Projecting Low Fertility: Some Thoughts about the Plausibility and Implications of Assumptions

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Abstract

Models, such as fertility projection models, are usually based on the record of countries that have earlier experienced fertility decline and on assumptions about what is reasonable in the future. There is sometimes a trade-off between a good statistical fit and factors substantively related to fertility change. The most authoritative and influential fertility projections are those by the United Nations Population Division, which in the last decade has changed their fertility projection assumptions three times.

Before 2004, the UN Population Division had long projected TFR to asymptotically reach replacement level, TFR=2.07. This assumed that all countries would eventually have low mortality, low fertility stationary populations.

In the 1990s, many countries had sustained below replacement fertility (TFR<2.07), sometimes falling to lowest-low fertility (TFR<=1.3). There were various theories about why sustained very low fertility occurred, the most influential being Second Demographic Transition Theory. After extensive consultation, fertility projection assumptions were changed **in 2004**, and all countries were then projected to asymptotically approach TFR=1.86, which implies long term population decline. This was a major departure from the earlier eventual stationary population assumption.

In the 2000s, TFR increased across at least three five-year periods (such as 1995-2000 to 2000-2005 and 2000-2005 to 2005-2010) in twenty-one below replacement fertility countries. Based on fertility increases in those countries**, in 2010** assumptions were again changed, so that in the new model TFR in below replacement fertility countries increased toward replacement, with the pace of increase more rapid the farther TFR was below replacement. For countries with above replacement fertility in 2005-2010 such as Algeria, TFR was projected to fall below replacement and then increase toward replacement. This marked a return to the eventual stationary population assumption.

Analyses found that in some below replacement fertility countries, such as Sweden, the dip in period TFR was the consequence of a shift in fertility to older ages, resulting in little change in cohort TFR. Low incompatibility between women having children and working for pay and relatively high gender equity were positively related to TFR in low fertility countries. In some low fertility countries, such as Singapore and the Republic of Korea, there was no indication of TFR increase by 2005-2010 and no indication of an increase in fertility at older ages. Some found the projected rapid increase in TFR in such countries implausible.

In 2012, TFR projection assumptions were again changed. By 2012, TFR had increased across at least three five-year periods in 25 low fertility countries. The new low fertility projection model for many individual countries was based both on the experience of these 25 countries and on the TFR record of the individual country. The 2012 projections resulted in less extreme departures from earlier projected TFRs than occurred between the 2004 and 2010 projections. In some countries, such as Sweden, the 2010 and 2012 projections differ little and are consistent with earlier empirical trends.

It would be prudent:

1) To make clearer the substantive reasoning behind changes in fertility assumptions in addition to the degree of fit to recent empirical patterns in some countries.
2) To consider whether conditions and relationships in countries that have experienced very low fertility are likely to be the same in all other countries in the future.
3) To have a longer observation period of new empirical patterns before major fertility projection assumptions are changed.

Introduction

Demographers want to estimate indicators for current and past populations, and new knowledge can influence thoughts about both the past and the future. Projections can differ based on the model chosen as the basis for the projection, as well as changes in estimates of past levels of demographic indicators.

An example of a large change in the base population occurred after the appearance of the 1953 Chinese census. That census revealed a larger population than had earlier been estimated. This resulted in an increase of 100 million people in the estimated population of China in 1950 between the United Nations estimates published in 1955 (before the 1953 Chinese census results were known) and the United Nations estimates published in 1958 (after the 1953 Chinese Census results were known). The new larger estimated Chinese population led to changes in estimates not only of the population of China but of the entire world (El-Badry and Kono, 1986; Keilman, 1998).

The UN Population Division continues to use newly available information and new analyses of existing data to improve estimates of demographic indicators for the past. For example, between the 2008 and 2010 editions of *World Population Prospects* the estimate of male expectation of life at birth for Bangladesh for 1970-1975 was revised downward from 44 years to 36 years. The e_0^0 estimates changed because new analyses indicated that the mortality impact of the 1971 Bangladesh Civil War was greater than had earlier been thought.[1] Also, as a result of the revised mortality estimates, the estimated population of Bangladesh in 1980 decreased from 90,397,000 in the 2008 estimate to 80,624,000 in the 2010 estimate. Since Bangladesh comprised 18% of the population of the Least Developed Countries in 2010, the estimated population of the Least Developed Countries in 1980 decreased from 405,847,000 in the 2008 estimate to 393,768,000 in the 2010 estimate.

Projecting future demographic values is an even more daunting task than estimating demographic values for the past. To project the future requires knowledge of current rates, but also involves a guess about unknown future trends. It also requires thinking about what kind of future is plausible.

This paper focuses on the challenges of estimating a very important component of projections, future fertility trends in populations after they have reached replacement fertility. Changes in the assumptions underlying the UN fertility projections and the empirical and theoretical bases for these decisions are discussed, as well as the implications of these changing assumptions, and possible alternative projection assumptions.

[1] email from Patrick Gerland of the United Nations Population Division, June 6, 2011.

Projections, Models and Theory

Projection of fertility or any other demographic measure relies on the construction and application of a model of demographic change. Models are usually based on logical relationships and on past empirical patterns.

Model construction based on curve-fitting to past empirical data has been strongly advocated by some (Coale and Trussell, 1996). A model should fit the empirical data on which it is based and should be able to be estimated using available data for the population to which the model will be applied. However, considerations of theory or what is plausible always enter into the construction of models and their application in projections. Projected values are often inspected to determine whether what they imply is reasonable.

Two challenges to the application of models are: 1) Are the populations on which the model is based representative of the populations to which the model will be applied, or are the populations on which the model is based so selectively different from populations to which the model will be applied to render the model irrelevant? and 2) Have the social conditions and norms that prevailed in the populations on which the model was based remained constant enough to be applicable to the future, or have these conditions and norms changed so much that the past behavior can no longer accurately predict future behavior?

A chronic issue in modeling is on what to base a model. In modeling mortality, most work has generalized from age-specific mortality patterns in populations for which there are high quality life tables by sex. Families of life tables have been identified based on differences in the relation between death rates at different ages.

The basis of the models for high mortality populations has usually been historical data for currently low fertility countries, mainly in Europe (Coale and Demeny, 1982). Expanding the set of high quality, high mortality life tables has met with limited success, as lower quality life tables have sometimes been included in the models. The inclusion of low quality life tables can result in a model of error rather than of actual mortality differences, which Dechter and Preston (1991) pointed out as a problem with some Latin American model life tables (United Nations, 1982a). The 1982 UN tables seem to fit the experience of some less developed countries more poorly than the earlierCoale-Demeny tables (Zhao, 2007). Life tables also have been developed using data from In-Depth Surveillance sites to model mortality in a sub-Saharan African setting. (INDEPTH Network, 2004).

