Markov Analysis of Contraceptive Behavior: Implications for the Family Planning Program in India

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Though countries continue family planning program effort to reach replacement levels, with progressive program efforts a continuous re-evaluation is required on the question of "where" to improve further. At a population level, this has been traditionally done by assessing intermediate program outcomes like contraceptive use. But, contraceptive behavior is a complex and stochastic behavior that varies from individual to individual. It involves not only contraceptive use but also non-use as well as irregular movement between these states. Furthermore, this behavior is intimately influenced by reproductive events and fertility intentions. As such, contraceptive utilization patterns show large variations over time, across different settings and life stages (Casterline, 2001). In an attempt to capture this complexity, there are a number of indicators[1] that measure different aspects of cross-sectional and longitudinal contraceptive behavior (Bertrand, Magnani, Rutenberg, 1994). Though this breakdown simplifies the measurement, it also results in disjointed information.

Moreover, none of the indicators gives insight into the impact of a population's contraceptive behavior on number of pregnancies. Nor is there any direct measure of pregnancy outcomes occurring as a result of varying contraceptive behaviors. Not only this, none of the available indicators accounts for irregular contraceptive use over a period of time and the subsequent impact on number of pregnancies. Contraceptive use, even irregular, provides better protection against pregnancies as compared to contraceptive non-use albeit for only that short window period. A number of such individual window periods added over time and at population level can have a substantive effect, and such a reality should not be ignored when measuring family planning program outcomes at the population level. It is imperative that when deciding strategy, any established FP program considers all dimensions of contraceptive behavior and closely related factors at the population level, their inter-dependence, and most importantly their impact

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[1] *The most commonly used ones are MCPR, continuation rates, contraceptive discontinuation, unmet need, contraceptive switching, and contraceptive failure rates.*

on reproductive events.

Yet another issue with contraceptive behavior is the data which is collected as event history recorded in a calendar format. Such data possess features like censoring[2], non-parametric time-dependent covariates, and presence of competing risks[3], that require due consideration during analysis. Though the afore-mentioned indicators have successfully employed survival methods to deal with data issues, some statistical concerns still remain. Contraceptive discontinuation and/or switching utilize multiple decrement life tables to account for competing risks. The probabilities obtained using life tables assume that censoring occurred uniformly throughout the given interval and that the censored observations were at risk for only half of the follow-up period (Namboodiri, 1987; Szklo, 2007). But apart from this basic limitation, multiple decrement life tables wrongly assume independence among competing risks, meaning that if the discontinuation due to one reason is removed the risk of discontinuation from other reasons remain the same (Vilaprinyo et al., 2008). The appropriate measure in such settings is cumulative incidence which is a function of hazards of all failure types (Kim, 2007). Cumulative incidence counts all failures as events when calculating the probability of event-free survival just prior to a certain interval and only the remaining observations are considered that are truly at the risk of failure.

The latest effort in dealing with contraceptive behavior has been the multistate life table method (Kuo, Suchindran, & Koo, 2008). This method has been successful in dealing with multiple states and complex transitions in a single analysis. However it has the limitation of being based on Markov assumption, traditionally accepted for demographic analysis, of lack of memory and reflects that any conclusions reached do not depend on past history. This drawback can be overcome by Semi-Markov models but so far these have not been applied in replicating contraceptive use behavior.

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[2] *Censored observations are observations that contain incomplete information relating to 'the time to event'. Some subjects may have come in the study after the process already started so that the time of origin is not known (left censored), others may have left the study or the study could have ended before the event occurred (right censored), or there may be interval censored (left in between and came back).*

[3] *"A competing risk is defined as an event whose occurrence either precludes the occurrence of another event under examination or fundamentally alters the probability of occurrence of this other event" (Gooley, 1999).*

This study aims to model contraceptive behavior of a population, allowing for its complexity, stochasticity, and heterogeneity, and come up with a set of summary measures that will be a better guide to future policy and strategy on family planning programs.

Methods

Data: Data for this model has been obtained from the National Family Health Survey (NFHS-3, 2007) which is a nationally and state representative household survey covering 99 percent of India's population. Information has been retrieved from the first two calendar columns on contraceptive history as well as from cross-sectional data in the woman's file. The first calendar column records information on contraceptive use whereas the second calendar column records the reason for discontinuation of each episode of continuous contraceptive use. Information in the first column is recorded by method type, contraceptive non-use, pregnancies and their outcome of either birth or termination on a monthly basis.

Target Study Population: The population cohort to be simulated includes women of reproductive age 15-49 years from the rural poor population subgroup. For this, the total population was first divided by region into rural and urban groups. The individual wealth scores were ranked separately in each region followed by division into tertiles - poor, middle class, and rich. In the original dataset, wealth scores have been constructed from household ownership of assets using Principle Components Analysis (PCA).

Structure of the Model: The model consists of seventeen initial states including the main states of permanent contraceptive use, modern temporary contraceptive use, traditional contraceptive use, contraceptive non-use, apart from the state of wants to become pregnant and the consequent states of pregnancy, birth, and termination for each of the four states other than permanent use (Figure 1). The study cohort enters the model based on initial probabilities in the Markov states and age and parity distribution in each state as on January 2004 and leaves the model at the end of 24 months or at completion of age 49 years, whichever comes first. Each state branches into three age-groups to account for different transition probabilities by age:15-19 years, 20-35 years, and 36-49 years. While youth in age-group 15-19 have been put in a separate category to understand conditions unique to adolescents and aid policy, women above age 35 years are presumed to show similar contraceptive behavior as the majority have usually completed their family. Age and parity distributions for each state reflect those on January 2004. Further movement is based on continuation or discontinuation in that state.

