Journal of Population and Development
Volume 1 December 2014, Pp.1-14

Relationship between Contraceptive Prevalence Rate and Total Fertility Rate: Revisiting the Empirical Model

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Abstract

Studies repeatedly showed a strong negative relationship between the proportion of women who are using contraceptives and their total fertility rates (TFR). The most recognized relationship between TFR and contraceptive prevalence rate (CPR) was illustrated by the empirical model developed by Bongaarts and Potter (1983). The model was based on data from 22 developing countries at the initial phase of fertility transition all over the world. To re-examine the empirical relation between fertility and contraception, DHS data of 74 different countries since 1990s were used in this study. Considering four different regions of the world separately and together, the results indicate that there is an association between decline in the expected level of natural fertility and increase in CPR. Besides Central and Sub-Saharan African countries, the country specific data suggest that due to fluctuation of TFR against irregular trend in contraceptive use, the predicting power of the fitted model also supported by corresponding measure of goodness of fit. The analysis shows that to achieve replacement level of fertility further increase in contraceptive use will be required in many of these developing countries.

Keywords: TFR; CPR; Developing Countries

Introduction

United Nations has projected that most countries will complete their fertility transition by 2050 (United Nations, 2001). Many developing countries experienced large fertility declines in recent decades (Bongaarts, 2003). Some of these countries have been designated previously as high fertility countries. For example, countries from Sub-Saharan Africa experienced a sustained fertility decline in recent years. Such steady decline in fertility occurred in most part of Asia, North Africa and Latin America (Bongaarts, 2008). Fertility transition in many developing countries has been associated with socio-economic factors. Rising age at marriage and widespread use of contraception are the most important factors contributed to fertility decline (Bongaarts and

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Potter, 1983). The pace of fertility decline has not been homogenous across the countries. Some parts of the world are experiencing a faster decline than others. Although higher total fertility is a known attribute in the under-developed countries, many wealthy and middle-income countries in Asia and Europe also have a comparably high fertility (Tabutin and Schoumaker, 2005). Many developing countries in Asia and Africa experienced second phase of fertility transition without much socioeconomic development. On the other hand, countries at similar levels of economic development are often seen to display different patterns of fertility behaviour (Bongaarts and Watkins, 1996).

Thus, the relationship between fertility and its determinants is complex. Studying the determinants of aggregate fertility level is not an easy task, because human reproduction is an outcome of both biological and behavioural factors along with cultural and socioeconomic factors (Bongaarts and Potter, 1983). Bongaarts termed these biological and behavioural factors as the proximate determinants of fertility since they directly affect fertility; and all other social, economic and cultural factors affect fertility indirectly (Bongaarts, 1978). Using data from 41 developed and developing countries they further observed that 96 percent of the variation in total fertility rates (TFR) of these countries could be explained by four principal proximate determinants. These include marriage, contraception, lactational infecundability, and induced abortion (Bongaarts and Potter, 1983). They provided several illustrations to show how the model may be used to gain insight into the operation of the proximate determinants (Bongaarts and Potter, 1983). In the application of the model, it has been observed that, contraceptive use received highest focus. The reason is simple as a population moves through the transition from natural to controlled fertility, there is, by definition an increase in deliberate marital fertility control and the control is exerted primarily through a rise in contraceptive use (Bongarrts and Potter, 1983). Although few populations may obtain this fertility decline due to rise in induced abortion, the situation is different for many developing countries where induced abortions are prohibited by law (Frejka, 1985).