Very low future mortality has been projected based on the experience of countries that have the lowest observed mortality. The most commonly studied very low mortality countries with good data are Japan and Sweden (Horiuchi and Wilmoth, 1998). For projecting mortality to

levels that have not been attained by any population, issues arise such as the limit of human life span and what pace of mortality decline by age should be anticipated (Lee and Carter, 1992; Wilmoth, 2000; Wilmoth *et al.*, 2000).

Sometimes analysis has shown that norms, attitudes and social factors are strongly related to changes in demographic indicators, then if these social factors follow one pattern in the populations on which the models are based and are expected to follow a different pattern in the populations to which the model is applied, questions of the relevance a model based on past trends arise.

For fertility projections, what would lead to a sustained fertility decline, and the timing of the beginning and the pace of fertility decline from a high level have been sources of uncertainty. Again, as in the case of mortality, the decline in fertility was modeled based on the experience of countries in which fertility had declined earlier. Also, similar to issues in modeling and projecting mortality, there are major challenges in projecting future fertility to a low level when such low fertility has not persisted for very long in any country.

Assumptions about what is plausible also have influenced fertility projection assumptions. Before 2004, fertility projection models almost always assumed that countries would move toward replacement fertility (TFR=2.07 in low mortality settings). This assumption was not based on analysis of empirical data but on an assumption or hope that population growth would converge to replacement fertility and would mean an eventually stationary population world with low fertility and mortality and zero population growth. This reasoning was based on the work of Raymond Pearl (1925), as encapsulated in Demographic Transition Theory (Thompson, 1929).

A criticism of modeling based on curve-fitting is that if the underlying mechanism or process leading to change is not understood, then the model might not be applicable to new situations where factors influencing behavior are different from those in the situations from which the model was developed. However, even if it is known that some factors are significantly related to the behavior to be modeled, often the statistical relationship is not sufficiently strong to make it clear how to incorporate these factors in the production of a useful, accurate model.

For fertility, this problem has sometimes been addressed through modeling the proximate causes of fertility. The proximate causes do not constitute a behavioral model, but are a partition of the factors that result in fertility. However, the idea is that it is easier to understand the proximate causes, such as sexual activity and contraceptive use, than to directly model fertility (Guegnant and May, 2009). The modelling of proximate causes has been more common in high fertility situations than in low fertility situations, because in low fertility situations almost all women and couples are very effective in controlling their fertility.

Impact of Incorrect Assumptions

Whenever a projection is done, it is stated that it is not a forecast or a prediction of the future. Rather the projection is what would result if given patterns of mortality, fertility and migration were in force over time for a given population. Nonetheless, authoritative projections, such as those by the UN Population Division, are often interpreted as predictions, and it is clear that the UN Population Division attempts to produce "best guess" estimates about the future population of the world and its constituent countries. The UN projections are often used as input data for a variety of analyses (c.f. Gradol, 2004; Potts and Henderson, 2012).

Sometimes the "best guess" is made with incomplete or inaccurate information or turns out to be incorrect for some other reason. The actual situation can be more favorable than anticipated. The development of a new vaccine or other way to prevent death can lead to an unexpected decline in infant and child mortality. For example, before World War II, few would have anticipated the mortality decline that accompanied the use of DDT in reducing malaria mortality. Also, in the United States and other highly developed countries projections of the future demand for pensions were too low due to larger than anticipated declines in old age mortality (Keilman, 1997; Lee, 2000). In 2010, in the United States there were 40.5 million people age 65+, but a projection done in 1980 expected there to be only 32.3 million people age 65+ in 2010 (United Nations, 1982b, 2011a).

When women and couples have a high degree of control over childbearing, fertility can be quite volatile in response to short-term changes in the economic outlook or other kinds of uncertainty. It is almost impossible to accurately project such rapid changes. Livingston and Cohn (2010) found a close relationship between the general fertility rate and per capita income 2000-2008 in 25 states.

Figure 1 shows the relationship between the general fertility rate and per capita income 2000-2008 for the United States as a whole. The close tracking of these two measures is striking. Orsal and Goldstein (2010) found a similar relation between the total fertility rate and the unemployment rate for the Netherlands from the 1970s through the 2000s. These rapid changes in fertility not only counter expectations about the course of fertility but also lead to short-term changes in the number of births that influence the size of adjacent cohorts.

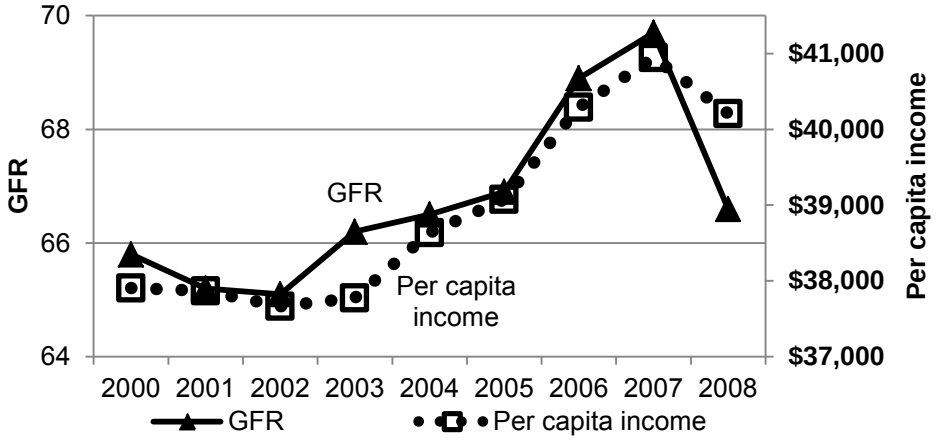

Figure 1 General Fertility Rate and Per Capita Income, USA: 2000-2008[2]

Response to the results of projections also can affect future empirical patterns. In the 1960s and 1970s, projections of high population growth in less developed countries alarmed many policy planners and governments. This concern led to programs that contributed to fertility decline in many countries. Thus there was a different future than the one that had been projected, but this was partially due to policy and program changes made in response to the implications of the earlier projections (Keilman, 2005).

There have also been inaccurate projections because fertility was expected to fall more than it actually did. The prospect of substantial population decline due to below replacement fertility has been forecast with presumed certainty for several times in the past. In 1938 Spengler (1938: 3) wrote:

> "Within the next quarter century true depopulation -- a persistent long-run excess of deaths over births -- will manifest itself in nearly all the countries of Europe and in those non-European countries to which Western civilization has spread."

By 1965-69, a quarter of a century after the above was written, the more developed region of the world had a natural rate of increase of 8 per 1000 population, and France had a natural rate of increase of 6 per 1000 (United Nations, 1999). In 1943, the demographers Warren Thompson and P. K. Whelpton forecast that the population of the United States would begin to decline after peaking in 1985 (Davis, 1948: 608; Thompson and Whelpton, 1943). The population of the United States has increased through 2010 and is projected to continue to increase at least through 2100 (United Nations, 2013b).