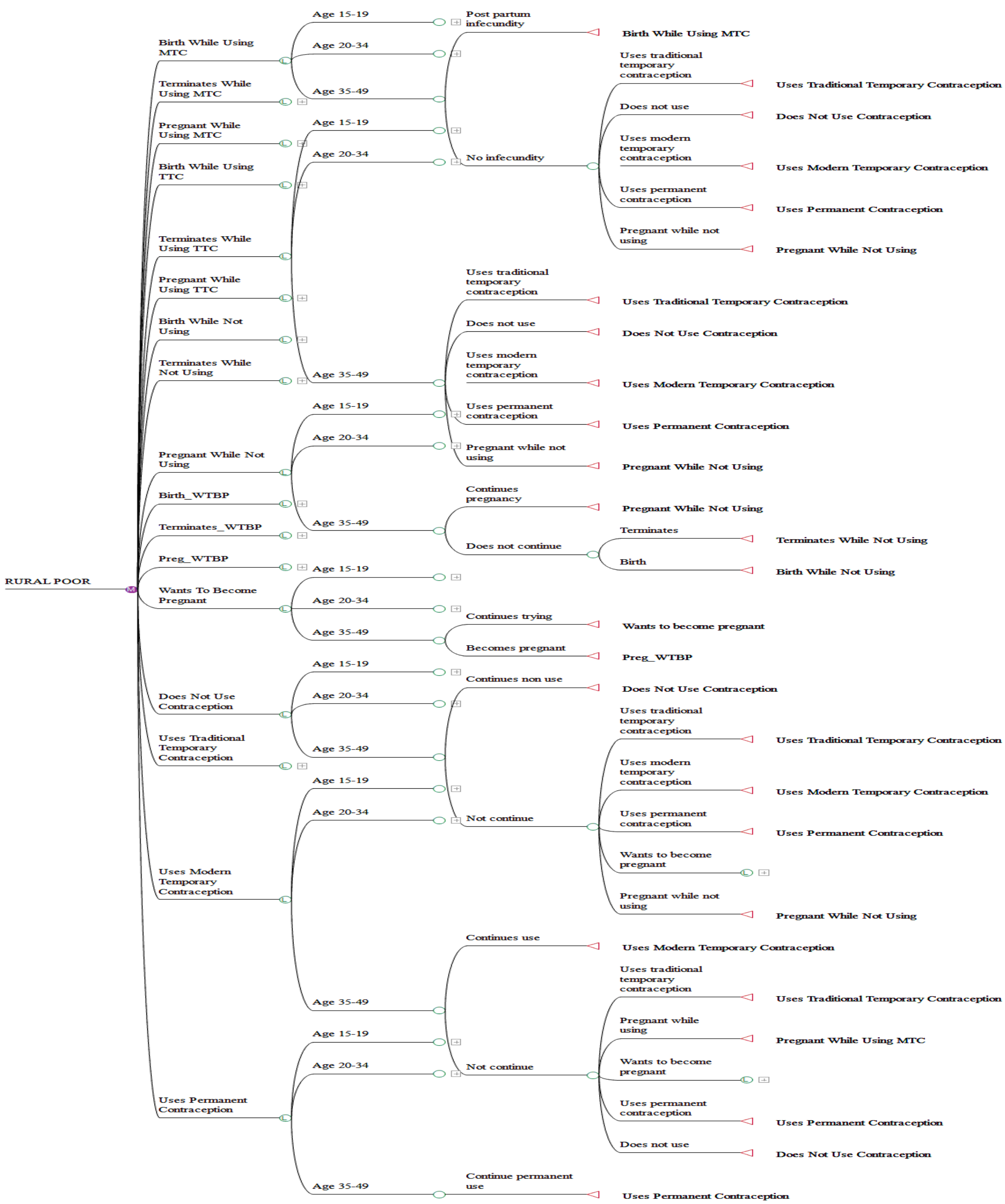

Figure 1. Model structure

For the population subset that does not use contraception, there are five possible likelihoods after discontinuation - adapting permanent contraception, adapting modern temporary contraception, adapting traditional contraception, wanting to become pregnant or getting pregnant while not using. Similarly for the population subsets that use modern/traditional contraception, there are five possible options on discontinuation- not using contraception at all, adapting permanent contraception, adapting traditional/modern temporary contraception, wanting to become pregnant or getting pregnant while using modern/traditional contraceptives respectively. For the state of permanent contraception, the cohort continues to remain in the state for their whole reproductive life. The state of 'Wants to become pregnant' reflects the fertility desires of the cohort. This separate state along with its consequent state of pregnancy distinguishes women who were not using contraception and consequently became pregnant from those who deliberately stopped using contraception to become pregnant. Once in the state of 'Wants to become pregnant', a woman keeps on trying until she becomes pregnant. Yet another addition to the model is the division of the transition branch of wanting to become pregnant from the states of non-use and temporary contraceptive use. Though the cohort progresses to the state of 'Wants to become pregnant' from either branch, the two branches based on parity distinguish between women who have a high demand for children and those who don't. Any woman who still wants to become pregnant at parity two or more is categorized as having a high demand for children.

The other twelve states and their sub-trees depict transitions from the state of pregnancy[4] and its outcomes. Once a woman is pregnant, she either discontinues in a termination[5] or continues being pregnant to end in birth. In case of pregnancy, only the complete episodes have been used to obtain the probabilities. The sub-trees for birth also represent post-partum insusceptibility following birth. The possible options for discontinuation from the states of birth and termination include adapting permanent contraception, adapting modern temporary contraception, adapting traditional contraception, not using contraception or getting pregnant while not using. Two points to note here- one, these transitions bring the cohort back to the main four states from where the

[4] *Pregnancy here is a common reference to women who 1) became pregnant because they wanted to become pregnant; 2) became pregnant while not using contraception; 3) became pregnant while using modern temporary contraception; and 4) became pregnant while using traditional contraception.*

[5] *The data reflects any still-birth as a termination too. On the other hand, no distinction has been made for spontaneous versus induced termination.*

process restarts. Note that all pregnancies following birth or termination have been indicated as pregnancy while not using.

Time base of the model: A fixed cycle length of one month has been used because it is the best unit applicable to all contraceptive methods and also the contraceptive history recorded in calendar data is monthly. Half cycle corrections[6] have been applied.

Transition probabilities: The probabilities for the model have been obtained using a two-year time period from January 2004 to December 2005. Either complete episodes or episodes longer than 20 months have been considered, the latter to account for long term continuation in any state. In case of probabilities related to pregnancies, only complete episodes have been considered.

The transition probabilities are obtained separately by age-groups. Continuation rates in any state are obtained by estimating hazard rates for 24 months. For the various likelihoods of transition on discontinuation from a state, time-dependent probabilities are estimated using the methodology of competing risks. This is followed by getting the proportion of each state transition at each time period (month) across multiple destination states.

Model validation: Four types of validity have been advocated for Markov models of which this study demonstrates three (Kim & Thompson, 2010). The model has face validity as it includes all the key features related to contraceptive behavior as evident from following subjects in the actual dataset.

For internal validation, trends in monthly population proportion from actual data and those obtained from extrapolation of the model are compared for a period of two years for four Markov states. The charts in Figure 1 illustrate converging trends in the two sets of values. Note that while the former values are point in time values i.e. cross-sectional they still are a function of contraceptive behavior in the previous months. The values from the model are an average

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[6] *Half cycle correction counts membership at the end of the cycle and adds a half-cycle for the initial membership thereby simulating that transitions occur half-way through the cycle.*

population proportion in a state derived from the average cumulative time spent by the population over 'x' number of months.

