rators is growing rapidly and at present there are about 20 odd electron accelerators operational in the country for this purpose. CAT has developed and operated a 20 MeV microtron as injector to a 700 MeV booster. Based on the experience gained on microtron, a 12 MeV microtron has been designed for applications like radiation physics studies and non-destructive testing and the same has been installed at Mangalore university. With addition of a Gantry, it is possible to make a radio therapy machine using the 12 MeV microtron. CAT is also at an advanced stage of building a 11 MeV cyclotron to produce short lived radio isotopes for positron emission tomography.

There exist also possibilities for use of accelerators in the nuclear fuel cycle, both for disposal of radioactive waste and for use as an 'energy amplifier' by introducing neutrons produced in spallation reactions into a subcritical assembly.

Summary

A possible strategy for accelerator-based research and applications can be summarized as follows:

- Research with existing facilities and utilization of the facilities for applied areas.
- Building new accelerator facilities for research and applications. Concentrating on reasonably large-size accelerators involving high technology but at moderate cost, which will enable work to be carried out in many frontier areas.
- International collaborations – physics research, participation in building accelerators and detector set-ups.

It is being realized that at least for research using big accelerators, cooperation amongst countries is very much needed not only for building expensive facilities but also for using the same. As we said before, no nation can any longer afford to go at such activities alone. However, our own national base has to be sufficiently strong and several national accelerator facilities are essential to provide this base. Our success in the international arena depends crucially on our expertise and competence built around our national facilities and development of manpower required to build and use the facilities both in India and abroad. A strong synthesis of the two programmes, national and international, should be the vision for our accelerator programme.

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Recent fertility trends and prospects in India

K. Srinivasan

There is an increasing pace of fertility decline in large parts of the country in the recent years. Among the proximate determinants, the variables that have played a dominant role in fertility changes directly, in the Indian context are natural fertility and contraceptive use and indirectly, female literacy and infant mortality. For future, we can expect the TFR to be in the range of 2.9 to 3.0 by the year 2001 and 2.00 to 2.13 by the year 2011. The spurt in the female literacy rate will have a major impact on the future fertility levels.

THE most recent census[1] conducted in India in March 991 placed her total population at 846.30 million, including an estimated figure of 7.72 million for the state of Jammu & Kashmir, where the census could not le conducted owing to political disturbances. Since 1951, vhen the first post-independence census was taken, the population of the country has increased by 485.22 million, nore than twice the population that lived in the country i1 1901, which was 238.40 million. During the decade 1981–1991 we have added to the country a whopping 162.97 million people, which is equal to the combined populations of France, Poland and the United Kingdom.

In terms of the rate of growth rather than numbers, during the decade 1981–91 the population has increased by 23.85%, or 2.12% annually, compared to 24.80%, or 2.20% annually, during the decade 1961–71. During the year 1991 the growth rate was 1.97%, almost the same as the average annual growth rate of 1.96% experienced 40 years earlier during the decade 1951–61. However, while the earlier growth rate was the result of a difference of an average crude birth of 42.4 and

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death rate of 22.8 (birth and death rates measured for 1000 population per year) in the decade 1951–61, the 1991 growth rate was the result of a birth rate of 29.5 and a death rate of 9.8. Thus, during the 35-year period from 1956 to 1990 both the birth and death rates have declined by 13 points, keeping the growth rate almost unchanged. Unfortunately, this stagnation in the growth rate since 1961 has occurred, in spite of a strong awareness of the population problem at the national level since the country's first five-year plan in 1951, consistent antinatal policies and family planning programmes by the government to reduce the fertility levels in the population. An expenditure of approximately Rs 5550 crores has been spent on family planning since its inception until 1990.

This seems to be a paradoxical situation, in which the fertility declines have been tardy in a population when both at the people's level as well as at the governmental policy and planning level there has been a strong motivation to lower fertility levels and population growth rates. Many countries such as China, Thailand, Indonesia, Mexico and Brazil that launched their family planning programmes almost a decade later have achieved lower fertility levels than India. In 1991, China with a population size of 1155.5 million added to her numbers 16.52 million compared to 16.67 million added to India's. India has gained the unique distinction of being the country that adds the maximum number of people every year within her territory, surpassing China, which has a larger population. In order to understand the dynamics of this growth and prospects for the future, it is necessary to go into the components of population change, mortality, fertility and migration and the factors that have contributed to modifications in these components over time. Particularly relevant are the factors that influence the fertility levels in the Indian population; the component that holds the key to the demographic future of the country.

Fertility trends since 1970

Since 1970, fertility has been declining in most parts of the country as indicated by fertility measures. Table 1 presents data on two fertility measures, crude birth rate (CBR) and total fertility rate (TFR) and also on three important contributory factors to fertility change, viz. infant mortality rate (IMR), female literacy rate (FLR) and effective couple protection rate (ECPR or percentage of couples with wife in the age range 15–44 years effectively protected by a modern method of contraception from within the programme) in the country and in sixteen large states (that account for 95% of the country's population), for the years 1971, 1981 and 1991. The table also provides the CBR and IMR values for the latest available year 1993. This spans a period when the fertility transition has been occurring in the

Table 1. Measures of fertility, IMR, contraceptive use and FLR in India and the major states for 1971, 1981 and 1991

