)	(4.45)	
Karnataka	6.25	-	-	-	-
Orissa	6.25	0.94	0.051	23.60	0.994
		(0.26)	(0.011)	(11.30)	
Maharastra	6.50				
Punjab	7.75	0.75	0.086	4.93	0.998
		(0.03)	(0.009)	(0.88)	
Assam	6.50	0.55	0.099	6.22	0.976
		(0.06)	(0.031)	(2.49)	
Gujarat	8.00	0.64	0.119	4.21	0.998
		(0.01)	(0.009)	(0.41)	
West Bengal	6.50	0.71	0.118	15.43	0.998
		(0.03)	(0.011)	(0.74)	
Rajasthan	7.75	-	-	-	-
Madhya Pradesh	7.50	0.53	0.085	9.34	0.960
		(0.11)	(0.036)	(5.37)	
Bihar	7.75	0.44	0.142	9.40	0.997
		(0.02)	(0.030)	(0.78)	
Uttar Pradesh	8.00	0.61	0.057	18.85	0.997
		(0.10)	(0.009)	(6.04)	
Haryana	8.50	0.66	0.105	9.01	0.994
		(0.34)	(0.014)	(1.21)	

Note: See note to Table A2.

Table A4: Times taken (in years) for Changes in Given Levels of Total Fertility Rate: Urban Areas

State	TFR 1971	T5-4	T 4-3	T 3-2
Tamilnadu	3.3	-	-	17.7
Karnataka	3.4	-	-	22.4
Kerala	3.8	-	8.0	12.7
Andhra Pradesh	3.8	-	14.8	14.7
West Bengal		-	24.5	21.6
Maharastra	3.9	-	19.2	20.6
Orissa	4.3	-	12.2	13.7
Assam	4.3	-	10.5	18.4
Punjab	4.4	-	13.4	14.8
Haryana	4.6	-	15.4	22.2
Gujarat	4.6	-	12.7	18.3
Madhya Pradesh	4.7	15.4	14.1	-
Uttar Pradesh	4.9	20.1	25.9	-
Rajasthan		19.1	24.6	-
Bihar		12.1	15.6	-

Note: T 5-4 represents years taken for TFR to decline from 5.0 to 4.0, etc. These are estimated from the logistic fits presented in Table A2; in the few cases where the logistic was a poor fit, a semi-log trend (ln Y = a +b*t) was used instead. The blank spaces indicate that the relevant T values are outside the observed TFR range during 1971-2005.

Table A5: Times taken (in years) for Changes in Given Levels of Total Fertility Rate: Rural Areas

State	TFR 1971	T5-4	T 4-3	T 3-2
Kerala	4.2	-	6.9	11.9
Tamilnadu	4.2	-	9.8	15.3
Andhra Pradesh	4.8	12.1	11.2	13.2
Karnataka	4.8	12.4	16	-
Orissa	4.8	16.3	13.5	-
Maharastra	4.9	12.4	16	-
Punjab	5.5	8.2	10.4	-
Assam	5.8	11.8	30.3	-
Gujarat	5.9	7.8	20.6	-
West Bengal	-	7.6	8.3	-
Rajasthan	-	18.6	-	-
Madhya Pradesh	4.7	17.2	-	-
Bihar		-	-	-
Uttar Pradesh	4.9	18.4	-	-
Haryana	4.6	8.5	23.9	-

Note: Derived from Table A3; see note to Table A4 for additional notes.

Table A6: Human Development Indices, 1981 - 2001

State	Rural 1981	Rural 1991	Urban 1981	Urban 1991	All 2001
Andhra Pradesh	0.262	0.344	0.425	0.473	0.416
Assam	0.261	0.326	0.380	0.555	0.386
Bihar	0.220	0.286	0.378	0.460	0.367
Gujarat	0.315	0.380	0.458	0.532	0.479
Haryana	0.332	0.409	0.465	0.562	0.509
Karnataka	0.295	0.367	0.489	0.523	0.478
Kerala	0.491	0.576	0.544	0.628	0.638
Madhya Pradesh	0.209	0.282	0.395	0.491	0.394
Maharastra	0.306	0.403	0.489	0.548	0.528
Orissa	0.252	0.328	0.368	0.469	0.404
Punjab	0.386	0.447	0.494	0.566	0.537
Rajasthan	0.216	0.298	0.386	0.492	0.424
Tamilnadu	0.289	0.421	0.445	0.560	0.531
Uttar Pradesh	0.227	0.284	0.398	0.444	0.388
West Bengal	0.264	0.370	0.427	0.511	0.472

Source: National Human Development Report 2001, Planning Commission, Government of India, March 2002.

Table A7: Villages Linked to Roads and Average Village Size, 1997

State	% Linked Villages	Village Size 1991
Andhra Pradesh	85.9	1829
Assam	90.7	807
Bihar	47.8	1746
Gujarat	94.4	1501
Haryana	98.8	1836
Karnataka	99.6	1148
Kerala	99.2	15476
Madhya Pradesh	28.4	711
Maharastra	70.8	1198
Orissa	49.2	584
Punjab	97.3	1150
Rajasthan	52.0	296
Tamilnadu	41.2	2325
Uttar Pradesh	50.4	989
West Bengal	48.7	1302

Source: Lok sabha, Starred question NO. 239 dated 13-03-2001 reproduced in http://www.indiastat.com/india/ShowDataSec.asp?secid=11690&ptid=6425

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