Before Bongaarts model, it has been noted repeatedly about high degree of correlation between fertility and contraception prevalence level of contemporary populations (Berelson, 1974; Nortman, 1980). Perhaps the most widely used relationship between a measure of fertility and contraceptive prevalence is based on the regression of the Crude Birth Rate (CBR) on Contraceptive Prevalence Rate (CPR). Later a regression equation was fitted from the data of 32 developing countries, which predicted the variability of CBR from CPR by 91 percent (Nortman, 1980). However, it is not completely clear how much contraceptive use causes change in fertility of the magnitude indicated by this equation. The CBR is influenced by factors other than contraception, such as the population's age structure, the marriage pattern, the duration of postpartum infecundability, and the incidence of induced abortion. It is necessary to control the influence of these factors before one can reach at the true relationship between fertility and CPR. With

these limitations, regression analysis was conducted by Bongaarts and Potter to examine the relationship between CPR and a number of measures of fertility controlling the confounding variables (Bongarrts and Potter, 1983). The effect of age of the population is removed by taking TFR as the measure of fertility instead of CBR. The data of the 22 developing countries from different regions of the world were used for illustration. Only those developing countries having presumably insignificant level of induced abortion were excluded from the model. The model explained the variability of TFR from CPR by 72 percent and the model is still well recognized for stating empirical relation between aggregate fertility level and CPR of a country. The fitted model established an inverse relationship between TFR and CPR. Besides predicting fertility rates indirectly, these estimates were used primarily by researchers to assess the use effectiveness of various contraceptive methods (Jain, 1997).

As these models were fitted before beginning of fertility transitions in many countries, recent situation may differ significantly. Correlation between TFR and CPR is examined for Sub-Saharan Africa and rest of the world was also considered for comparison (Westoff and Bankole, 2001). Many countries of Asia and Latin America achieved replacement level of fertility and many other countries are approaching to replacement level of fertility (Bongaarts, 2008). Moreover, considering large number of countries from different regions of the world may signify the empirical relation between aggregate fertility level and contraceptive prevalence level more precisely. For example, most of the Asian countries have shown significant increase in CPR for the last two decades, while many countries of Sub-Saharan Africa are far behind them. Few developing countries with fertility transition also reported to have inconsistent contraceptive prevalence level with fertility (Saha and Bairagi, 2007). The socio-demographic status, labour force participation and economic opportunities are significantly different in these regions. Agro-based economy with higher primary education level may be seen in African region, while transition in economic policy from agriculture to industrialization or both may be seen in Asia and Latin America. Labour force participation is increasing in Southeast Asia since the last two decades, which may be one of the driving forces of fertility transition (United Nations, 2001). In this paper the empirical relation between TFR and CPR is examined using the data of the last two decades. The analysis will enable the researchers to understand the consistency of CPR and the aggregate fertility rate. This will also help to estimate the country-specific contraceptive level which will be required to achieve replacement level of fertility.

Data and Methods

Secondary data from Demographic Health Surveys (DHS) were used in this study. DHS project is responsible for collecting accurate and nationally

representative data on health and family planning in many developing countries. The DHS is being implemented by ICF International and is funded by USAID with contributions from other donors such as UNICEF, UNFPA, WHO, and UNAIDS. Similar to the earlier World Fertility Surveys (WFS) and the Contraceptive Prevalence Surveys (CPS), the DHSs are highly comparable to the Multiple Indicator Cluster Surveys. Since 1984, the MEASURE Demographic and Health Surveys (MEASURE DHS) project has provided technical assistance to more than 260 DHSs in over 90 countries - advancing global understanding of health and fertility trends in developing countries. More specifically, the DHSs collect information on fertility, reproductive health, maternal health, child health, immunization and survival status of under five children, HIV/AIDS and nutrition status among women and children. DHSs are nationally representative population-based surveys with large sample sizes (usually between 5,000 and 30,000 households). Stratified multi-stage cluster sampling design is used in all DHSs, though selection of sampling frame and primary sampling unit in a country specific context. In all households, women aged 15-49 years are eligible to participate and in many DHSs men aged 15-54 (in some cases 59) years from a sub-sample are also eligible to participate. STAT compiler (online database of MEASURE DHS) was used in this study to aggregate data of various countries.