	CBR				TFR			IMR				ECPR			FLR		
	1971*	1981*	1991*	1993	1971**	1981*	1991*	1971*	1981*	1991*	1993	1971	1981	1991	1971	1981	1991
Andhra Pradesh	35 4	31.3	25 6	24.3	4 7	3.9	3 0	106	86	71	64	11.2	26.2	44 3	19 2	24.2	33.7
Assam	37 9	33.0	30 5	29 5	5 2	4.1	3.4	139	104	78	81	4 6	18.5	28.2	22.8	NA	43.7
Bihar	32.3	38.1	32 0	32 0	5.0	5 7	4 6	NA	118	72	70	5.0	12.3	26.0	10.7	16.5	23.1
Gujarat	40 4	34 8	28 4	28 0	5 6	4 4	3.2	144	113	69	58	11.4	32.5	57.8	30 3	38 5	48.5
Haryana	39 6	36 8	32 3	30 9	6.6	5 0	3.9	72	99	71	66	12 9	28.3	56 6	18 6	26.9	40.9
Himachal Pradesh	34.4	32 0	28 0	26.7	4 4	4 0	3 1	113	75	70	63	7 6	25.6	52.1	24.7	37.7	52 5
Karnataka	32.0	27.9	27.1	25 5	4 2	3 6	3.1	95	68	73	67	8 9	23.4	46.9	25.7	33.2	44.3
Kerala	31.3	26.2	18 5	17.4	4 1	2.9	1 8	58	36	17	13	14.6	29.7	55.6	65 4	75.7	86.9
Madhya Pradesh	39.2	37.7	35.9	34.9	5 9	5 2	4 6	135	139	111	106	9 2	21 5	40.3	13.7	19 0	28.4
Maharashtra	32 0	29 1	26 3	25 2	4.5	3.7	3 0	105	75	59	50	15.2	34 9	56.2	32.4	41.0	50.5
Orissa	35.8	32 7	28.9	27.2	4 6	4 2	3 3	127	137	120	110	13.8	27.1	41.0	17.0	25.1	34.4
Punjab	34.2	30 2	27.5	26 3	5 3	4 0	3.1	102	82	57	55	16 8	24.1	75 8	31.3	39 6	49.7
Rajasthan	41 1	37.9	34.5	35 1	6.2	5.4	4.5	123	103	84	82	5.0	13 8	29.0	10.5	14 0	20.8
Tamil Nadu	31.3	27 8	21 0	19.5	4.0	3.4	2 2	113	89	58	56	12 4	27 8	57.3	32.3	40 4	52 3
Uttar Pradesh	44 5	39.2	35 9	36 2	6 6	5.8	5.2	167	152	98	94	5.5	11.1	35.5	13 0	17 2	26.0
West Bengal	NA	32 4	26.7	25.7	NA	4 2	3.2	NA	91	66	58	NA	22 2	33.7	27.8	36 1	47.2
All India	37.2	33 8	29 6	28.7	5.2	4 5	3.7	129	106	80	74	10.1	22.8	44 1	22.9	29 8	39.4

Notes: (i) Figures indicate average rates over three consecutive years centred round the years 1971, 1981 and 1991. For example, CBR* for 1981 is the average of CBRs for 1980, 1981 and 1982. The rest of the figures are for the years 1971, 1981, 1991 and 1993.
(ii) TFR** for 1972 is based on SRS sample survey in 1972 and taken from ref. 6. The data are given for rural and urban areas and weighted by the 1971 rural–urban proportions in the census.
(iii) ECPR: Effective couple protection rate as on March 1971, 1981 and 1991.
(iv) FLR. Female literacy rate is percentage of literate among females aged 7 and above.
(v) 1993 figures are provisional estimates published by the Registrar General in September 1994.
Sources: (1) Various publications of the Sample Registration System by the Registrar General, including refs. 4 and 5.
(2) Ref. 3.

country. The fertility and mortality figures have been compiled from the official publications[2–6] of the Registrar General of India from the Sample Registration System, the female literacy rates from the 1971, 1981 and 1991 censuses and ECPR values from the Family Planning Year Books[7,8] put out by the Ministry of Health and Family Welfare. Since the Sample Registration System (SRS) is a dual record system based on data compiled on births and deaths from a sample of villages and urban blocks in the country (and though the sample sizes are fairly large enough to estimate fertility and mortality levels within 5% coefficient of variation), we have used three-year averages of vital rates, wherever available, centred around 1971, 1981 and 1991, especially for the study of long-term trends in these rates.

The CBR, defined as number of births per 1000 population per year, has declined from 37.2 in 1971 to 33.8 in 1981 and 28.7 by 1993. Thus, the annual decline in the CBR during 1981–93 was 0.425 compared to 0.340 during 1971–81, or 25% more than the earlier period. In 1993, among the states the CBR has ranged from a minimum of 17.4 in Kerala to a maximum of 36.2 in Uttar Pradesh. The CBR values for the rural and urban areas for 1993 for the country as a whole were 30.4 and 23.7, respectively. In Kerala the rural and urban CBR values were 17.5 and 17.3 respectively, while in UP they were 37.2 and 31.1 respectively.

It has been found that as fertility levels decline, the differences in fertility between the rural and urban areas as well as between the other segments of the population, such as by religion, caste or income categories, tend to narrow down and fertility becomes more homogeneous across the population. The more recently conducted National Family Health Survey (NFHS) that covered a representative sample of 88,562 households from most of the country has estimated the CBR for 1992–93 at 28.9, with 30.7 in rural areas and 28.9 in urban areas, which varied from a minimum of 17.2 in Goa and 19.6 in Kerala to a maximum of 36.0 in Uttar Pradesh, figures that are close to the estimates from the SRS, and provide independent validation to the SRS figures.

The changes in fertility or any variable can also be studied in relation to the progress made towards reaching the long-term goal set for different measures by an 'index of progress' (IP), by relating the actual decline in a fertility measure over a period of time to the required decline to reach the specified long-term goal in the measure. The recently appointed 'Expert Group

Table 2. Percentage progress towards long-term goals during 1971–81, 1981–91 and 1971–91 in CBR, TFR and ECPR

	Percentage changes in CBR (goal of 21)			Percentage changes in TFR (goal of 2 1)			Percentage changes in IMR (goal of 30)			Percentage changes in ECPR (goal of 70%)		
Long term goals	1971–81	1981–91	1971–91	1971–81	1981–91	1971–91	1971–81	1981–91	1971–91	1971–81	1981–91	1971–91
Andhra Pradesh	28.5	39.6	68 1	30 8	34 6	65.4	26.3	19.7	46 1	25.5	30 8	56.3
Assam	29 0	14.8	43 8	35.5	22.6	58 1	32.1	23 9	56 0	21.3	14.8	36.1
Bihar	–51.3	54 0	2.7	–24 1	37.9	13 8	NA	NA	NA	11 2	21 1	32.3
Gujarat	28 9	33.0	61.9	34.3	34.3	68 6	27 2	38 6	65.8	36.0	43 2	79 2
Haryana	15 1	24 2	39 2	35 6	24 4	60 0	–64.3	66.7	2.4	27.0	49 6	76.5
Himachal Pradesh	17.9	29.9	47.8	17 4	39 1	56.5	45 8	6 0	51.8	28 8	42.5	71.3
Karnataka	37.3	7.3	44 5	28 6	23.8	52 4	41.5	–7.7	33 8	23.7	38 5	62.2
Kerala	49.5	74 8	124.3	60.0	55.0	115.0	78 6	67.9	146 4	27.3	46 8	74 0
Madhya Pradesh	8.2	9 9	18 1	18 4	15 8	34.2	–3 8	26.7	22 9	20 2	30.9	51 2
Maharashtra	26.4	25.5	51.8	33.3	29.2	62.5	40.0	21.3	61 3	35 9	38 9	74 8
Orissa	20 9	25.7	46.6	16 0	36.0	52.0	–10 3	17 5	7.2	23.7	24.7	48.4
Punjab	30.3	20.5	50 8	40 6	28 1	68 8	27 8	34.7	62 5	13.7	97.2	110 9
Rajasthan	15.9	16 9	32 8	19.5	22 0	41.5	21 5	20 4	41.9	13 5	23 4	36.9
Tamil Nadu	34 0	66 0	110.0	31.6	63.2	94 7	28 9	37 3	66.3	26 7	51.2	78 0
Uttar Pradesh	22.6	14 0	36.6	17 8	13.3	31 1	10.9	39.4	50 4	8.7	37 8	46 5
West Bengal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
All India	21 0	25.9	46 9	22.6	25 8	48.4	23.2	26 3	49.5	21 2	35.6	56 8

Notes: (i) The percentage progress made is measured as a ratio of the change in given period to the required change to reach the goal. For example the progress in CBR during 1971–81 is 100 * (B71 – B81)/(B71 – 21), where B71 and B81 are the CBRs for 1971 and 1981 and 21 is long-term goal for CBR.