[2] General fertility rate from Livingston and Cohn (2010) and Tejada-Vera and Sutton (2010). Per capita income from Livingston and Cohn (2010).

Notestein (1956) reflected on how he and others had earlier underestimated American fertility. Writing in 1950, after the beginning of the post-War Baby Boom, he still thought this was a short-term, adjustment to the aftermath of World War II and did not expected the Baby Boom to last more than a decade, ending in the mid-1960s.

Different world views also have influenced assumptions about the future course of fertility. Marshall (2012) showed that although the level and the trajectory of the total fertility rate were very similar in Great Britain and France since World War II, the fertility projection assumptions used by French demographers were consistently lower than those used by British demographers. She attributed this partially to different institutional arrangements in the two countries. French demographers who made official projections typically were in non-governmental research institutes, while British demographers making official projections were typically in government departments. There had long been a concern with the possibility of very low fertility in French thought, which could have contributed to assumptions of future low fertility by French demographers. In Britain there had been much less concern about a very low fertility future.

The Record of TFR in Europe and Other Low Fertility Countries 1950-2010

Projecting future fertility for moderate and high income countries involves generalizing or modeling the pattern of historical fertility change in countries with moderate or low fertility. As the course of fertility in low fertility countries proceeds, decisions need to be made concerning when to change the fertility projection model based on evolving empirical patterns.

Patterns of TFR in the 1990s and 2000s in some countries motivated changes in fertility projection assumptions. Specifically, by the 1980s, many countries had maintained below replacement fertility (TFR<2.07) for a sustained length of time. In the 1990s TFR achieved lowest-low fertility (TFR<=1.3) in several countries. Then, in many low fertility countries TFR increased in the 2000s.

Figure 2 plots the values of estimated TFR for the MDR as a whole, as well as for regions of Europe 1950-2010. Since 1975-1980, TFR has been below replacement in the MDR as a whole, and this has been the case since 1970-1975 in Western Europe, since 1980-1985 in Southern Europe, since 1975-1980 in Northern Europe and since 1990-1995 in Eastern Europe.

There was special concern about countries that had moved to lowest-low fertility (TFR<=1.3). In 1995-2000 Southern Europe as a whole had lowest-low fertility, which was also true for Eastern Europe in 1995-2005. We also see in Figure 2 that TFR increased between 1995-2000 and 2005-2010 in the MDR as a whole and in every European region.

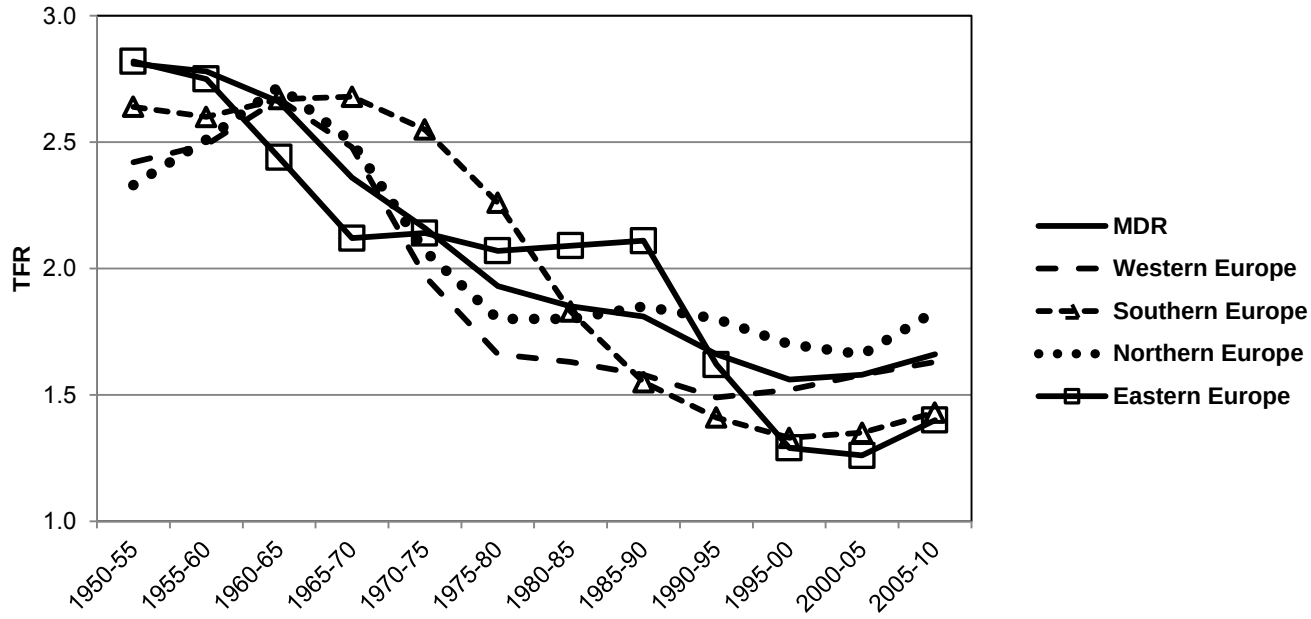

Figure 2 Estimated TFR in the MDR and in Regions of Europe, 1950-2010, Based on *2010 World Population Prospects*

Table 1 shows the total fertility rate 1950-2010 for all countries for which estimated TFR ever fell to 1.3 or lower in any five-year time period. TFR is also shown for several other more developed countries in which TFR never fell below 1.3 (United Nations, 2011a).[3] A five-year period in which TFR was below 2.07 (below replacement level fertility) is indicated by **bold**, and a period in which fertility is less than or equal to 1.3 (lowest-low fertility) is indicated by ***italics bold underlined*** and is shaded grey.

[3] The definition of More Developed Region Countries used here is that used by the United Nations. It includes all of the countries of Europe, Northern America (United States, Canada, Bermuda, Greenland and Saint Pierre and Miquelon), Australia, New Zealand and Japan. The division into the More Developed Region and the Less Developed Region has been criticized by some (Thornton, 2012), but it has the advantage of including a consistent set of countries over time.