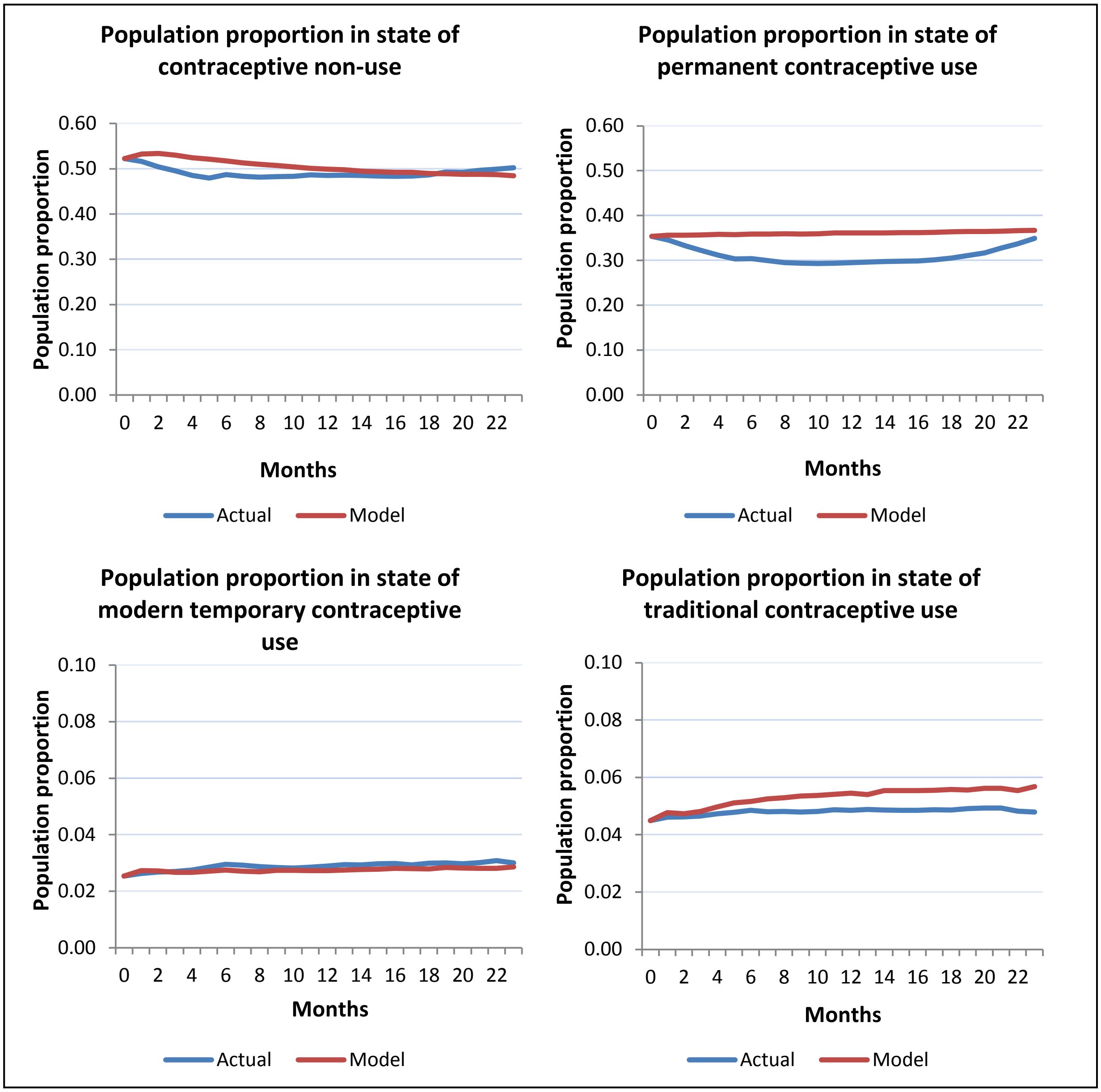

Figure 3. Internal validation: Trends in proportion in the four states of contraceptive behavior

Prospective validation has been carried out similarly by comparing trends in probabilities from actual survey data beyond December 2005 and those obtained from model extrapolation for the third year. The charts in Figure 2 show the trends to be similar thereby imparting prospective validation to the model.

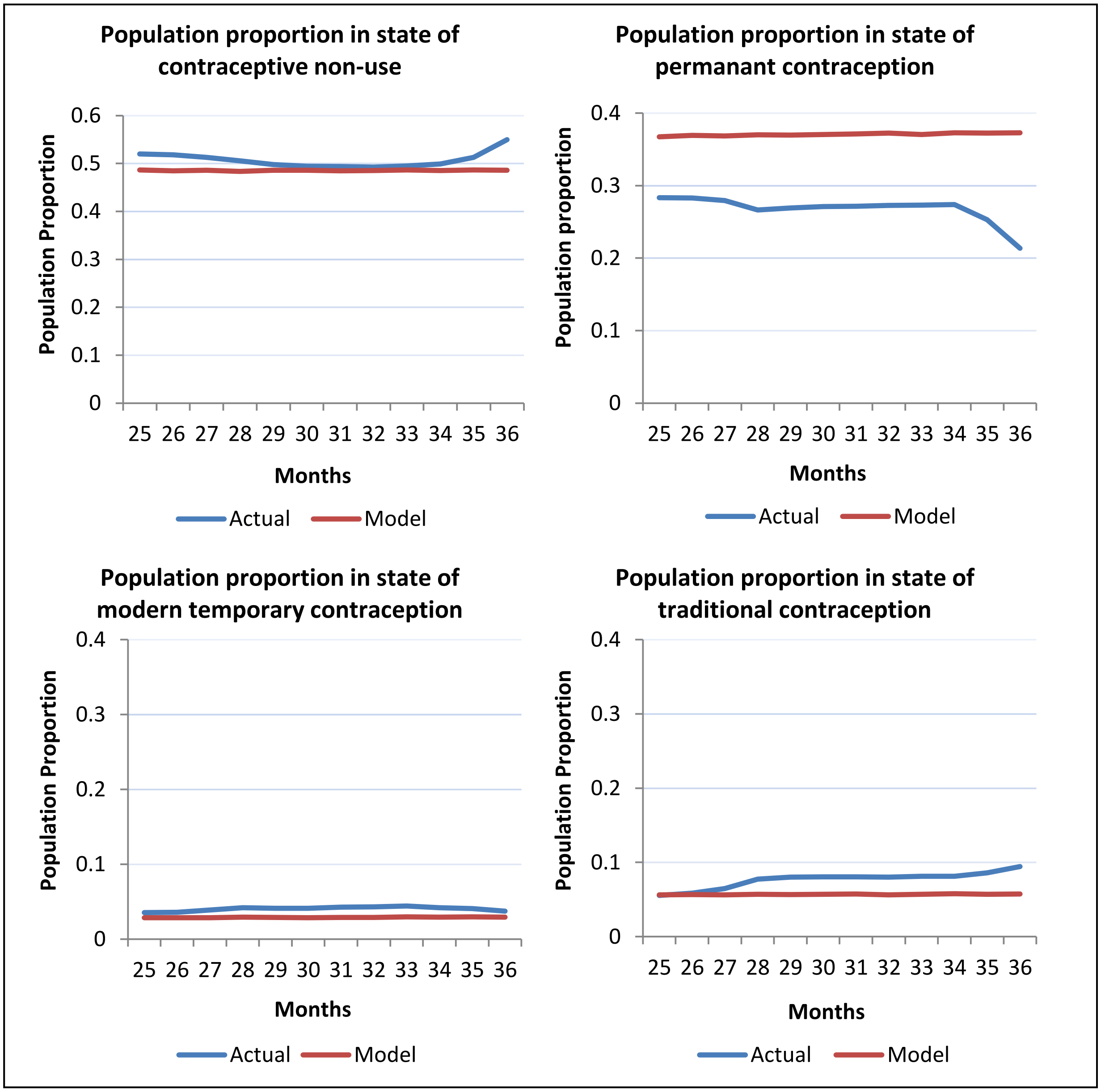

Figure 4. Prospective validation: Trends in proportion in the four states of contraceptive behavior

External validation of the model was not possible due to lack of data with similar representation and same time-period.