(ii) The percentage progress made during two periods for the same area is additive; i.e. the progress made during 1971–91 is the sum of the progress made during 1971–81 and 1981–91.

(iii) *For TFR 1971–81 and 1971–91 the changes are from 1972 to 1981 and 1972 to 1991 The rest of the figures are for years 1971, 1981, 1991 and 1993.
**The ratio of change in 1981–91 to 1971–81 is not computed if there is an increase in CBR, TFR or IMR values during a period.

(iv) The long-term goals for all the states are assumed to be the same though they may be achieved in different years

Sources: (1) Various publications of the Sample Registration System by the Registrar General, including ref. 5.
(2) Ref 3.
Computed from figures given in Table 1.

on Population Policy' under the chairmanship of M. S. Swaminathan that submitted its report[9] in May 1994 has recommended the long-term demographic goals for TFR as 2.1 and IMR of 30 infant deaths per 1000 live births to be achieved by the year 2010. The Eighth-Plan document (1992–97) has recommended a long-term goal for a CBR of 21 to be reached by 2006–11, that implies an effective couple protection rate (ECPR) of 70%. The IP with regard to decline in the CBR value during 1971–91 towards the long-term goal of 21 can be measured as 100 × (CBR-71 minus CBR-91)/(CBR-71 minus 21).

Table 2 provides data on the IP values computed for major states for selected measures of fertility, mortality and contraceptive use in relation to their long-term goals. For the country as a whole the IP value for CBR during 1971–81 was 21% [100 * (37.2 – 33.8)/(37.2 – 21)], during 1981–91 was 28% and during 1981–91 was [100 * (33.8 – 29.5)/(37.2 – 21)]. Thus, during the whole period 1971–91, IP was slightly less than half (49%) towards the long-term goal of 21 set for CBR and the progress towards the goal during 1981–91 was 33% more than in the earlier decade. The IP values are studied only for the periods 1971–91 since we preferred to use three-year average values that are statistically more reliable around 1971, 1981 and 1991.

The decline in fertility during the period 1971–91 measured in terms of TFR, a more refined measure of fertility that denotes the average number of children born to a woman in her entire reproductive span assuming that she experiences the level of age-specific fertility rate obtained in a given year or period, is more pronounced. In 1991, TFR (average of 1991–93 values) was 3.7 births per woman in the country as a whole, ranging from a low of 1.8 in Kerala to a maximum of 5.2 in Uttar Pradesh. In the country as a whole, TFR declined from 5.2 in 1972 to 4.5 in 1981 to 3.7 in 1991. IP towards the long-term goal of 2.1 for TFR was found to be 49% during 1971–91, made up of 23% during 1972–81 and 26% during 1981–91. In this connection, it is worth mentioning that, as a starting point for the measure of TFR, we have used the estimate obtained from the Special Survey on Fertility and Mortality[10] conducted by the Registrar General in 1973, providing estimates for 1972, since those computed from the routine SRS, during the early seventies are considered to be underestimates[11]. Thus, while we have the change in TFR measured for a period of nine years during 1972–91, it is for a period of ten years during 1981–91.

IP in TFR has been more than 100% in Kerala, implying that the state had already achieved by 1991 the goal set for the country for 2010. The IP value was 96% in Tamil Nadu, which had almost reached the replacement level of fertility by 1991. It is, however, less than 50% in the states of Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh, states that are euphemistically referred to as 'Bimaru' states. The problem of fertility control is thus largely confined to the four large Hindi-speaking states in the north. Figures 1 and 2 provide a graphic presentation of the states arranged according to their progress or IP values on CBR and TFR during 1971–81 (1972–81 for TFR) and 1981–91. From Table 2 it can be seen that the pace of change during 1981–91 is more than during 1971–81 excepting in Assam, Karnataka, Punjab and UP. In other words, there is an increasing pace of fertility decline in large parts of the country in the recent years.

Factors contributing to fertility change

Earlier studies on factors associated with fertility levels and changes in India and other developing countries have identified the determinants at two levels, viz.