Table 1 Estimated TFR in Some Regions and Countries: 1950-2010, Based on *2010 World Population Prospects*[4]

	1950-55	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00	2000-05	2005-10
MDR	2.81	2.78	2.66	2.36	2.16	1.93	1.85	1.81	1.66	1.56	1.58	1.66
Western Europe	2.42	2.49	2.67	2.48	1.97	1.66	1.63	1.58	1.49	1.52	1.58	1.63
Southern Europe	2.64	2.60	2.67	2.68	2.55	2.26	1.83	1.55	1.41	1.33	1.35	1.43
Northern Europe	2.33	2.51	2.72	2.50	2.07	1.80	1.80	1.85	1.80	1.70	1.66	1.83
Eastern Europe	2.82	2.75	2.44	2.12	2.14	2.07	2.09	2.11	**1.62**	*1.29*	*1.26*	1.40
All Countries that had Lowest-Low Fertility (TFR Less than or Equal to 1.3) in at least One Five-Year Period												
Asia												
Japan	3.00	2.16	1.99	2.02	2.13	1.83	1.75	1.66	1.48	1.37	*1.30*	1.32
Republic of Korea	5.05	6.33	5.63	4.71	4.28	2.92	2.23	**1.60**	**1.70**	1.51	*1.22*	*1.29*
Singapore	6.61	6.34	5.12	3.65	2.82	1.84	1.59	1.70	1.84	1.58	**1.33**	*1.25*
Former Soviet Union												
Belarus	2.61	2.73	2.69	2.38	2.25	2.09	2.09	2.05	1.68	1.31	*1.24*	1.39
Russia	2.85	2.82	2.55	2.02	2.03	1.94	2.04	2.12	**1.55**	*1.25*	*1.30*	1.44
Ukraine	2.81	2.70	2.20	2.04	2.16	2.00	2.02	**2.03**	**1.64**	*1.23*	*1.15*	1.39
Latvia	2.00	1.95	1.85	1.81	2.00	2.00	2.00	2.09	1.63	*1.17*	*1.25*	1.41
Lithuania	2.71	2.66	2.40	2.27	2.32	2.12	2.03	2.09	1.81	1.47	*1.28*	1.41
Eastern Europe												
Bosnia & Herzegovina	4.82	4.28	3.81	3.17	2.63	2.24	**1.99**	**1.90**	1.53	1.54	*1.28*	*1.18*
Bulgaria	2.48	2.27	2.18	2.15	2.17	2.17	**2.01**	**1.92**	1.51	*1.22*	*1.25*	1.46
Czech Republic	2.68	2.37	2.24	1.96	2.19	2.32	**2.00**	**1.93**	1.66	*1.18*	*1.19*	1.41
Hungary	2.73	2.21	1.82	1.98	2.09	2.12	1.81	1.82	1.73	1.38	*1.30*	1.34
Poland	3.62	3.29	2.65	2.27	2.25	2.26	2.33	2.15	1.89	1.48	*1.27*	1.32
Romania	2.87	2.62	2.04	2.96	2.62	2.52	2.25	2.27	1.50	1.35	*1.28*	1.33
Slovakia	3.50	3.24	2.91	2.54	2.51	2.46	2.27	2.15	1.87	1.41	*1.22*	*1.27*
Slovenia	2.80	2.39	2.32	2.32	2.19	2.20	1.88	1.66	1.36	*1.25*	*1.23*	1.39
Other Europe												
Greece	2.29	2.27	2.20	2.38	2.32	2.32	**1.96**	**1.53**	**1.37**	*1.30*	*1.28*	1.46
Italy	2.36	2.29	2.47	2.52	2.35	**1.94**	**1.54**	**1.34**	*1.28*	*1.22*	*1.25*	1.38
Spain	2.53	2.70	2.81	2.84	2.85	2.55	**1.88**	**1.46**	*1.28*	*1.19*	*1.29*	1.41
Germany	2.16	2.30	2.49	2.32	1.64	1.52	1.46	1.43	*1.30*	1.34	1.35	1.36
Some More Developed Countries Which Never had Lowest-Low Fertility in Any Five-Year Period												
Austria	2.08	2.50	2.78	2.57	2.04	1.65	1.59	1.44	1.47	1.37	1.39	1.38
Australia	3.18	3.41	3.27	2.87	2.54	1.99	1.91	1.86	1.86	1.78	1.75	1.93
Canada	3.65	3.88	3.68	2.61	1.98	1.73	1.63	1.62	1.69	1.56	1.52	1.65
Denmark	2.55	2.55	2.58	2.27	1.96	1.68	1.43	1.54	1.75	1.76	1.76	1.85
France	2.76	2.70	2.85	2.65	2.31	1.86	1.87	1.80	1.71	1.76	1.88	1.97
Ireland	3.42	3.58	4.07	3.77	3.82	3.25	2.76	2.18	1.91	1.94	1.97	2.10
Netherlands	3.05	3.10	3.17	2.80	2.06	1.60	1.51	1.55	1.58	1.60	1.73	1.74
New Zealand	3.69	4.07	4.02	3.35	2.84	2.18	1.97	2.03	2.07	1.95	1.95	2.14
Portugal	3.10	3.12	3.19	3.12	2.83	2.55	2.01	1.62	1.51	1.48	1.45	1.36
Sweden	2.21	2.23	2.32	2.16	1.89	1.66	1.65	1.91	2.01	1.56	1.67	1.90
United Kingdom	2.18	2.49	2.81	2.57	2.01	1.73	1.78	1.84	1.78	1.74	1.66	1.83
United States	3.45	3.71	3.31	2.55	2.02	1.79	1.80	1.89	1.99	1.96	2.04	2.07

1.3 < TFR < 2.07 bold; TFR<=1.3 *italics bold underlined* and shaded grey.

[4] Data from United Nations (2011a).

In 1960-1965, only some Eastern European countries that had experienced political disorder temporarily fell below replacement level. Japan and Singapore fell below replacement level in 1975-1980. However, the fall to replacement level fertility received increasing attention after 1970-75 when many European countries fell and retained below replacement level fertility for an extended time period. By 1990-1995 virtually all more developed countries had below replacement fertility, and by 2000-2005, many countries had lowest-low fertility. Many researchers and policy analysts expected continued very low fertility in lowest-low fertility countries, but by 2005-2010, TFR had increased in almost all more developed countries.

The changing number of lowest-low fertility countries across five-year periods is striking. In 1985-1990 there were no lowest-low fertility countries; in 1990-1995, there were 3 lowest-low fertility countries; by 1995-2000, it had increased to 9 countries; in 2000-2005 it had increased to a high of 18 countries. However, in 2005-2010, it had declined to 4 countries,

Research Related to Fertility Decline and Subsequent Fertility Increase in Low Fertility Countries

There is reason to think that changes in social processes have led to the distinctive fertility patterns in the last 20 years. In some countries views of the appropriate timing of childbearing have changed, as has the relation between fertility and female labor force participation. The status of women and the extent of gender equity also seem to play a crucial role in fertility decisions in low fertility countries where women and couples have a high degree of control over childbearing. These considerations raise additional complications in projecting future fertility, as the extent to which these changes have occurred has varied among low fertility countries.

Very Low Fertility in the 1990s

There have been four main explanations of the transition to very low fertility seen in the 1990s and early 2000s. One set of explanations involves changes in norms and values about the importance of childbearing. The other set of explanations involves a shift in the timing of childbearing to older ages.