Assumptions: There are several assumptions involved in this model. 1) For coital dependent methods like condoms or jelly, and temporary methods like oral pills, it is assumed that the method was used for the whole month. 2) Menopause is assumed to occur at the age of 49 years for the whole population and women are assumed to have a zero risk of pregnancy subsequently.

3) Any pregnancy resulting as a failure of sterilization or due to re-canalization procedures is assumed to be zero. 4) The cohort is assumed to be static with zero migration and no change in economic status. 5) Based on prior research (Strickler, Magnani, McCann, Brown, & Rice, 1997), some error in the calendar data has been assumed to be negligible.

Limitations: Study findings should be interpreted with caution owing to certain limitations. 1) Probabilities are obtained from the years 2004-2005 which is very old and as such results cannot be applied to recent times. However, the study aims to give insight into a number of interesting findings and the model can always be updated with more recent data. 2) The cohort does not allow for entry of new subjects and any mortality. 3) Terminations reflect both natural as well as induced abortions because the data does not offer any distinction between the two. 4) Terminations and births, though being momentary events, have been modeled for one whole month due to the way data has been entered. This might lead to some bias in estimates. 5) The reason of "Wants to become pregnant" has not been recorded for non-users in the calendar format. As such, there is no movement of population from non-use to the state of "Wants to become pregnant". Therefore, there is probability of slight (cross-sectional data indicates this as a reason for 2 percent of non-use) underestimation of pregnancies when wanting to become pregnant and an equal over-estimation in pregnancies following non-use. 6) As we move towards the branches on the right of the model, the sample size keeps on reducing and so there are certain branches where the probabilities are based on very small samples. As a result, conclusions cannot be drawn with sufficient precision for branches on the extreme right of the model.

Results

Monte Carlo trials of Markov models are performed for a period of two years with a cycle length of one month i.e. 24 cycles to simulate a population of 500,000. For each simulation, contraceptive and reproductive behavior is followed, from cycle to cycle for one woman at a time, based on age- and time-dependent probabilities obtained from actual population data. Transition from one contraceptive category to another is governed by computer-generated random numbers mapped onto the relevant age- and time-dependent cumulative transition probability distributions. However, for simulations this random generation is compromised by using seeding.

The model computes mean lengths of stay in different Markov states over 500,000 trials along with mean of total months spent in the model. Table 1 displays data for the four main states of contraceptive behavior- contraceptive non-use, traditional contraceptive use, modern temporary contraceptive use, and permanent contraceptive use. Over a period of 23.97 months, the average cumulative time spent by the population (referred to as 'stay') in the state of contraceptive non-use is approximately 11.65 months accounting for the highest stay of 48.61 percent. This is followed by stay in the state of permanent contraceptive use of 36.71 percent.

Table 1. Average stay (in months) and proportion of stay (in percent) in the four Markov states at the end of two years following 500,000 trials

	Average stay (in months)	Proportion of stay (%)**
Contraceptive non-use	11.65	48.61
Traditional contraceptive use	1.35	5.63
Modern temporary contraceptive use	0.68	2.85
Permanent contraceptive use	8.80	36.71
Mean of total cycles completed*	23.97	

** Deviation from a total of 24 months is due to some women "aging out (exceeding 49 years)" of the model.*
*** Percentages do not add to 100 because of presence of "Other" states (pregnancies, births, and terminations) in the model which account for the remaining 6.2%.*

Table 2 shows pregnancy estimates over the two year period. The table shows absolute number of pregnancies, proportion of pregnancies in each category to the total, as well as number of pregnancies in hundred women-years[7]. The latter indicator provides a standardized insight into pregnancy estimates. Pregnancies occurring as a result of wanting to become pregnant indicate demand for children while all other pregnancies can be assumed to be unwanted pregnancies. Pregnancies following modern temporary contraceptive use indicate modern temporary contraceptive failure while those following traditional contraceptive use indicate traditional contraceptive failure.

[7] *Number of pregnancies in hundred women-years=* $\frac{\text{Absolute number of pregnancies over 24 months} * 12 * 100}{\text{(Mean length of stay over 24 months)} * 500000}$

The high standardized estimates for pregnancy when wanted to become pregnant are understandable. More surprising are the standardized pregnancy estimates for contraceptive failures that show a higher number of modern contraceptive failures as compared to traditional contraceptive failure.

Table 2. Pregnancies at the end of two years

	Absolute # of pregnancies	Proportion of total pregnancies	Average stay in previous state (in months)	# of pregnancies per 100 women-years
Pregnant when wanted to become pregnant	5453	0.09	0.04	323.96
Pregnant while not using contraception	51726	0.83	11.65	10.66
Pregnant while using traditional contraception	3376	0.05	1.35	6.01
Pregnant while using modern temporary contraception	1403	0.02	0.68	4.96
Total	61958	1.00	23.97	6.20

Comparing average stay in a Markov state at the end of two years with total number of pregnancies over the two year period indicates that the number of absolute pregnancies seems to be directly proportional to the average length of stay in a state. However, further disaggregation of above estimates by age-group gives a slightly different picture (Figure 4 and table 3). Absolute number of pregnancies are not proportional to the length of stay in a state. For example, age-group 15-19 years accounts for 28 percent stay in the state of contraceptive non-use whereas the proportion of absolute number of pregnancies following non-use in this age-group is 20 percent. On the other hand, age-group 20-35 years accounts for approximately 41 percent of stay in the state of contraceptive non-use but more than 75 percent of pregnancies following non-use. Standardized estimates of pregnancies indicate the lowest rate of unwanted pregnancies in the age-group 36-49 years. A point of concern is that almost 20 percent of the total pregnancies are teenage pregnancies which should be totally averted. More alarming is the high number of pregnancies per hundred women-years due to contraceptive failures in this age-group. Also note the high number of pregnancies per hundred women-years following contraceptive non-use in the age-group of 20-35 years.