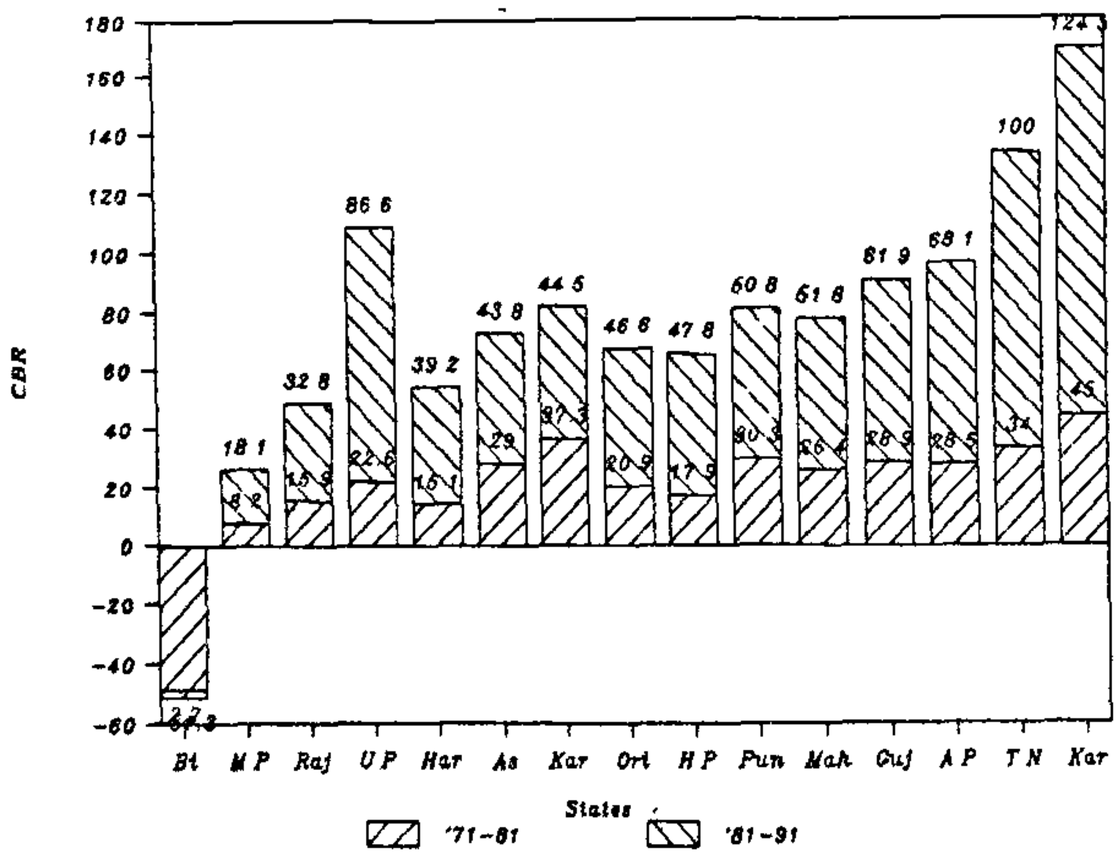

Figure 1. Percentage progress in CBR to goal 21 during 1971–81 and 1981–91.

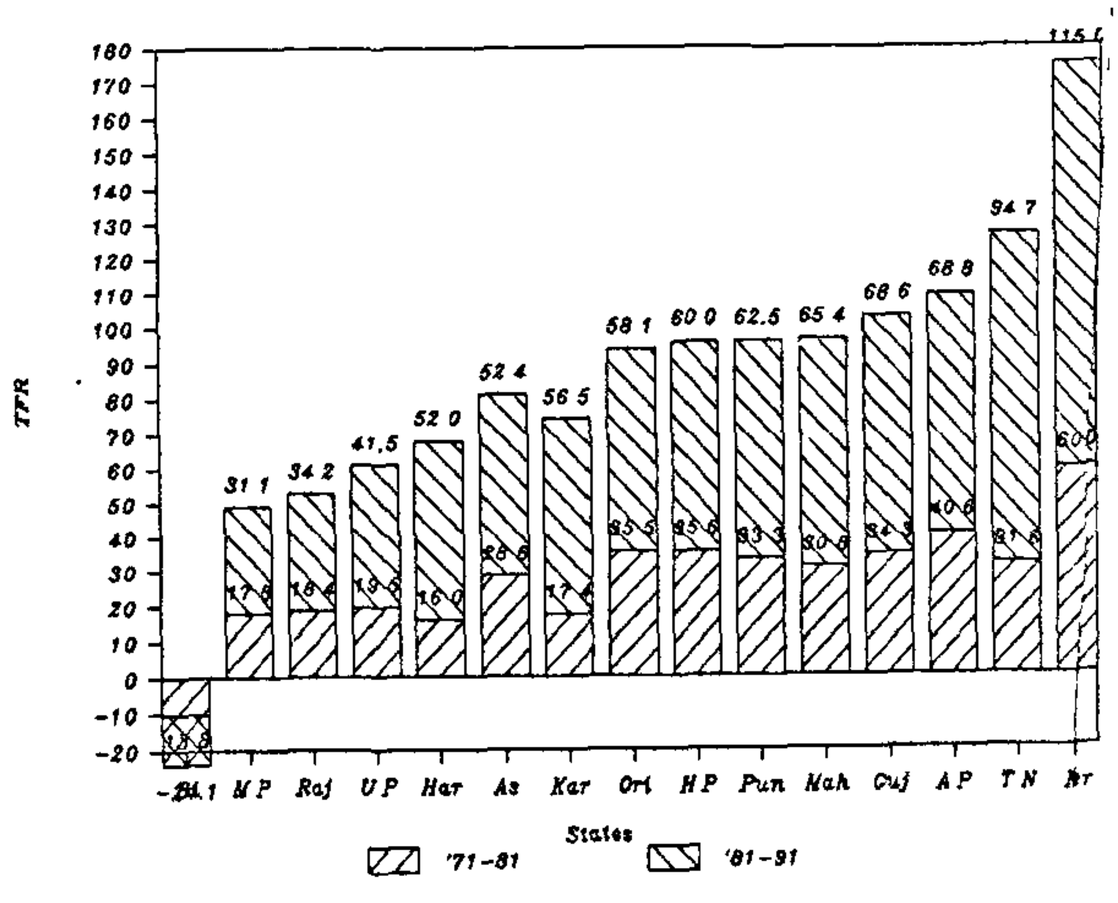

Figure 2. Percentage progress in TFR to goal 2.1 during 1971–81 and 1981–91.

proximate determinants and factors influencing proximate determinants. The proximate determinants of fertility are those intermediate variables through changes in any of which any modification in human fertility has to be brought about, viz. (a) *natural fertility* (NF), (b) *nuptiality* (NU), (c) *contraceptive use* (CU) and (d) *abortions* (AB) and three directly manipulable modernizing factors that are causally more distant from fertility as compared to the proximate variables, but that affect fertility powerfully through one or more of the proximate determinants, viz. (a) *family planning programmes* (FPP), (b) *female literacy* (FLR) and (c) *infant mortality* (IMR)[12–14]. Among the proximate determinants, the variables that have played a dominant role in fertility changes (increase or decrease) directly in the past in the Indian context are natural fertility and contraceptive use and indirectly, female literacy and infant mortality. We will briefly discuss their contributions one by one in the Indian context, and what they portend for the future of fertility in this country. To discuss the contributions of all the proximate determinants and their determinants will go beyond the scope of this article.