Illustration of country specific model for Bangladesh is done using several BDHSs, WFS, CPSs, Bangladesh Maternal Mortality and Health Care Survey (BMMS) and Urban Health Surveys. In addition, data from Matlab Health and Demographic Surveillance System (HDSS) was used for comparison. Matlab HDSS is recognized worldwide as one of the long-term demographic surveillance sites in a developing country. Since 1966, Matlab HDSS has been maintaining the registration of births, deaths, and migrations, in addition to carrying out periodical censuses in Matlab. The trend of CPR was not available since beginning, so the values of TFR and CPR since 1981 to 2011 were considered.

Modeling CPR and TFR

Linear regression models are fitted in the current study for various regions of the world similar to the fitted model of Bongaarts and Potter (1983). The data from 22 different developing countries were used by Bongaarts and Potter (1983). Developing countries having insignificant level of induced abortion were excluded from that model. The fitted model was,

$$TFR = 7.3 - 6.4 \times u;\ R^2 = 0.72 \qquad (1)$$

$$= 7.3 \times (1 - 0.88 \times u)$$

In the derived model of Bongaarts and Potter (1983), an intercept of 7.3 represents the expected level of natural fertility, i.e. fertility in the absence of

contraceptive use (and/or induced abortion). The slope was 6.4, which indicates decline in the level of TFR due to increases in the level of current contraceptive use (u), and the relative slope 0.88 gives the proportional decline in TFR. Bongaarts and Potter (1983) explained this result with the assumption that if 50 percent of currently married women of reproductive age were current users of contraception (u=0.5), then expected TFR will be 6.4 × 0.5 = 3.2 below the natural level of 7.3, a reduction of 44 percent (0.88 × 0.5 = 0.44) in the aggregate level of fertility. The relative slope in equation (1) is virtually the same as the model obtained by Nortman (Nortman, 1980). This implies that the age structure of the population does not have an important disturbing effect on the regression of CBR on contraceptive prevalence rate (Bongaarts and Potter, 1983). It should be noted that all the models fitted in this study are under assumption that other proximate determinants will remain the same (Bongaarts and Potter, 1983).

Results

The results of the fitted model are summarized considering four different regions of the world. These include Southeast Asia, Central and Sub-Saharan Africa, North Africa, part of Europe and Latin America. Table 1 summarized the recorded TFR and CPR.