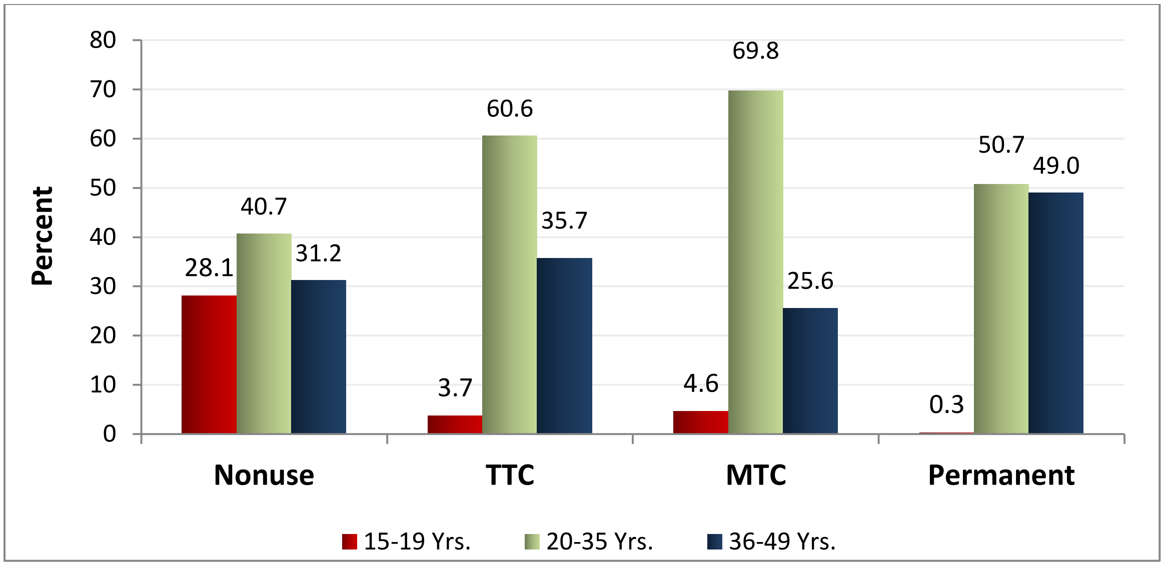

Figure 5. Percent contribution by age-group in stay in the four Markov states at the end of two years

TTC- Traditional contraception; MTC- Modern temporary contraception

Table 3. Pregnancies at the end of two years by age groups

	Absolute number of pregnancies	Proportion of total pregnancies	Average length of stay in previous state (in months)	Number of pregnancies per 100 women-years
15-19 years				
Pregnant when wanted to become pregnant	1162	0.10	0.01	311.74
Pregnant while not using contraception	10367	0.84	3.28	7.59
Pregnant while using traditional contraception	421	0.03	0.05	20.18
Pregnant while using modern temporary contraception	345	0.03	0.03	26.29
Total	12295	1.00	3.37	
20-35 years				
Pregnant when wanted to become pregnant	4183	0.09	0.03	321.77
Pregnant while not using contraception	38815	0.83	4.75	19.63
Pregnant while using traditional contraception	2696	0.06	0.82	7.90
Pregnant while using modern temporary contraception	870	0.02	0.48	4.39
Total	46564	1.00	6.07	
36-49 years				
Pregnant when wanted to become pregnant	167	0.06	0.00	200.80
Pregnant while not using contraception	2303	0.78	3.63	1.52
Pregnant while using traditional contraception	272	0.09	0.48	1.36
Pregnant while using modern temporary contraception	200	0.07	0.17	2.75
Total	2942	1.00	4.29	

A series of sensitivity analyses are done replicating four different scenarios. In the first and second sets, initial probability in state of contraceptive non-use is reduced by .005, .01, .02, .05, .10, .15 and .20 from the original value with a corresponding increase in initial probabilities in states of modern temporary contraceptive use and permanent contraceptive use respectively. In the third and fourth sets, probability of continuation in state of contraceptive non-use is reduced by .5%, 1%, 2%, 5%, 10%, 15% and 20% with consequent switch to states of modern temporary contraceptive use and permanent contraceptive use respectively.

Figure 5 depicts the final proportions of stay in the relevant Markov states at the end of two years after graded improvements in modern temporary contraceptive prevalence at the beginning of the period. Table 4 provides the pregnancy estimates over the two year period following this sensitivity analysis. Correlating the two sets of results, the least number of absolute pregnancies during the two year period corresponds to a reduction of .05 in initial probabilities in state of contraceptive non-use. Further increase in pace of uptake of modern temporary contraception among contraceptive non-users leads to a gradual rise in absolute number of pregnancies.

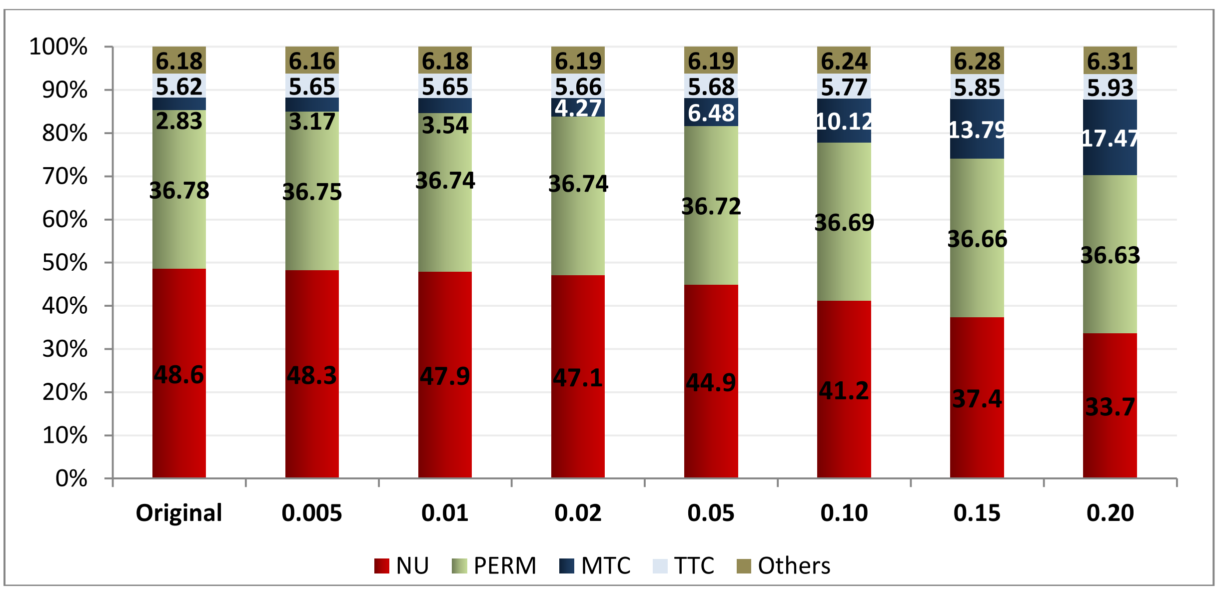

Figure 6. Stay in Markov states at the end of two years following sensitivity analysis: Improvement in modern temporary contraceptive prevalence at time 0

Table 4. Pregnancy estimates over two years following sensitivity analysis: Improvement in modern temporary contraceptive prevalence at time 0

Sensitivity Analysis	# of pregnancies per 100 women-years	Absolute # of total pregnancies	Pregnancy following nonuse	Pregnancy following MTC	Pregnancy following TTC	Pregnancy when WTBP
Original	6.20	61958	83.49%	2.26%	5.45%	8.80%
0.005	6.18	61731	83.02%	2.47%	5.49%	9.03%
0.01	6.19	61779	82.64%	2.69%	5.46%	9.20%
0.02	6.20	61890	81.87%	3.07%	5.45%	9.61%
0.05	6.19	61856	79.70%	4.26%	5.37%	10.66%
0.10	6.20	61948	75.88%	6.16%	5.25%	12.70%
0.15	6.22	62100	72.04%	8.03%	5.51%	14.41%
0.20	6.20	61951	68.43%	9.96%	5.37%	16.24%

As can be seen pregnancies because of wanting to become pregnant make a big fraction of the total increase in pregnancies followed by modern temporary contraceptive failures. Note that proportion of modern temporary contraceptive failures has jumped to more than five times its original share when initial probability of modern temporary contraception is increased by .20 from .0271 to .2271.