Proximate determinants of fertility

Natural fertility. Natural fertility is defined as the fertility of a married couple in the absence of any deliberate control to increase the spacing between children or to limit the family size. In India, the natural fertility has been historically quite low, probably the lowest in the world. It was only about six births per woman, or just 60% of the number observed in European populations in the eighteenth and nineteenth centuries, when they did not practice any contraception. Fertility levels have been kept in check in India by various social and cultural practices and to some extent are attributable to the high prevalence of febrile diseases such as tuberculosis, malaria and malnutrition that reduced the biological fecundity and in some cases caused infertility in the couples. Despite the tradition of early and universal marriage, various religious and cultural restrictions on sex, prohibitions against widow remarriage, prolonged breast feeding contributed to low natural fertility. With modernization gaining rapid momentum after independence, these traditional and cultural practices that kept the natural fertility of Indian population at low levels for centuries have weakened considerably. Further, the increases in life expectancy and improvements in nutritional and health status attributable to green revolution and control of many communicable diseases, the duration of married life that a woman spends in the reproductive period has increased rapidly and the natural fertility levels have increased steadily to approximately 7 children in the seventies to 9 in the eighties[14–16]. From a detailed analysis of data on age-specific marital fertility rates compiled from two large-scale sample surveys conducted in 1959 and 1972 in 11 major states in India, Srinivasan and Jejeebhoy[17] observed:

'The results consistently indicate an increase in the total marital fertility rates in eight of the eleven states (the exceptions being Kerala, Orissa and Punjab) between 1959 and 1972. The most striking increases in marital fertility have been observed in those states where there has been practically no prevalence of contraception. The increase is 28% in Uttar Pradesh, 26% in Rajasthan, 13% in Madhya Pradesh and all these states were practically under natural fertility conditions . . .' (p. 103).

This tempo of rise in natural fertility initiated in the early sixties continued into the seventies and in the state of Bihar the rising trend is observed even in the eighties. Pathak and Ram[16], using indirect techniques, estimate the level of natural fertility to be slightly more than 9 children in the eighties. Thus, it has to be recognized that whatever decline in the birth rate that has occurred in India has taken place in the context of an almost steady rise in the natural fertility levels of the population to about one-and-a-half times the initial level. The plateauing of this rise seems to have occurred in the eighties, and there may not be any further fertility-increasing effects of modernization. It is to be noted that in the absence of the vigorous family planning programme that we had in the past few decades, the observed fertility levels in the Indian population would have risen considerably.

Contraceptive use. India can take legitimate pride in the fact that it is the first country in the world, developed or developing, to realize at the governmental level the extent of hurdles to development posed because of rapid population growth and launch an official programme of family planning as early as 1951 to control fertility as a part of the first five-year plan (1951–56). The governmental emphasis on the programme has accelerated over the years with plan expenditure on the programme rising sharply from a meagre Rs 14.5 lakhs in the first plan to 2304.5 crores in the seventh plan period, 1985–90. The current level of annual expenditure on the programme incurred by the states and the centre (plan and non-plan), mostly by the centre, is about 1000 crores per year. In 1991, there were about 131,000 subcentres, 22,060 Primary Health Centres, 1930 Community Health Centres, 1515 Urban Family Welfare Centres and about 554 district/state-level hospitals providing family planning services across the length and breadth of the country.

The impact of such a massive expansion of activities in the field of family planning over the years is seen from the data on the increasing prevalence of contraceptive use in the country (given in Table 1). The effective couple protection rate (ECPR) or the percentage of married women in the reproductive ages (15–44)

protected effectively from pregnancy by a modern method of contraception has increased from almost zero level in the late fifties, to 10.1% in 1971, 22.0% in 1981 and 44.1% in 1991. In actual numbers, 64.07 million couples are effectively protected by contraception under the programme. Out of this 44.1% of couples using contraception effectively in 1991, 30.3% (or 68% of those protected) have been protected by sterilization (of the husband or wife), 6.7% (or 15% of those protected) by IUD and 7.2% (17% of those protected) by other methods that include oral pills, condoms, injectibles and others. Thus, sterilization, vasectomy until 1976 and tubectomy thereafter, has been the dominant method promoted by the programme from its very inception and accounts for the bulk of the protection in the country.

In 1991 among the states the ECPR values ranged from a low of 26.0% in Bihar to 75.8% in Punjab. The IP values in ECPR furnished in Table 2 reveal that while towards the long-term goal of achieving 70% in the ECPR values, only 21.2% progress was made during 1971–81; during 1981–91, 35.6% was made and the ratio of progress between the two decades is thus 1.7. This ratio has ranged from 7.1 in Punjab (where the progress during the 1971–81 decade was poor) to 0.7 in Assam. In all the states other than Assam, the IP values in 1981–91 are higher than in the previous decade, indicating a rapid acceleration in the use of contraception in recent years. A considerable degree of caution has to be exercised in projecting this trend to future years because of the various assumptions made by the Department of Family Welfare in the computation of ECPR values. However, even if we assume that the quantum of increase in the ECPR values experienced during 1981–91, i.e. 21.8%, will be maintained during 1991–2001, it will lead to an ECPR level of 65.1% in the year 2001 for the country as a whole, a level quite close to what is required to realize the replacement level of fertility. It has to be realized that further increase in ECPR values has to come mostly from the hitherto poorly performing states of Assam, Bihar, Rajasthan, Orissa, Madhya Pradesh and Uttar Pradesh, that have performed below the national average in 1991 and that have about half the population of the country.

An additional positive feature of changes occurring in the country during the past two decades is the reduction in the gender bias of the population. The people of this country have for centuries placed undue emphasis on the male child and this gender bias has been institutionalized in a number of ways through religion and other social institutions. The female child has been given a secondary position in the family and society in all aspects, including education, property ownership, health care and decision making. This bias seems to be breaking down in recent times. The data collected in a large-scale survey[18] conducted during 1988–89 by the Operations Research Group (ORG), Baroda, to study the levels, trends and determinants of contraceptive use in the country revealed that among couples in the reproductive ages (wife in the age range 15–44), among those with two surviving children, both daughters, 35.6% were using a modern method of contraception and 15.6% have undergone sterilization. Even among those with no surviving children 12.0% were using a modern method of contraception. Figure 1 provides the contraceptive prevalence rate by numbers of surviving children and surviving sons. While there is an increased use of contraception among couples with more sons, the practice among those without any son has also risen substantially.

One of the major reasons for the reduced impact of the family planning programme on the fertility levels in India is the undue emphasis placed by the programme on the method of sterilization, vasectomy for males until 1976 and tubectomy for females thereafter. Since this is largely an irreversible and permanent method, couples prefer to adopt it after they have reached the desired family size and at older ages and higher parities. Couples who wanted to space their children and keep the option of their fertility open did not take to these methods and invariably landed up with a larger family size than what they would have liked to have if good temporary, reversible methods were made available to them from the early years of the programme. The sterilization programme has been like 'locking the stables after the horses have been bolted away'. Further, with the rise in natural fertility pushing up the fertility levels of the younger married couples (because of relaxation of traditional checks on fertility and control of febrile diseases and better nutrition) only the tail end of the fertility curve was affected by the programme while at the peak ages of fertility, viz. 20–29 years, the marital fertility was rising during the sixties and seventies. Since the rising phase of natural fertility had largely been completed by the late eighties (possibly with the exception of Bihar) and increasing emphasis is being placed on the spacing methods in recent years, the fertility impact of the programme is likely to increase in the coming years with more and more younger women coming to use modern methods of contraception.