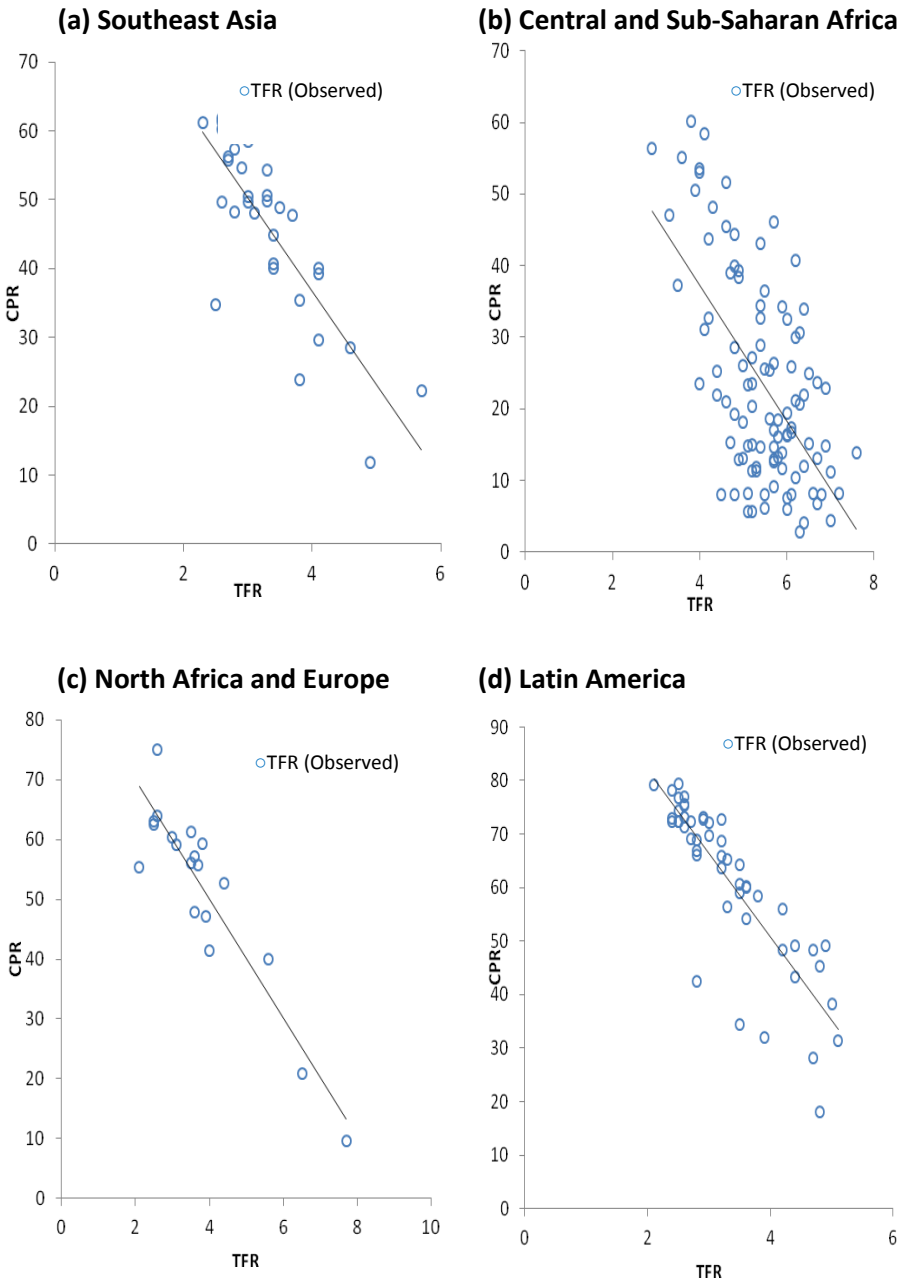
Table-1: Level of TFR and CPR for different regions of the world (DHS 1990-2012)*

Region	Highest observed TFR	Lowest observed TFR	Highest observed CPR	Lowest observed CPR
Africa (Central and Sahara)	7.6 Niger (DHS-2012)	3.3 Lesotho (DHS-2009)	60.2 Zimbabwe (DHS-2005-06)	2.8 Chad (DHS-2004)
Latin America	5.1 Guatemala (DHS-1995)	2.1 Colombia (DHS-2010)	70.9 Colombia (DHS-2010)	18 Haiti (DHS-1994-95)
North Africa and Europe	5.6 Jordan (DHS-1990)	2.5 Morocco (DHS-2003-04)	69.3 Albania (DHS-2008-09)	40 Jordan (DHS-1990)
Southeast Asia	5.7 Timor-Leste (DHS-2009-10)	2.3 Bangladesh (DHS-2011)	61.9 Indonesia (DHS-2012)	22.3 Timor-Leste (DHS-2009-10)

* *Only data of DHS surveys are summarized here along with truncation criterion (omission of countries with TFR<2.1).*

Observed and predicted values of the models are presented in the following figure (Figure 1). The small circles present the observed values of CPR against TFR, while the black straight line represents the predicted values from the fitted model.

Figure-1: Relation between TFR and CPR for different regions of the world (DHS 1990-2012).



It should be noted that limited DHS data are also available for few other countries of Central Asia. But due to lack of complete data set those Central Asian countries were not considered as a separate region in the analysis. For all the models, DHS data before 1990 are omitted and also countries that achieved below replacement level of fertility (TFR<2.1) were also dropped from the analysis to make the comparison at similar level. The fitted models along with number of countries for each region are summarized in Table 2.