Second Demographic Transition

Based on declining fertility in European countries such as the Netherlands and France, the Theory of the Second Demographic Transition was proposed, which included an increase in nonmarital births, in age at first marriage, in age at first birth, in permanent childlessness and in cohabitation. It also included a decrease in and postponement of marriage (van de Kaa, 2001).

The behavioral explanation embodied in the Second Demographic Transition is that in the modern world women have many more options for finding fulfillment and meaning in their lives than raising a family. The availability of these options motivates many women to be permanently childless. It also results in a late age at first birth for women who eventually have children, as they first concentrate on roles other than motherhood.

The empirical observations and the Second Demographic Transition reasoning led people to question whether the long term decline in TFR should be expected to stop at replacement fertility. As seen in Table 1, in 2000-2005, in 18 countries TFR declined to a lowest-low fertility value of 1.3 or less.

There are three other versions of changing values leading to very low fertility: 1) Perelli-Harris's work on the sources of low fertility in Russia and Ukraine, 2) Livi-Bacci's work on family values leading to low fertility in Italy, and 3) Lutz's work on a trap leading to low fertility in Korea and some other Asian countries.

Low Fertility but Early Childbearing in Russia and Ukraine

Russia and Ukraine have very low fertility, but this has been mainly the result of very few women having more than one child, while almost all women have one child and have that child at a fairly young age. These Eastern European examples show that there is more than one path to lowest-low fertility. Perelli-Harris (2005) finds that in Ukraine the ideal age for the birth of a first child is between 20 and 25, and that in any case a woman should have her first child before age 30. Almost all Ukrainian women reported that their first child was wanted at the time of their pregnancy, suggesting that early childbearing was not the result of accidental pregnancies. Ukrainian women were also reluctant to end their first pregnancy with an abortion due to fear of secondary sterility. However, especially in a time of economic uncertainty, there was little motivation to have a second or third child.

Too Much Family in Italy

Livi-Bacci (2001) proposed that very low fertility in Italy was motivated by specific conditions in Italy. Livi-Bacci (2001) observes that in Italy as the rate of economic growth declined, it became more difficult and took longer for young people to complete their education, obtain a good job and buy a house, with each of these milestones achieved at an older age than previously. At the same time, Italian young people felt that completion of education, securing of a good job and home ownership were necessary preconditions for having children.

These economic conditions and views of necessary prerequisites for marriage and childbearing combined with strong ties within Italian families and feelings of obligations to their adult children on the part of parents. Parents were willing for their adult children to live with them for many years with little or no pressure to marry and set up an independent household. All of these factors together contributed in Italy to a late age at marriage, a high proportion of women permanently childless and low fertility among those women who have children.

Low Fertility Trap Hypothesis

Lutz and his colleagues developed a low fertility trap hypothesis (Lutz, Skirbekk and Testa, 2006; Lutz, 2008) which sees continuing low fertility as the result of three factors: 1) negative population momentum, leading to fewer women in the reproductive ages and thus fewer births, 2) changes in fertility norms related to experience of low fertility in surrounding families while people are children, and perhaps the kinds of shifts in values described by Second Demographic Transition Theory, and 3) concerns about future income combined with high aspirations leading to an assessment that children are unaffordable. They saw some East Asian countries, such as South Korea as potentially caught in this trap.

Recovery from Very Low Fertility in the 2000s

Once there is a decline to very low fertility, there are various possibilities of what will happen after that point. One view is that the decline to very low fertility is temporary and is the result of a shift in fertility to older ages. Others think that fertility is only likely to recover to close to replacement level if certain social conditions are met, such as if there is a relatively high level of gender equity. These views are discussed next.

Cohort and Period Shifts

The Second Demographic Transition changes lead to a lower TFR, especially due to decreased age-specific fertility rates at younger ages. Figure 2 shows how a shift to an older age of childbearing and an increase in childlessness can lead to a decline in the TFR from 2.1 to 1.3 through the change from Time 1 to Time 2. This change leads to a large decline in period TFR and, if the age-specific rates at Time 2 persist, there will be a substantial decline in cohort TFR.

However, another view of the changes in Table 1 and Figure 2 is that there has not been a change in lifetime desired number of children but simply a change in the timing of childbearing from earlier ages to later ages.

Figure 3 shows replacement level fertility at Time 1. At Time 2, fertility at younger ages has declined, resulting in much lower TFR. The "Recovered Low Fertility" line at Time 3 shows how the shift in the age pattern of fertility could eventually lead to a TFR similar to that at Time 1. In terms of Bongaarts's and Feeney's conceptualization (1998), this would mean a change in the tempo of fertility with no change in the quantum of fertility.

A change from the age pattern at Time 1 to the age pattern at Time 3 would lead to a decline and then an increase in period TFR but little change in cohort TFR. Hoem (2005) argues that this is what has happened in Sweden. Andersson *et al.* (2009) look at cohort fertility in Denmark, Sweden, Norway and Finland. They find that cohort TFR has declined only slightly since the birth cohort of 1935, and that there has been extremely little change in cohort TFR for those born in the mid-1940s through the early 1960s, although the age pattern of childbearing has shifted to an older age.

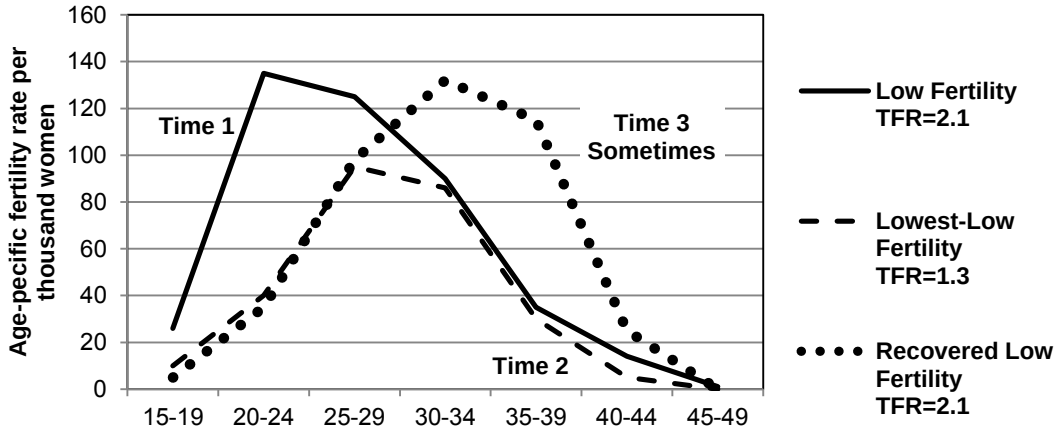

Figure 3 A Path from Low Fertility to Lowest-Low Fertility and Back to Low Fertility[5]

Gender Equity and Decreased Role Incompatibility

It has long been thought that a reason for low fertility in high income countries was an inherent incompatibility between a woman having children (or having several children) and working for pay (Becker, 1960, 1965). However, Brewster and Rindfuss (2000) showed that between the 1970s and the 2000s, for OECD countries, there was a shift from a significant negative relation between TFR and female labor force participation to a significant positive relation.