Another indication of major changes taking place in the population is on the extent to which couples have reported not desiring any more children at different stages of their family building in the early eighties and nineties. In a large-scale sample survey conducted by the ORG, Baroda, in 1980–81, the percentage of eligible couples who did not desire any additional children in the country as a whole was 1.0, 12.7, 43.3, 68.7 and 83.7, among married women with 0, 1, 2, 3 and 4 or more living children respectively. The corresponding percentages in the 1992–93 National Family Health

Survey[19] are 2.3, 19.1, 61.8, 78.0 and 83.6, respectively. These figures include a sizeable proportion who have already resorted to sterilization to avoid further child bearing. Particularly impressive is the rise in the proportion of women with two living children not wanting any more children, which is 62%, half of whom had already undergone sterilization.

Nonproximate developmental factors in fertility change

Declines in infant mortality. Detailed studies of the demographic transition in the developed and developing countries have revealed a strong link between declines in the mortality levels of a population, especially in the infant and child mortality and fertility levels. The well-known 'theory of demographic transition' is based on the empirical evidence from a number of countries that have successfully achieved the transition from a high-fertility–high-mortality to low-fertility–low-mortality regime. In all these cases, mortality declines always preceded fertility declines with a time lag and the pace of mortality decline determined the pace and timing of fertility decline even in the absence of any organized contraceptive services. Family planning programmes assist and expedite the pace of fertility decline once they have commenced as a part of the multiphasic social response to earlier mortality declines[20].

Life expectancy in India has improved substantially from the third decade of this century from an estimated 20 years in 1921 to 60 years in 1991. During the four decades 1941–51 to 1981–91, life expectancy rose by 25 years with about 0.6 years added to an Indian's life each year. Credit for this considerable achievement goes to various public health measures undertaken by the central and state governments. Life expectancy varies considerably among the states, with 71.1 years in Kerala to 49.6 years in Uttar Pradesh for the quinquennium 1986–91. The crude death rate has declined from 47.2 fatalities per thousand population during 1911–21 to 9.3 in 1993. The decline in the death rate seems to have begun after 1921, and since 1951 has been quite rapid. Infant mortality rate (IMR; deaths of children below age one year per 1000 live births), was estimated at 222 for the decade 1901–11, declined to 129 for 1961–71 and to 74 by 1993. There are sizeable interstate variations in the IMR values. In 1993, IMR ranged from 110 in Orissa to 13 in Kerala. There are also rural–urban differentials in the IMR values, 82 in the rural areas compared to 45 in the urban areas in 1993. The differentials can be largely attributed to the prevalence of better health and medical care facilities in states such as Kerala, Maharashtra, Tamil Nadu and West Bengal and to the relative concentration of these facilities in the urban areas in most states. It has been observed that as the infant mortality levels decline, rural–urban differentials tend to narrow down. For example, in Kerala, in 1993 the rural IMR was 15 compared to 8 in the urban areas while in Orissa the rural rate was 115 compared to 69 in urban areas. The reduced differentials in mortality seem to be an indicator of the extent of dispersion of basic health services across the country. The declines are attributable to the control of various infectious and communicable diseases that had been taking heavy tolls among children. Concomitantly, there is a tendency for mortality rates among the adults and the elderly to rise because of increases in noncommunicable diseases, including cardiovascular problems, cancer and accidents. The shift from the age pattern of deaths from younger to older ages and predominantly infectious to noninfectious diseases has been termed as the 'epidemiological transition' and many states in India are almost completing such a transition. The basic requirement for a sustained fertility transition, viz. decline in the mortality levels, especially the infant and child mortality levels, is present in the Indian population with varying degrees of success in different states. The states that have achieved faster declines in mortality levels such as Kerala have achieved lower fertility levels well ahead of the other states.

Analysing the progress made in the reduction of IMR values towards the long-term goal of 30 infant deaths per 1000 live births, through the index of IP given in Table 2, it is found that in the country as a whole the IP during 1971–91 is about 50%, with 23% during 1971–81 and 26% during 1981–91. There is thus a 13% acceleration in the pace of decline in IMR values in recent years. Figure 3 gives a graphic representation of IP values in different states during 1971–81 and 1971–91. The minimum decline has been recorded in the state of Orissa and more than 50% IP values are found in