Table-2: Information on model fitting between TFR and CPR for different regions of the world (DHS 1990-2012)

Regions	No. of countries considered in model	Fitted model	Model R^2	p-value (model)	p-value (CPR)	p-value (Const.)
Africa (Central and Sub-Sahara)	38	TFR = 6.358 - 0.039 × CPR	0.369	0.000	0.000	0.000
Latin America	13	TFR = 6.167 - 0.046 × CPR	0.725	0.000	0.000	0.000
North Africa and Europe	7	TFR = 7.938 - 0.082 × CPR	0.772	0.000	0.000	0.000
Southeast Asia	9	TFR = 5.634 - 0.050 × CPR	0.682	0.000	0.000	0.000

It should be noted that, these models are fitted considering CPR as independent variable, whereas Bongaarts and Potter (1983) considered proportion of women use contraception (*u*) as the independent variable. Multiplying the slope by 100 will generate the model equivalent to Bongaarts and Potter (1983).The models will remain same as regression coefficients are independent of scale. All the fitted models are highly significant in terms of goodness of fit. The relationship between TFR and CPR is not consistent among all the regions, which may be due to regional variation in the use of contraception as well as variations in the use effectiveness. Consequently, it affects the reality of the fitted model for predicting the required level of contraception required to achieve desired fertility goal.

Most of the countries of Southeast Asia are developing countries. Many of these countries are close to reach replacement level of fertility (for instance, India and Bangladesh) and some of these countries already reached below replacement level of fertility (Vietnam has a TFR of 0.9 according to DHS-2002). With significant presence of fertility transition, all the countries showed increasing trend in the use of contraception. For example, according to 1990-91 DHS, CPR in Pakistan was 11.9 percent which increased to 35.4 percent in the last DHS (2012-13). In Southeast Asia, highest CPR was observed in Indonesia (61.9 percent) in the DHS 2012, while the lowest was observed in

Timor-Leste in DHS 2009-10 (22.3 percent). In few of the countries the DHSs were conducted since last decade. New DHS may indicate more accurate scenario about the relationship between TFR and CPR. Among the nine countries of Southeast Asia, CPR can explain 68.2 percent of the total variation of the observed TFR (R^2=0.682). Although CPR and TFR explain 68 percent of the variation among the nine countries of Southeast Asia, country specific variation will not be uniform because the strength of the relationship is dependent on the use effectiveness of the methods.

Figure 1(b) shows the dispersion in the values of CPR which were high in Central and Sub-Saharan Africa. As a result of this, goodness of fit of the model is poor (R^2=0.369). Previous research also showed weak correlation between TFR and CPR (Westoff and Bankole, 2001). The association becomes stronger when modern methods are substituted for the traditional methods (Westoff and Bankole, 2001). Fluctuations in the use of contraception were observed in several countries. The lowest CPR was observed in Chad (DHS-2004). Only 2.8 percent of the currently married women of Chad use any kind of contraceptive methods; while TFR was 6.3 at that time. Highest CPR was observed in Zimbabwe DHS 2005-06 (60.2 percent) with TFR 3.8. However, almost all the countries of this region are showing increasing trend in contraceptive use.

Several countries of Europe and North Africa are excluded from this study because those countries have already reached below replacement level of fertility. DHSs are conducted only in few countries of Europe because most of the countries of Europe are industrialized and their major population concern is ageing. Among the seven countries considered for this region, three are from Europe– Turkey, Albania and Azerbaijan. Albania and Azerbaijan are now at below replacement level of fertility, so DHSs before achieving below replacement level fertility were considered. In all the countries of this region, CPR was increased sharply in the last two decades. Before being deviated from regional fitted model, highest CPR was observed in Albania DHS 2002 (75.1 percent) and lowest in Jordan DHS 1990 (40 percent). Morocco is approaching to replacement level of fertility steadily. According to 2003-04 DHS, TFR and CPR in Morocco were 2.5 and 63 percent, respectively. It should be mentioned that North Africa and Europe region has the highest explaining power of CPR (77.2 variation of observed TFR can be explained from the current CPR).