[5] Author's construction.

Similar results are shown in Figure 4 which shows the relation between the female labor force participation rate and TFR in the early 1980s and in the late 2000s in 24 more developed countries.[6] These relations are on the level of countries. Within countries, women with more children always were less likely to work for pay than women with fewer children. However, these results are consistent with the idea that countries in which the incompatibility between women being mothers and women working for pay is relatively low, whether due to policies or attitudes, tend to both have relatively high fertility and relatively high female labor force participation.

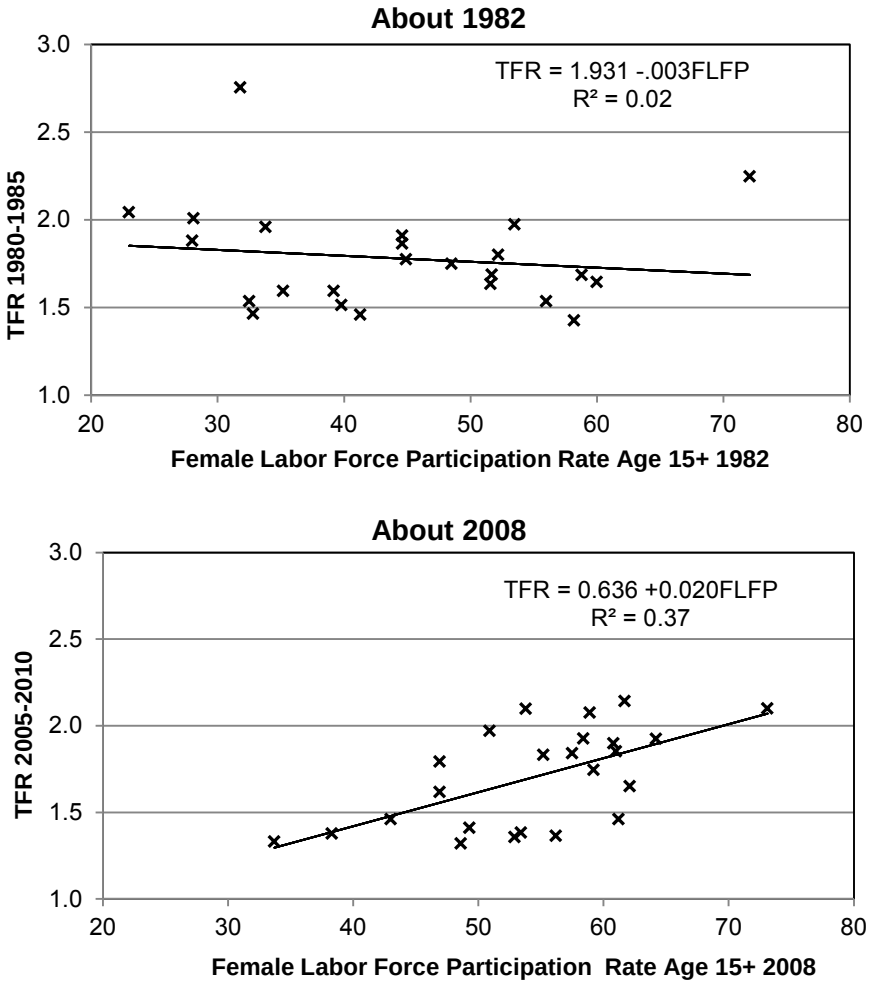

Figure 4 Relation of Female Labor Force Participation Rate and TFR in 24 More Developed Countries: About 1982 and About 2008[7]

[6] Former state socialist countries of Eastern Europe and the former Soviet Union are not included due to the very different history of female labor force participation in those countries, especially the very different situation in 1982.

[7] TFR from United Nations (2011a); female labor force participation data from World Bank (2012).

Feyrer and his colleagues thought that changes in women's status led to changes in fertility rather than changes in fertility leading to changes in women's status. They related fertility changes to changes in the amount of work in the home done by men. They proposed a three-stage model of the relation between female labor force participation and fertility related both to development level and to the extent of gender equity in the society (Feyrer, Sacerdote and Stern, 2008).

Consistent with Feyrer's views, Myrskylä and his colleagues used the global gender gap index to assess the extent of gender inequality (Hausmann, Tyson and Zahidi, 2009). The global gender gap index incorporates indicators of the gap between men and women in a country in economic activity, education, health and political involvement. It is based on the ratios in each area for men and women, and is not affected by the average level of each indicator.[8] Myrskylä and his colleagues concluded that in high development countries, when there is substantial gender equity fertility rises from the very low levels to which it has fallen (Myrskylä, Kohler and Billari, 2009, 2011). Goldstein and his colleagues made a similar argument (Goldstein, Sobotka and Jasilioniene, 2009).

The work on gender equity and role incompatibility suggests that in populations in which there is a high level of gender equity and in which there are behavioral patterns and social policies that make it possible for women both to have children and pursue other aspects of their lives, such as paid work, TFR should rebound, at least to some extent, mainly through at increase in fertility at older ages. It also suggests that in situations in which there is a low level of gender equity and in which combining childbearing and childrearing with activities such as work for women is difficult, that TFR should remain low or perhaps fall even further. Myrskylä, Goldstein and Cheng (2012, 2013) looked at the relation of cohort fertility in developed countries to various development indicators and found that the gender gap index had a stronger positive relation to cohort fertility that the log of GDP per capita or the Human Development Index.

[8] For details on the construction of the global gender gap index, see Hausmann, Tyson and Zahidi (2009: 3-7).