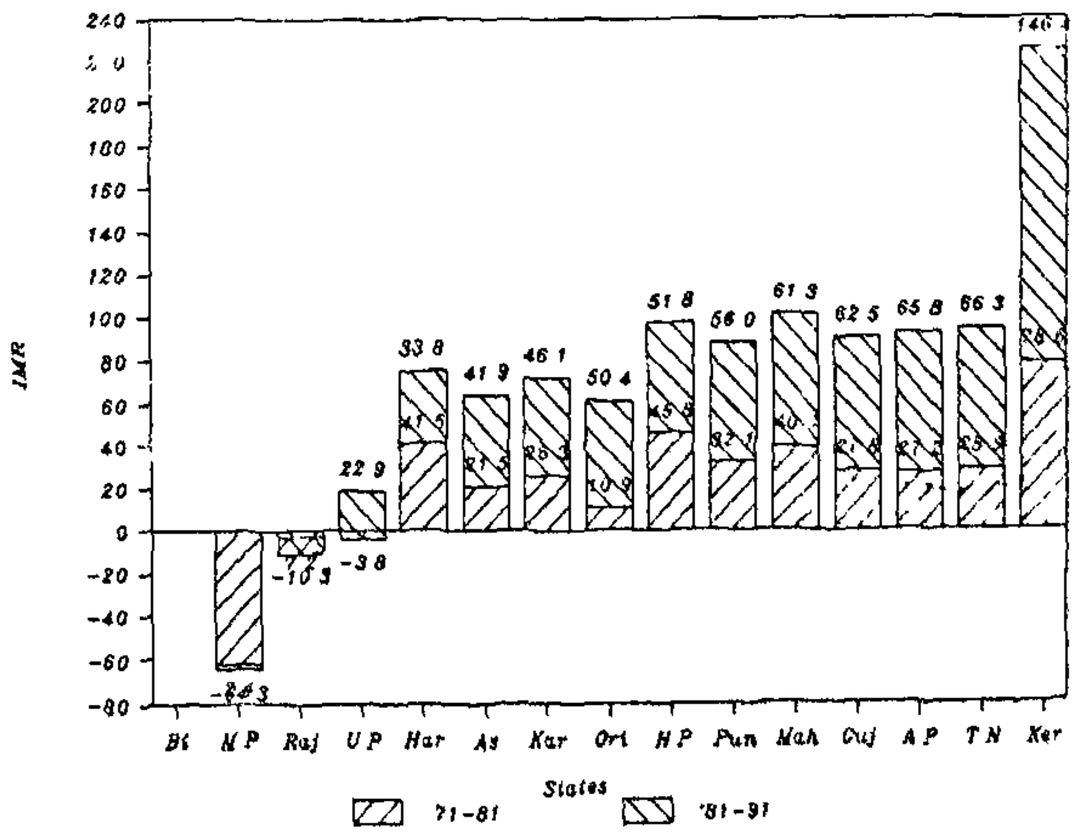

Figure 3. Percentage progress of IMR to goal 30 during 1971–81 and 1981–91

the states of Assam, Himachal Pradesh, Kerala, Maharashtra, Punjab, Tamil Nadu and Uttar Pradesh. It is found that among the larger states only the state of Kerala has already achieved both the fertility and infant mortality goals set for 2010, with a TFR of 1.8 CBR of 18.3 and IMR of 16 by 1991. While Tamil Nadu has almost reached the fertility goals with TFR of 2.2 and CBR of 20.8 by 1991, its infant mortality rate of 56 in 1993 is still distant from the goal of 30. However, Tamil Nadu and Punjab have achieved the IMR goals set by the earlier National Health Policy of 1983, wherein the goal was to reach a level of 60 or less by the year 2000. Thus, the picture that emerges from an analysis of the changes in the IMR values between *1971 and 1991 is that the tempo of change (decline)* in the IMR values has accelerated in the recent decade 1981–91 compared to the earlier decade and this is bound to have an effect in accelerating the pace of decline in fertility in the coming years.

Female literacy. One of the major determinants of demographic transition leading to declines in infant and child mortality, overall mortality, increase in age at marriage, rise in use of modern methods of contraception, declines in the fertility levels of the population and development *per se* is education of women. Societies that have achieved universal literacy of females and higher educational attainments for women have all recorded more rapid demographic transition. The fertility transition in China, Sri Lanka and Kerala state in India all bear ample testimony to the above conclusion. This is demonstrated strongly by data in Table 1, wherein a strong negative association between female literacy rate and fertility levels is observed in all the three census years (e.g. -0.85 in 1991).

Literacy rate for females aged 7 and above increased from 22.9% in 1971 to 29.8% in 1981 to 39.4% in 1991. In 1991 it ranged from a high of 86.9% in Kerala to a low of 20.8% in Rajasthan. While the literacy rate both among the males and females has been rising over the decades, the absolute number of illiterate females in the population aged 7 and over has been increasing steadily, to 126.7 million in 1991, with an increase of 5.7 million during the decade 1981–91. Almost 80% of the illiterate female population of the country (about 96 million) are concentrated in the four large Hindi-speaking states of Bihar, Madhya Pradesh, Rajasthan and Uttar Pradesh.

A multivariate model

The combined and separate effects of three of the four contributory factors discussed above, viz. FLR, IMR, ECPR on the TFR can be assessed by a simple path model. We are not in a position to take account of the factor of natural fertility since we do not have direct data on the same and any measure of natural fertility has to be derived only indirectly from the observed fertility measures and the extent of the use of contraception.

In the path model (Figure 4) each variable is assumed to be influenced only by others posited to the left of it and not by any on its right. In the above model the TFR is assumed to be influenced by all the three factors – FLR, IMR and ECPR; ECPR is assumed to be influenced by IMR and FLR, and IMR by FLR, in addition to the other factors not explicitly entering into the model but affecting the variability of the factors. The zero-order correlation coefficients among the four variables for the years 1981 and 1991 are furnished in Table 3, where the figures in the upper triangle of the matrix provide the coefficients for 1981 and the lower triangle for 1991. Using the data for 1991 given in Table 1 the following regression equations emerge by applying the simple least-square method of estimation. All the correlation coefficients are statistically significant and reveal the strong interrelationships that exist among them.

Using the above path model and standardized variables, the regression equations among the variables are as follows. In this case the regression coefficients are the path coefficients, as per the above causal model.

$$\text{TFR} = -0.79 * \text{FLR} + 0.01 * \text{IMR} - 0.10 * \text{ECPR}, \quad (1)$$
$$n = 16 \text{ and } R\text{–squared} = 0.74,$$

$$\text{ECPR} = 0.58 * \text{FLR} - 0.01 * \text{IMR}, \quad (2)$$
$$n = 16 \text{ and } R\text{–squared} = 0.35,$$

$$\text{IMR} = -0.79 * \text{FLR}, \quad (3)$$
$$n = 16 \text{ and } R\text{–squared} = 0.63.$$

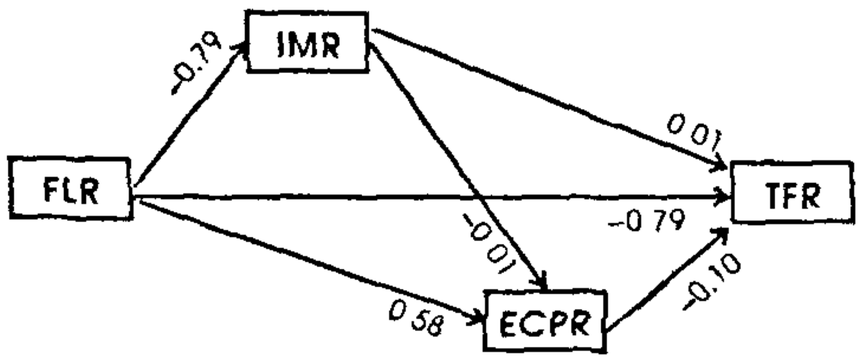

Figure 4. Path model

Table 3. Correlation matrix of selected variables in 1991

TFR	1.00000			
IMR	0.68190	1.00000		
ECPR	–0.56962	0.47290	1.00000	
FLR	–0.85386	0.79412	0.58982	1.00000
Critical value	(1-tail, 0.05) = ±0.42706			
	(2-tail, 0.05) = ±0.49580			

$n = 16$

The above analysis reveals that 74% of the variability in TFR is explained by the three factors considered but among them only FLR has a significant direct impact on fertility with a very high magnitude path coefficient of −0.79. Similarly, FLR has a statistically significant impact on the IMR as well as on the ECPR value. Thus, in the present context FLR seems to have a major effect, directly on TFR through its effect on age at marriage, use of induced abortions, etc., and indirectly on marital fertility rate through better acceptance of contraception from within the programme.