Demographic characteristics of Latin America are different from other regions. Countries of these regions differ significantly from the rest of the world in terms of culture, socioeconomic characteristics, and reproductive behaviour. Increase in the use of contraception was observed in all Latin American countries with corresponding decrease in fertility rates. Thirteen

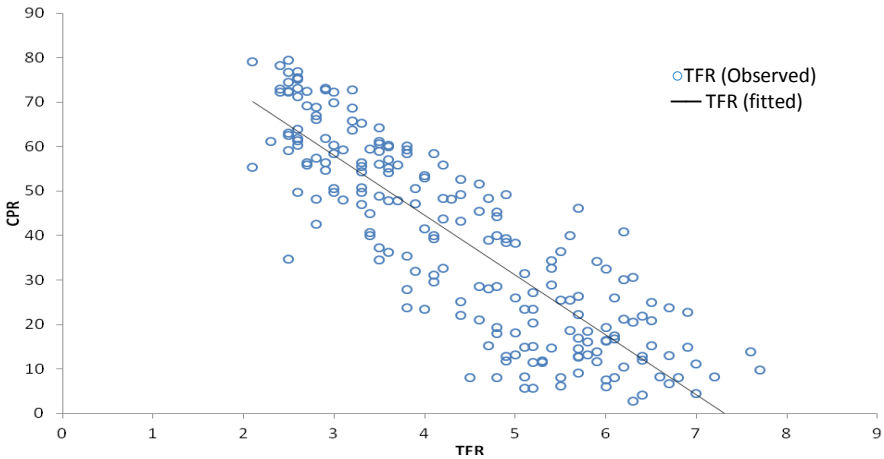
countries were considered for this region, and 72.5 percent variability of observed TFR may be explained from CPR. The highest CPR (79.1 percent) was observed in Colombia as per DHS 2010, Colombia just achieved replacement level fertility (TFR=2.1) in 2010 DHS. Few other countries of these regions are close to achieve replacement level of fertility. Recent DHSs indicate that Dominican Republic, Jamaica, Peru and Paraguay may achieve replacement fertility soon given the current trend. The lowest contraceptive use rate was observed in Haiti with 34.5 percent use of CPR, and the corresponding TFR in Haiti was 3.5 in DHS 2012. The relationship between CPR and TFR in this region can be attributed to socioeconomic and cultural practices of the local people.

Among the four regions, higher contraceptive use was observed in North Africa and Europe while least was observed in Central and Sub-Saharan Africa. The scenario was almost similar to Southeast Asia and Latin America. In the full model we considered 74 countries to investigate the consistency between fertility level and contraceptive use. The omitted countries from Central Asia were also included in the full model, thus the total number of countries increased from 67 in the regional model to 74 in the full model. The fitted model becomes,

$$TFR = 6.529 - 0.054 \times CPR;\ R^2 = 0.731 \qquad (2)$$

Observed and predicted values of TFR and CPR are presented in the following diagram, where small circles present the observed values while black straight line represents the fitted regression model.

Figure-2: Relation between TFR and CPR for 74 countries of the world (DHS 1990-2012).



In the fitted model (Equation 2), the intercept 6.5 represents the expected level of natural fertility, i.e., fertility in the absence of contraception (and/or induced abortion). The results indicate a decline in natural fertility all over the world since 1980s. In addition, predicting power of the model is slightly better than the model of Bongaarts and Potter (1983). The current model can explain the variability of the observed TFR 73.1 percent against the values of CPR. The fitted model also suggests that on an average 82 percent of the contraceptive use would be required for achieving replacement level of fertility around the world.