Figure 6 and Table 5 show the results of graded improvements in permanent contraception in the model population with corresponding reductions in the initial probability of contraceptive non-use. Results indicate that even a small reduction of .5 percent in initial probability of contraceptive non-use with corresponding improvement in initial probability of permanent contraceptive use reduces absolute number of pregnancies by 24 percent over a two year period. However, percentage gain in reduction in absolute number of pregnancies per new client gained gradually declines from 24 percent to 18 percent and then remains stationary at 14 percent. A closer look at absolute number of pregnancies shows reduction in all four categories of pregnancies.

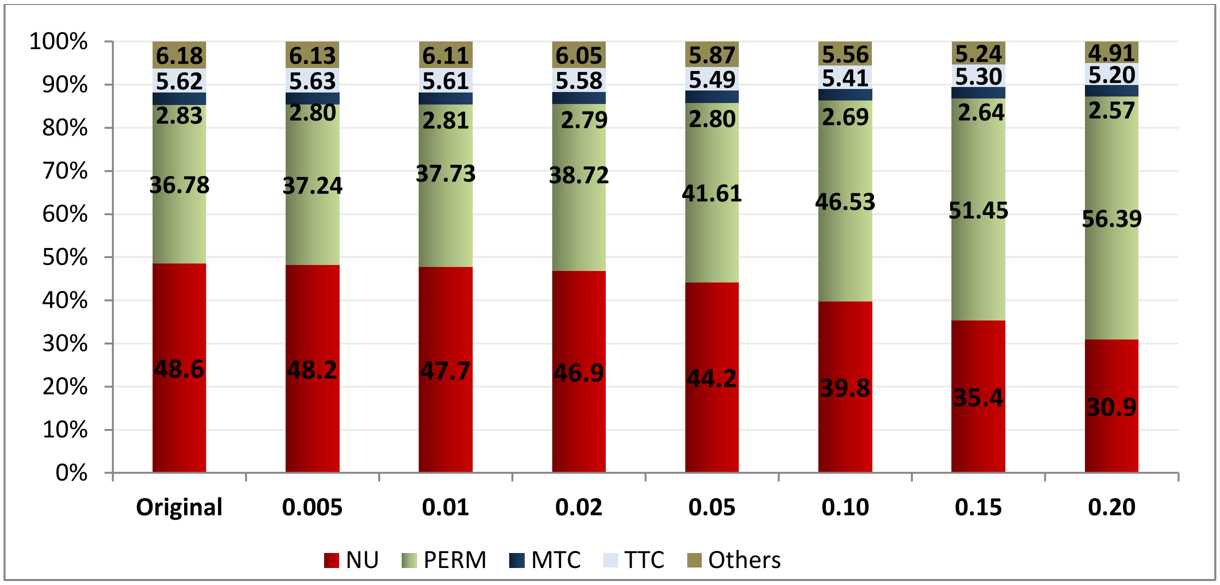

Figure 7. Stay in Markov states at the end of two years following sensitivity analysis: Improvement in permanent contraceptive prevalence at time 0

Table 5. Pregnancy estimates over two years following sensitivity analysis: Improvement in permanent contraceptive prevalence at time 0

Sensitivity Analysis	# of pregnancies per 100 women-years	Absolute # of total pregnancies	Pregnancy following nonuse	Pregnancy following MTC	Pregnancy following TTC	Pregnancy when WTBP
Original	6.20	61958	83.49%	2.26%	5.45%	8.80%
0.005	6.14	61350	83.36%	2.26%	5.50%	8.88%
0.01	6.11	61060	83.29%	2.29%	5.51%	8.90%
0.02	6.06	60484	83.12%	2.33%	5.56%	9.00%
0.05	5.85	58423	82.78%	2.45%	5.58%	9.18%
0.10	5.51	55048	82.17%	2.46%	5.67%	9.69%
0.15	5.17	51664	81.42%	2.57%	6.14%	9.88%
0.20	4.81	48044	80.85%	2.64%	6.23%	10.28%

The results of graded reductions in probability of continuation in state of contraceptive non-use with consequent switch to state of modern temporary contraceptive use are shown in Figure 7 and Table 6. With continuous switch of contraceptive non-users to the state of modern temporary contraceptive use each month, the absolute number of total pregnancies in a two year period show a dramatic rise. As compared to original estimates, a continuous switch of 20 percent non-users to modern contraception every month for two years results in near half reduction in number of pregnancies following non-use but more than eleven times rise in pregnancies due to modern contraceptive failure and a four times increase in pregnancies because of demand for children.