Interestingly, repeating the above analysis with the data for 1981 and using the standardized variables, the following equations emerge. Since the regression coefficients are based on standardized variables and they are the path coefficients, they permit comparison of the effects of variables over time and among the different variables.

$$\text{TFR} = -0.28 * \text{FLR} + 0.39 * \text{IMR} - 0.38 * \text{ECPR}, \quad (4)$$
$$n = 15 \text{ and } R\text{–squared} = 0.82,$$

$$\text{ECPR} = 0.63 * \text{FLR} - 0.01 * \text{IMR}, \quad (5)$$
$$n = 15 \text{ and } R\text{–squared} = 0.41,$$

$$\text{IMR} = -0.78 * \text{FLR}, \quad (6)$$
$$n = 15 \text{ and } R\text{–squared} = 0.78.$$

Comparison of the results for 1991 and 1981 reveals that the effect of FLR on IMR has remained stable and significant over time with over 75% of variance in IMR value explained by FLR. The effect of FLR on ECPR has declined over time. With regard to their direct impact on TFR values, while IMR and ECPR were having a significant effect and FLR not a significant effect in 1981, the effects are reversed in 1991 with only FLR having significant effect on fertility in 1991. This suggests that in the coming years more than the family planning programme, which offers the family planning services, education of women may play a more crucial role in shaping the fertility values in the country. The increased emphasis placed by the state and central governments on the literacy programme through the national literacy campaigns with emphasis on female literacy will have its direct and indirect impact of the fertility levels in the coming years.

Future prospects for fertility

As with any prediction exercises of future human behaviour, prediction of future fertility levels in India is a highly probabilistic endeavour, with the level of uncertainty increasing with the time span over which the predictions are made and the smaller level of population aggregation at which it is made. Predictions over a longer time span and for smaller geographic or population size zones are more loaded with uncertainty than predictions over a shorter time span and for the country as a whole.

Let us undertake this venture at two levels, one a simple and the other a more complex modelling. For example, TFR was 3.7 in 1991, 4.5 in 1981 and 5.2 in 1972.

During 1972–81 it declined by 0.7 points (5.2 to 4.7) while during 1981–91 by 0.8 points (4.5 to 3.7), implying that the reduction in TFR over the 20-year period was almost at the rate of 0.8 points per decade. If this trend of decline continues into the future, i.e. at 0.08 point reduction per year, then the TFR will be 2.9 by 2001 (3.7 − 0.8). Similarly, with regard to CBR, if we assume that the pace of decline during 1981–91 will continue into the future, the expected value in 2001 will be 25.5 (29.6 − 4.2). These are simplistic extrapolations of earlier trends.

We can make the projections of fertility a bit more complex and indirect by using regression of TFR on the important contributory factors discussed above, viz. IMR, FLR and ECPR and using the projected values of the predictors. The regression equation using the actual values (rather than standardized values as needed for the path model), based on the 1991 data is:

$$\text{TFR} = 5.6324 + 0.0004 * \text{IMR} - 0.0066 * \text{ECPR} - 0.0446 * \text{FLR} \quad (7)$$
(multiple $R = 0.8578$).

The projected values of the three predictors by the year 2001 can be obtained as follows under as realistic and conservative an approach as possible.

1. *Infant mortality rate*. For the country as a whole IMR has declined from 129 in 1971 to 106 in 1981 and to 80 in 1991. The governments at the state and central level have, in recent years, intensified their child immunization programmes throughout the country in collaboration with and assistance from the UNICEF under the Child Survival and Safe Motherhood Programmes (CSSM). There has also been tremendous media blitz on the need for immunization, and child care and nutrition, and we can expect, on a conservative assumption, that in the next ten years, during 1991–2001, the quantum of decline in the IMR values will be of the same magnitude as in the decade 1981–91, i.e. a decline by 26 points. Under this assumption we can project the IMR value in 2001 at 54.

2. *Effective couple protection rate*. For the country as a whole the ECPR values have increased during the decade 1981–91 by 21.3 points from 22.8 to 44.1%. With the increased emphasis on spacing methods and concern for improvement of the quality of services, in recent years, we can expect this tempo to be maintained in the period 1991–2001 and we can expect ECPR to increase to 65% (44 + 21) by the year 2001. This assumption seems to be a bit optimistic and hence we will

make another assumption, on the more conservative side, 55%, in which we assume that the increase in the ECPR value is only 11%, slightly less than what was achieved in the decade 1971–81, which was 12.7%. We will thus have two assumptions of 55% and 65% for the ECPR values by the year 2001.

3. *Female literacy rate*. FLR is going to be the cutting edge of demographic change, especially fertility transition, in this country in the years to come. It has increased from 22.9% in 1971 to 29.8% in 1981, to 39.4% in 1991, or by a factor of 1.30 and 1.32 in the two decades. In recent years there has been considerable emphasis on the literacy of women and the girl child through the national literacy campaigns, mid-day meal schemes for school children, and various mass media programmes. I expect such a national movement to increase FLR exponentially by the same factor between 1981 and 1991. In other words, I expect the literacy rate among females aged 7 and over by the year 2001 to be FLR-91 * (FLR-91/FLR-81) or 52.0.

Under these assumptions of future changes in the predictors of fertility, i.e. IMR of 54, ECPR of 65 or 55 and FLR of 52 by 2001, using equation (7) we get TFR in 2001 as 2.91 or 2.97, with ECPR at 65 or 55, respectively. With the same reasoning as above, if we extrapolate the predictor values to 2001, IMR will be 28, ECPR will be 86 or 66 and FLR will be 69 by that year. Using these values for the predictors in the regression equation we get a TFR for 2011 as 2.00 or 2.13 for the two ECPR alternatives. The long-term goal of TFR of 2.1 to be reached by the year 2011 will definitely be reached under these assumptions. Thus, we can expect TFR to be in the range 2.9–3.0 by the year 2001 and 2.00–2.13 by the year 2011. If there is going to be a spurt in FLR in the coming years (which is not unlikely), it will have a major impact on the future fertility levels. It has to be realized that a 20% point increase in the FLR value will reduce TFR by one child.

I have not discussed in this exercise the various difficulties that are going to be faced in the programmes for reduction of IMR, increase in the use of contraception within the programme (ECPR) or raising the FLR, and these are by no means to be underestimated. The need to intensify our efforts on immunization and child nutrition programmes, improvements in the quality of services offered in the maternal, child health and family planning programmes and achievement of universal literacy for all with emphasis on the schooling of the female child are to be emphasized at the risk of repetition. However, I wish to point out that fertility has started its downward trend in this country, that the pace of decline is accelerating in the past decade and that the changes in three important determinants of fertility, IMR, ECPR and FLR, are also changing fast enough to have synergistic dampening effect on fertility and that the goal of replacement level of fertility or TFR of 2.1 will definitely be reached by the year 2010 as targeted in the recent population policy document, if not earlier.

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