Illustration of country specific model: Bangladesh

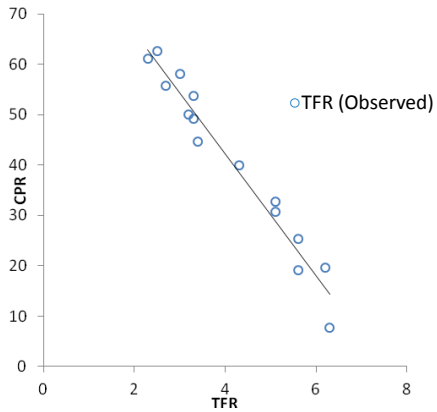
For detailed discussion of the model we considered Bangladesh as a case. Bangladesh showed remarkable success in terms of fertility decline and increasing use of contraceptives in the last two decades (NIPORT et al., 2013). We considered Bangladesh as a case for two reasons. Firstly, Bangladesh showed sharp fall in fertility among the Southeast Asian countries (currently it has the lowest TFR in the region), and secondly, due to availability of data for a long period (from WFS, BFS, CPS and DHS). Current TFR in Bangladesh is 2.3 children per woman against the CPR of 61.2 percent (NIPORT et al., 2013). More than half (52 percent) of the currently married women aged 15-49 years use a modern method of contraception. The four most popular modern methods used by married women were the pill (27 percent), Injectable (11 percent), the male condom (6 percent), and female sterilization (5 percent). Little over 8 percent of the married couples used long-term and permanent methods (NIPORT et al., 2013). Although an increase has been observed in the current use of family planning methods in the recent DHSs, but the relationship between fertility level and CPR is not consistent as expected. The CPR of 61 percent reflects a notable rise from previous BDHSs, but much of that rise was due to nation-wide stock-out for certain methods just before previous survey. Since 2000, the annual rate of increase in CPR has been less than 2 percent (NIPORT et al., 2013).

Since 1993 six DHSs were conducted in Bangladesh. For model fitting other data sources were also used. Data for TFR and CPR were obtained from World Fertility Survey (WFS 1975) and Bangladesh Fertility Survey (BFS 1989); five rounds of Contraceptive Prevalence Surveys (CPS 1979-1991); six rounds of DHSs (BDHS 1993-2011), and two rounds of BMMS (2001 and 2010).

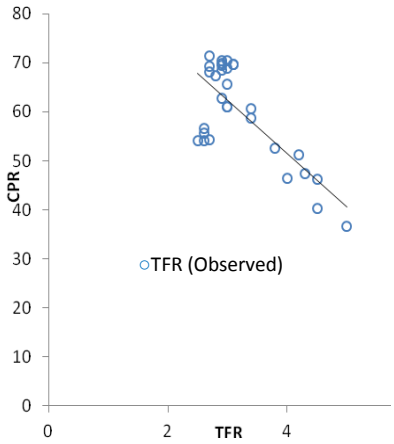
Though these data covered almost 40 years, it was not enough for model fitting; and in view of that we also used data of Matlab HDSS (ICCDRB, 2012). Matlab HDSS is recognized worldwide as one of the long-term demographic surveillance sites in a developing country like Bangladesh. As the trend of CPR was not available since the beginning of Matlab HDSS, so the values of TFR and CPR since 1981 to 2011 were considered. Current TFR and CPR of Matlab HDSS is 2.6 and 54.1 percent, respectively (ICCDRB, 2012). Figure 3 presents both observed and predicted values of TFR and CPR in Bangladesh.