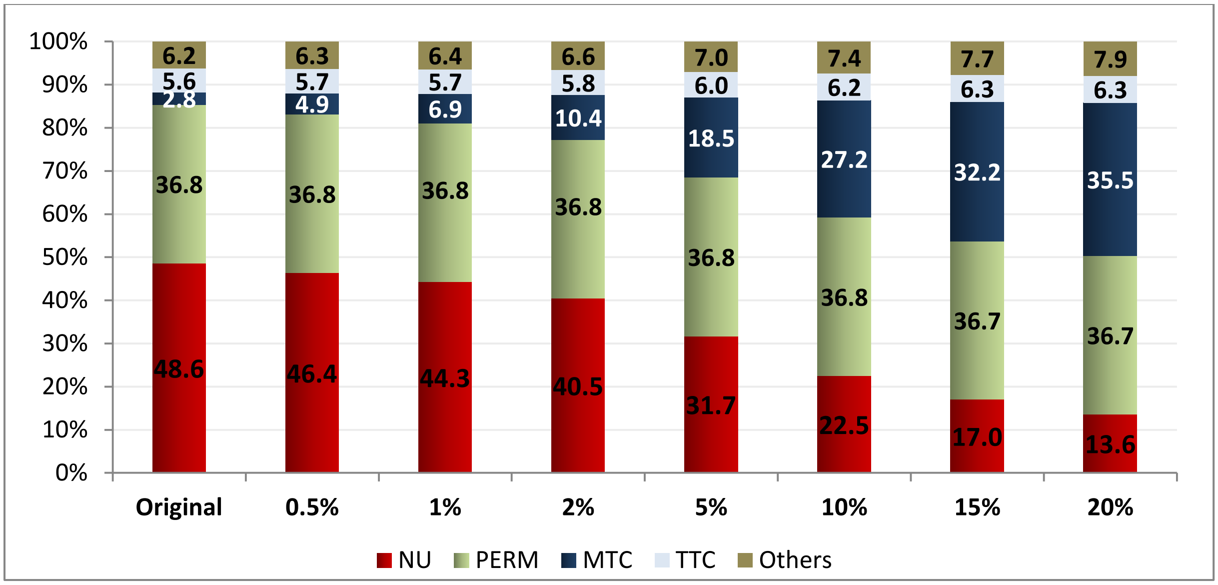

Figure 8. Stay in Markov states at the end of two years following sensitivity analysis: Probability of continuation in state of contraceptive non-use reduced with consequent switch to state of modern temporary contraceptive use

Table 6. Pregnancy estimates over two years following sensitivity analysis: Probability of continuation in state of contraceptive non-use reduced with consequent switch to state of modern temporary contraceptive use

Sensitivity Analysis	# of pregnancies per 100 women-years	Absolute # of total pregnancies	Pregnancy following nonuse	Pregnancy following MTC	Pregnancy following TTC	Pregnancy when WTBP
Original	6.20	61958	83.49%	2.26%	5.45%	8.80%
0.5%	6.32	63104	80.21%	3.87%	5.41%	10.51%
1%	6.44	64316	77.02%	5.38%	5.36%	12.24%
2%	6.65	66401	71.62%	8.15%	5.25%	14.98%
5%	7.10	70882	59.95%	13.65%	5.12%	21.29%
10%	7.44	74277	48.48%	18.70%	5.07%	27.75%
15%	7.64	76291	41.64%	21.26%	5.07%	32.03%
20%	7.71	77045	37.01%	23.12%	5.13%	34.73%

Figure 8 and Table 7 provide an insight into average length of stay in different Markov states and pregnancy estimates after probability of continuation in state of contraceptive non-use is reduced with consequent switch to state of permanent contraceptive use. Results of this sensitivity analyses show that continuous effort at converting non-users to permanent contraceptive users has a cumulative impact on the absolute number of pregnancies. Also note that the average length of stay in Markov states other than permanent contraceptive use declines.

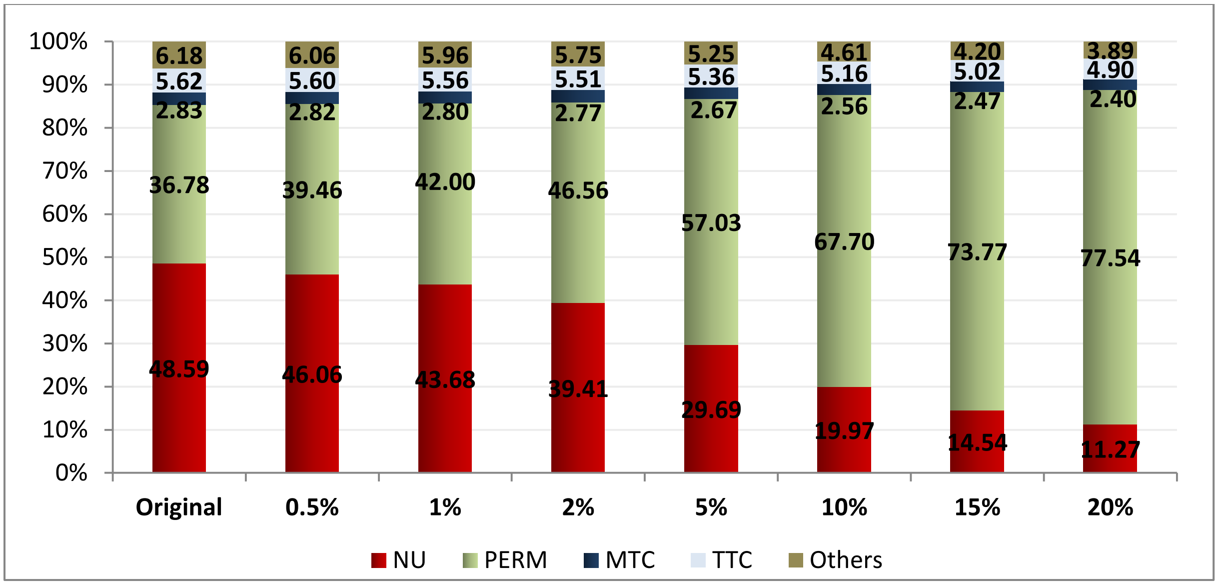

Figure 9. Stay in Markov states at the end of two years following sensitivity analysis: Probability of continuation in state of contraceptive non-use reduced with consequent switch to state of permanent contraceptive use

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0.5%	6.05	60428	83.19%	2.29%	5.56%	8.96%
1%	5.91	59001	82.89%	2.32%	5.64%	9.15%
2%	5.64	56321	82.28%	2.43%	5.82%	9.47%
5%	5.01	49986	80.73%	2.67%	6.35%	10.26%
10%	4.26	42495	78.27%	3.01%	7.13%	11.59%
15%	3.79	37897	76.36%	3.23%	7.82%	12.59%
20%	3.47	34624	74.81%	3.43%	8.35%	13.41%

Discussion

Some of the findings from the study seem to be counter-intuitive. Logically, contraceptive failures should be higher in the population subgroup who use modern temporary contraceptives the most. But girls in age-group 15-19 years show highest number of pregnancies per hundred women-years consequent to modern temporary contraceptive use but have the lowest stay in the state. It follows that there must be other factors, apart from contraceptive prevalence, that have an important bearing on number of pregnancies in a population subgroup. High mean number of pregnancies following modern temporary contraceptive use can be attributed most importantly to incorrect and/or inconsistent use of temporary contraceptives resulting in higher contraceptive failures (Potter, 1996; Steiner, Dominik, Trussell, & Hertz-Picciott, 1996), a fact further corroborated by the switching patterns seen in the state of temporary contraceptive use (explained later). Similarly, number of pregnancies per hundred women-years following non-use is disproportionately high among women of age-group 20-35 years. Here again, contraceptive non-use alone cannot explain the differences and points to other factors at play like frequency of sex and age-wise differentials in biological fertility. The same explanations on the reverse apply to the age-group 36-49 years where low standardized pregnancy estimates are seen across all categories.

The above findings can be better understood by looking at switching patterns between states. Of the population in state of non-use, Table 8 shows that major fraction is composed of never-users while the rest is constituted by post pregnancy nonusers and modern temporary contraceptive users and traditional contraceptive users who have switched to non-use. Never-users comprise the major fraction across all age-groups, and are comparatively lower in age-group 20-35 years. However, the underlying reason is not higher modern contraceptive use but because a comparatively higher fraction is being constituted by post-pregnancy non-users. Another noteworthy issue is that switching from state of non-use is mainly due to pregnancies following non-use. These are highest among age-group 20-35 years. Note that total discontinuation from the state of non-use is higher than the total switch from other states.