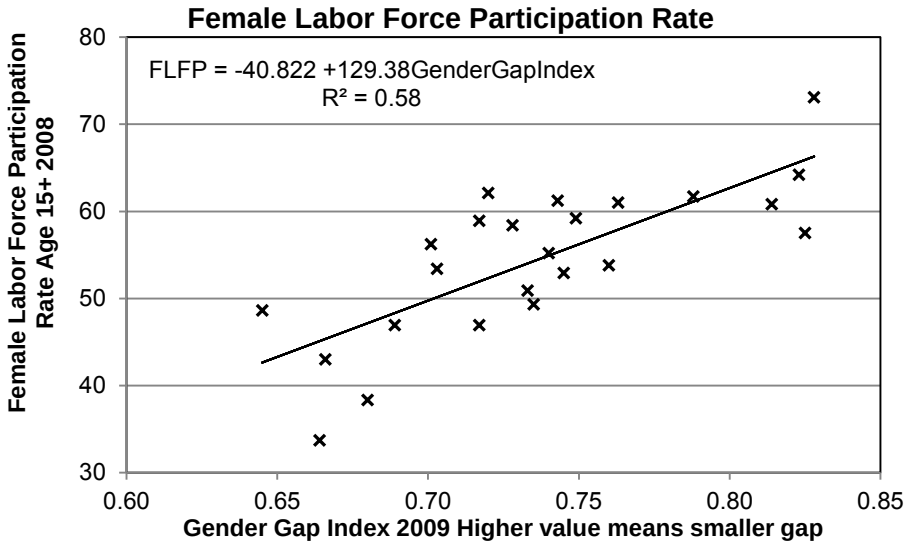

Figure 5 Relation of the Female Labor Force Participation Rate 2008 to the Gender Gap Index 2009 in 24 More Developed Countries[9]

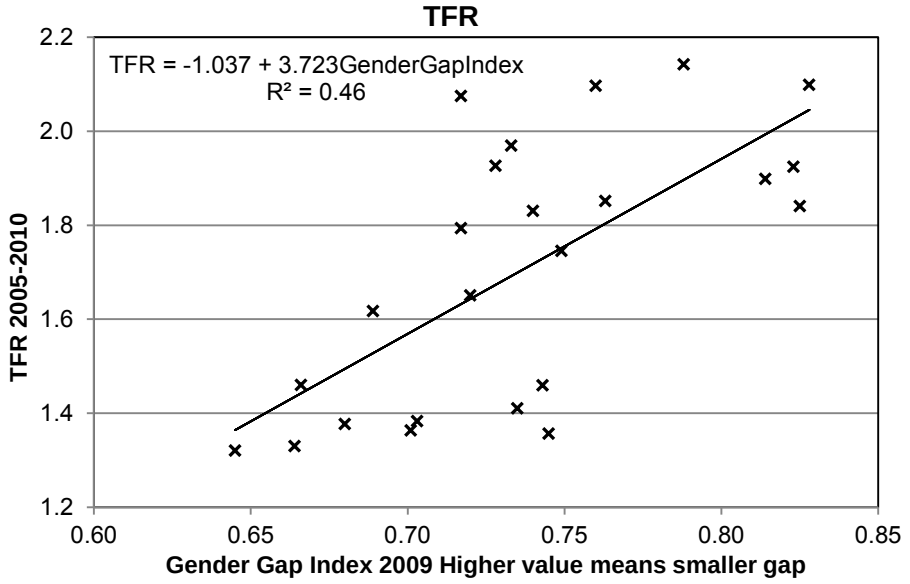

Figure 6 Relation of TFR 2005-2010 to the Gender Gap Index 2009 in 24 More Developed Countries[10]

The relation between the female labor force participation rate and the gender gap index is shown in Figure 5, and the relation between TFR and the gender gap measure is shown in Figure 6 for about 2008 in the same set of 24 countries. The strong relation of both of these to the gender gap index also supports the idea that countries where there is greater parity between men

[9] Female labor force participation data from World Bank (2012); gender gap index from Hausmann, Tyson and Saadia Zahidi (2009).

[10] TFR from United Nations (2011a); gender gap index from Hausmann, Tyson and Saadia Zahidi (2009).

and women across various areas end up with both relatively high fertility and relatively high female labor force participation, and that both high female labor force participation and relatively high facility are facilitated by women having a comparable role in various aspects of society to men.

United Nations Fertility Projections

A major source of population projections and a center for thinking about projections has been the UN Population Division. Since 1951, it has produced estimates and projections for the total population, fertility and mortality for the world, major regions and for every UN member country.

Many national statistical agencies, including those in almost all more developed countries, project fertility, mortality and population size for their own country. Sometimes individual countries can do a better job projecting their country's population than the UN Population Division because they know more about their country, they have access to the most recent available data, and they can spend more time on their own country than the UN Population Division can devote to any individual country.

Individual countries also can sometimes do a better job than the United Nations Population Division because the UN aims to adopt a consistent approach to projection in all countries. When the approach varies, it should do so for sets of countries that differ from other countries in some clearly definable way. For example, the UN Population Division uses a different procedure to project mortality in countries with a high HIV prevalence than in other countries, due to the distinctive age pattern of HIV mortality. Also projection of HIV mortality requires country-specific assumptions about future infection rates and the coverage of preventive treatments and of medications that delay death among those who are HIV-positive (United Nations, 2013d).

The UN Population Division projects fertility in countries in which fertility is moderate or high based on the pattern of fertility decline in countries in which fertility declined earlier. For countries with very low fertility at a given point in time, fertility projection involves anticipating the future movement of fertility from a situation which no country or very few countries have yet experienced. For countries where fertility has declined to a very low level and then fluctuated, it is difficult to know whether recent fluctuations reflect short-term changes or are part of a new low fertility regime.

The UN Population Division has long projected fertility according to a three-stage model. In stage 1 fertility is high, in stage 2 fertility pursues a downward trajectory, and in stage 3 the course of fertility after TFR has fallen to replacement or lower is tracked. Four versions of this model are shown schematically in Figure 7. The model for the first stage has been unchanged. In the model applied before 2004, the second stage ended when replacement fertility was reached. In 2004-2008, the second stage ended when the TFR reached 1.86. In 2010 and 2012, the second stage ended after TFR had declined to below replacement and then stopped declining or increased at least slightly. Before 2004, in the third stage, TFR fluctuated around replacement. In 2004-2008, in the third stage TFR fluctuated around 1.86. In 2010, in the third stage, TFR increased to replacement, while in 2012, TFR pursued variable paths in the third stage.