Figure-3: Relation between TFR and CPR in Bangladesh (National and Matlab HDSS)

(a) National Data (BDHSs, WFSs, CPSs, BMMSs; 1975-2011)



(b) Matlab HDSS (1981-2011)



In Bangladesh, TFR declined gradually in the last three decades along with sharp increase in contraceptive use. Both TFR and CPR in Matlab HDSS area fluctuated over time, but the relation between TFR and CPR was not always an inverse one. Use of modern family planning methods was higher in Matlab HDSS area compared to national level data. Among the current users, 78 percent women used any kind of modern methods (ICCDRB, 2012). The fitted model for national data and Matlab HDSS data are shown below in equations 3 and 4, respectively.

$$TFR = 7.351703 - 0.079213 \times CPR;\ R^2 = 0.9601 \quad (3)$$

$$TFR = 6.285299 - 0.051067 \times CPR;\ R^2 = 0.5589 \quad (4)$$

Both the models and their parameters are statistically highly significant. The fitted models indicate that, even after a long decline in fertility rate, the expected level of natural fertility is high in Bangladesh. Expected level of natural fertility is lower in Matlab (6.29) compared to national data (7.35). Expected level of natural fertility is higher in both models than that of regional model for Southeast Asia (5.63), which implies that contraceptive plays vital role in decreasing fertility levels. Fitted model for national data has high degree of goodness of fit in terms of R-square. CPR can explain 96 percent variability in the observed TFR for the national data as opposed to 56 percent in Matlab HDSS suggesting relatively poor goodness of fit for Matlab HDSS. Unusual fluctuation in values of TFR and CPR might have affected such low value of R^2 in Matlab HDSS. The nature of variation is quite unusual for a surveillance system where sophisticated healthcare services are available for better health outcome for the well-being of the community. In this study, only countries of Central and Sub-Saharan Africa showed large fluctuations than Matlab HDSS. Further research on data quality may enable the researchers to understand such fluctuation on the levels of TFR and CPR. However, fitted model suggests that 66.3 percent and 82 percent contraceptive uses are required for national level and Matlab HDSS, respectively for achieving replacement level of fertility on the assumptions that other proximate determinants will remain the same.

Discussion and Conclusion

Many studies showed negative association between the proportion of currently married women who are using contraceptives and their TFR (Westoff and Bankole, 2001). The basic question was addressed by examining the empirical relation between TFR and contraceptive use by applying Bongaarts and Potter model (1983). We reinvestigated the analysis for different regions of the world as well as for Bangladesh data. Empirical relationship between aggregate fertility level and contraceptive use has been revised considering the recent data of 74 countries. These data offered greater regional diversity and permitted more detailed statistical analysis. Besides, the results from regional analysis are consistent supported by country-specific data of Bangladesh from both national level and Matlab HDSS. The analysis shows an inverse relationship between the level of contraceptive use and TFR in Bangladesh.

The implication of such empirical relation between aggregate fertility level and contraceptive use is important for policy-makers to consider further strategy in this respect. The intercept of the model represents expected level of natural fertility and the model suggests a decline in TFR all over the world since 1980s. However, this level is not same all over the world despite showing success in fertility control. North Africa and European regions showed a different pattern (Bongaarts and Potter, 1983; Johnson-Hanks, 2007). The limitation of this study is that the full model is not free of unobserved heterogeneity of the aggregate fertility level or country level influence on other proximate determinants. The results are affected by large variations in contraceptive use, which reduces the goodness of fit of the model. In particular the lower use of contraceptive is observed in central and Sub-Saharan Africa that shows a poor fit of the model between CPR and TFR. This sort of relation between TFR and CPR diminishes the explanatory power of the empirical model. Besides comparing the expected natural fertility level, the fitted model can be used to estimate required level of contraceptive use in particular country or region. Considering the time dependent rates, projection of contraceptive use is also possible.

Another common scenario was also observed all over the world regarding the trend of contraceptive use and country-specific fluctuation over time. This scenario is common for Central and Sub-Saharan Africa, and such unusual result is also observed in Matlab HDSS data. Empirical relationship between TFR and CPR got weak in presence of fluctuations both in TFR and CPR. Migration in a particular year may be attributable for such variation for a certain time, but cannot affect over a long time period. More in-depth analysis may enable the researcher to understand such unusual trend in the Matab HDSS.

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