Table 8. Switching to and from the state of contraceptive non-use

	Total	**15-19 years**	**20-35 years**	**36-49 years**
Number of non-use episodes	298270	93756	129294	75220
State of origin				
Never users	88.50%	94.28%	79.75%	96.31%
Post-pregnancy	9.27%	4.89%	16.28%	2.70%
Modern temporary contraceptive use	1.54%	0.54%	2.87%	0.50%
Traditional contraceptive use	0.69%	0.29%	1.10%	0.49%
Total switch from other states	11.50%	5.72%	20.25%	3.69%
State of destination				
Pregnancy following non-use	12.21%	8.61%	20.61%	2.25%
Traditional contraceptive use	3.95%	2.20%	6.53%	1.70%
Modern temporary contraceptive use	2.58%	1.49%	4.32%	0.96%
Permanent contraceptive use	1.94%	0.46%	3.90%	0.41%
Total discontinuation	20.68%	12.76%	35.36%	5.32%

Table 9 shows that proportion switching to state of temporary contraceptive use is pretty high as compared to proportion discontinuing from state of temporary contraceptive use across all age-groups. Of all the episodes of modern temporary contraceptive use in the two years, the highest share is from those continuing in the state followed by switching from state of contraceptive non-use and post-pregnancy. An encouraging fact is the high uptake of modern contraception in the age-group 15-19 years following non-use and post-pregnancy but at the same time it is disheartening to find high discontinuation rates in the same age-group.

Table 9. Switching to and from the state of modern temporary contraceptive use

	Total	15-19 years	20-35 years	36-49 years
Number of modern temporary use episodes	23150	2177	17235	3738
State of origin				
Continuous users of modern temporary contraception	57.12%	23.89%	57.65%	73.97%
Non- use	33.28%	64.35%	32.39%	19.32%
Post-pregnancy	7.60%	11.07%	7.75%	4.92%
Traditional contraceptive use	2.00%	0.69%	2.21%	1.79%
Total switch from other states	42.88%	76.11%	42.35%	26.03%
State of destination				
Contraceptive non-use	19.84%	23.29%	21.51%	10.09%
Want to become pregnant	5.65%	16.54%	5.50%	0.00%
Pregnancy following modern temporary contraceptive use	4.63%	8.87%	4.32%	3.64%
Traditional contraceptive use	4.39%	5.33%	3.95%	5.86%
Permanent contraceptive use	0.69%	2.16%	0.66%	0.00%
Total discontinuation	35.20%	56.19%	35.94%	19.59%

Switching patterns from the state of modern temporary contraceptive use show the main reason for contraceptive discontinuation to be non-use followed by desire for children. Across age groups, both these reasons account for almost 40 percent discontinuations in age-group 15-19 years as compared to 27 percent in age-group 20-35 years and 10 percent in age-group 36-49 years.

In case of traditional contraception, apart from continuous users of traditional contraception, the next big fraction is composed of those switching from the state of contraceptive non-use. Main reasons for discontinuation from the state is either to become pregnant or because of failure of traditional methods resulting in pregnancy. Total switch to the state of traditional contraceptive use is higher than discontinuation from the state.

Table 10. Switching to and from the state of traditional contraceptive use

	Total	15-19 years	20-35 years	36-49 years
Number of modern temporary use episodes	38442	3028	25162	10252
State of origin				
Continuous traditional users	62.33%	21.27%	58.71%	82.59%
Non-use	30.67%	68.26%	33.56%	12.48%
Post-pregnancy	4.36%	6.64%	5.02%	2.79%
Modern temporary contraceptive use	2.64%	3.83%	2.71%	2.14%
Total switch from other states	37.67%	78.73%	41.29%	17.41%
State of destination				
Want to become pregnant	9.91%	36.03%	10.81%	0.00%
Pregnancy following traditional contraceptive use	6.57%	11.56%	8.15%	1.21%
Contraceptive non-use	5.39%	9.05%	5.67%	3.62%
Permanent contraceptive use	0.54%	0.00%	0.73%	0.23%
Modern temporary contraceptive use	1.20%	0.50%	1.51%	0.65%
Total discontinuation	23.61%	57.14%	26.87%	5.71%

Conclusions:

In conclusion, this study successfully models all dimensions of contraceptive behavior and related reproductive events. The model not only provides information on longitudinal contraceptive behavior in a population through estimates of mean length of stay in a state but also measures reproductive consequences throughout the specified time-period. Furthermore, the model computes all possible switching behavior in a population over the specified period and can also do future predictions and sensitivity analysis.

Apart from corroborating past research, this study quantifies the actual impact of family planning program efforts on pregnancy outcomes and shows the undesirable and unexpected consequences of a generalized approach of improving contraceptive uptake. In addition, the switching patterns computed from the model give insight into the probable contextual factors at play. For example, model results show that increasing uptake of modern temporary contraception among rural poor Indian women actually results in increase in pregnancies due to contraceptive failure and desire for children. While the former points to incorrect use of temporary contraceptives, the latter indicates demand for children. Results also indicate that more than one-third of modern temporary contraceptive users discontinue over the two year study period, majority of these going back into the state of contraceptive non-use. This is probably due to dissatisfaction with the method being used. In case of the adolescent population subgroup, both uptake of modern temporary contraception and discontinuation from the state is pretty high along with disproportionately high estimates of contraceptive failures. These results show the willingness to use contraception but such favorable intentions suffer due to poor counseling and follow-up. Also, increase in permanent contraception though averts pregnancies, after a certain point stagnation is observed in its impact on reducing pregnancies. This is because of discrepant uptake of permanent contraception by higher ages (results not shown) once their desired family size is achieved so that number of pregnancies averted does not rise proportionately with uptake. Thus, increasing MCPR among rural poor Indian women does not bring the desired impact on number of pregnancies because improving permanent contraception is associated with completion of desired family size whereas improving temporary contraception shows high failures and discontinuations, which in turn lead to high number of pregnancies- unwanted and wanted.

More importantly, the study underscores the fact that the different dimensions of contraceptive behavior and reproductive consequences are very much interconnected, highlights the changing relative importance of these different dimensions, and calls attention to the futility of focusing on isolated aspects of contraceptive dynamics. This raises the question of how to reduce the number of pregnancies and which particular aspects of FP program to strengthen. The study's projections of different targeting strategies, analyses results and switching patterns emphasize targeting specific population subgroups and dimensions of contraceptive behavior in a sequential manner along with continuous re-evaluation of targets with changing dynamics. Thus, owing to a number of factors playing a role in the complex scenario, a delicate and careful balance is needed for the FP program in any country to actually bring about a decrease in number of pregnancies.

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