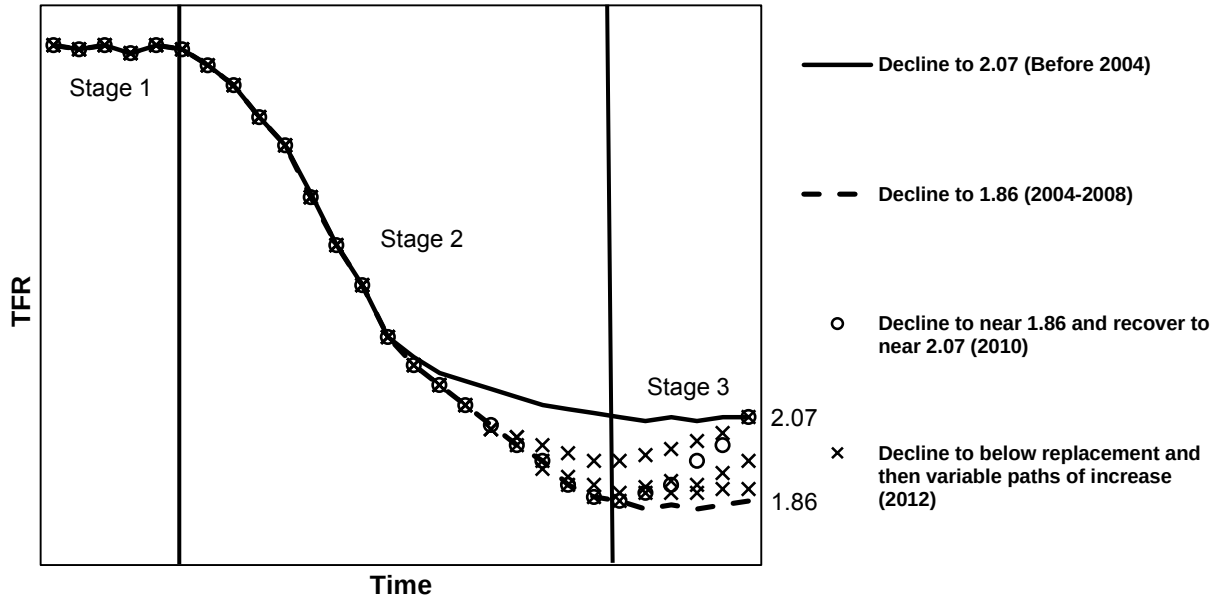

Figure 7 United Nations Population Division Three-Stage Model of Fertility Decline Under Assumptions Before 2004, 2004, 2010 and 2012[11]

If a fertility projection is made for many years into the future, an important question is: What is the level of fertility that will be approached? Through the *2004 World Population Prospects*, the assumption was that in the third stage TFR would decline to about 2.07 and would remain at about 2.07 indefinitely, maintaining the long held assumption that fertility and mortality would eventually reach a state of equilibrium at zero population growth. This means there would eventually be a stationary population, with replacement fertility. This is indicated in Figure 7 by a solid line.

[11] Author's construction, adapted from United Nations (2013a: 26).

Assuming convergence to replacement level fertility was fairly non-problematic as long as the only countries with below replacement fertility were those in which low fertility could be attributed to some special event or special situation. Social and political unrest in Eastern Europe was a reason given for below replacement in countries such as Hungary and Romania in the 1960s. However, as a larger and larger number of more developed countries maintained below-replacement fertility, how to project fertility and how to think about below replacement fertility became more challenging.

Many demographers wondered whether less developed countries, especially those with intermediate fertility rather than high fertility, could also be moving toward persistent below replacement fertility. In 2002, the UN Population Division held a major conference that resulted in a change in the stage 2 and stage 3 fertility assumptions for United Nations fertility projections. The new assumption was that TFR was moving asymptotically to a level of 1.86 children per woman in all countries, including countries with above replacement fertility (United Nations, 2002). This change was implemented in the *2004 World Population Prospects* and remained in effect through the *2008 World Population Prospects*. Thus, there was a change in the projection model for stage 2 and stage 3 in Figure 7 from the solid line to the dashed line. The change in the fertility projection assumption resulted from a change in thinking among demographers and an assessment and interpretation of the future implications of fertility trends in some low fertility countries. The changes in these countries were seen as predicting what would happen in all countries.

The fertility projection assumptions were again changed in the *2010 World Population Prospects*. The new projections assumed that in stage 2 TFR would fall far below 2.07, and in stage 3 rise to approach 2.07 and then fluctuate around that level (United Nations, 2011). At that time, the model for stage 2 and stage 3 in Figure 7 changed to that indicated by the line of circles.

The 2010 procedure was motivated by fertility increases in several low fertility countries as shown in Table 1. For example, in France, Spain, Sweden and several other highly developed, low fertility countries, TFR increased between 2000-2005 and 2005-2010. Of the 18 countries with TFR<=1.3 in 2005-2010, in all but 4 TFR>1.3 in 2005-2010. Again, these changes in a set of countries were seen as predicting the future of all countries.

The 2010 fertility projection model posited that TFR would increase more rapidly the farther below 2.07 TFR was in the given country. This resulted in projected increases in some countries, such as Singapore and South Korea, that many thought were implausible (Basten,

Coleman and Gu, 2012; Basten, 2013). Jones (2011) discussed the policy and cultural barriers to a substantial fertility increase in some Asian countries. Lutz (2008) earlier had questioned why any near-term increase in TFR should be expected in some Asian countries.

These objections were some of the reasons for modifications in the projection procedure used for the *2012 World Population Prospects*, in which country-specific information was used to modify the projections for some countries. Overall, a more diverse set of fertility futures was projected. As is written in the *Assumptions Underlying the 2012 Revision* (United Nations, 2013d):

> "While the long-term assumption of a fertility increase is supported by the experience of many low-fertility countries in Europe and East Asia, the new approach additionally draws upon the country-specific experiences. In this approach, the projections for countries that have experienced extended periods of low fertility with no empirical evidence of an increase in fertility, can result in continuing low fertility with no fertility increase in the near future, as the research on 'low fertility trap hypothesis' has argued for some low-fertility countries in Europe and East Asia (United Nations, 2013d: 3)."

The major changes between the 2010 and the 2012 fertility projection model were:[12]

1. By the time the work for the *2012 World Population Prospects* was completed, results were available from the 2010 census round and from some surveys which led to revision of TFR estimates for 2005-2010 for some countries. For countries with TFR estimates available for 2011 or 2012, the 2010-2015 values were used as estimates rather than as projections and were used as part of model fitting, even though half the five-year period was yet to occur.
2. The model of fertility change for below-replacement fertility countries was based on 25 countries that had at least two periods of increase in TFR (including an estimated increase between 2005-2010 and 2010-2015 for Canada and Lithuania, rather than on the 21 countries used in the *2010 World Population Prospects*.
3. Rather than assuming that all countries would approach TFR=2.07, a projected TFR distribution, based on the 25 countries is used in the projections. Country-specific asymptotic values of TFR are constrained to not exceed 2.07.
4. The historical record of a below-replacement fertility country is also used in the TFR projections. Thus, below-replacement fertility countries that have shown no sign of an increase in TFR show much slower increases in the 2012 than in the 2010 projections. This was seen as incorporating "expert opinion" in the TFR projections.

The 2012 changes projected all countries to eventually achieve TFR <=2.07, which would mean overall eventual population decline. It also led to a less rapid recovery to replacement fertility after a less deep decline below replacement fertility. The three lines of **X**'s in Figure 7 represent the variability of fertility projections from the *2012 World Population Prospects*.

[12] This is based on United Nations (2013d), which is a preliminary version of a technical paper on the 2010 Assumptions. The final version had not appeared by the end of 2013.

Two examples of the relation between estimated TFR and projected TFR are shown in Figure 8 for Singapore and for Algeria. Singapore has had persistent low TFR, while Algeria had above replacement fertility through 2005-2010.

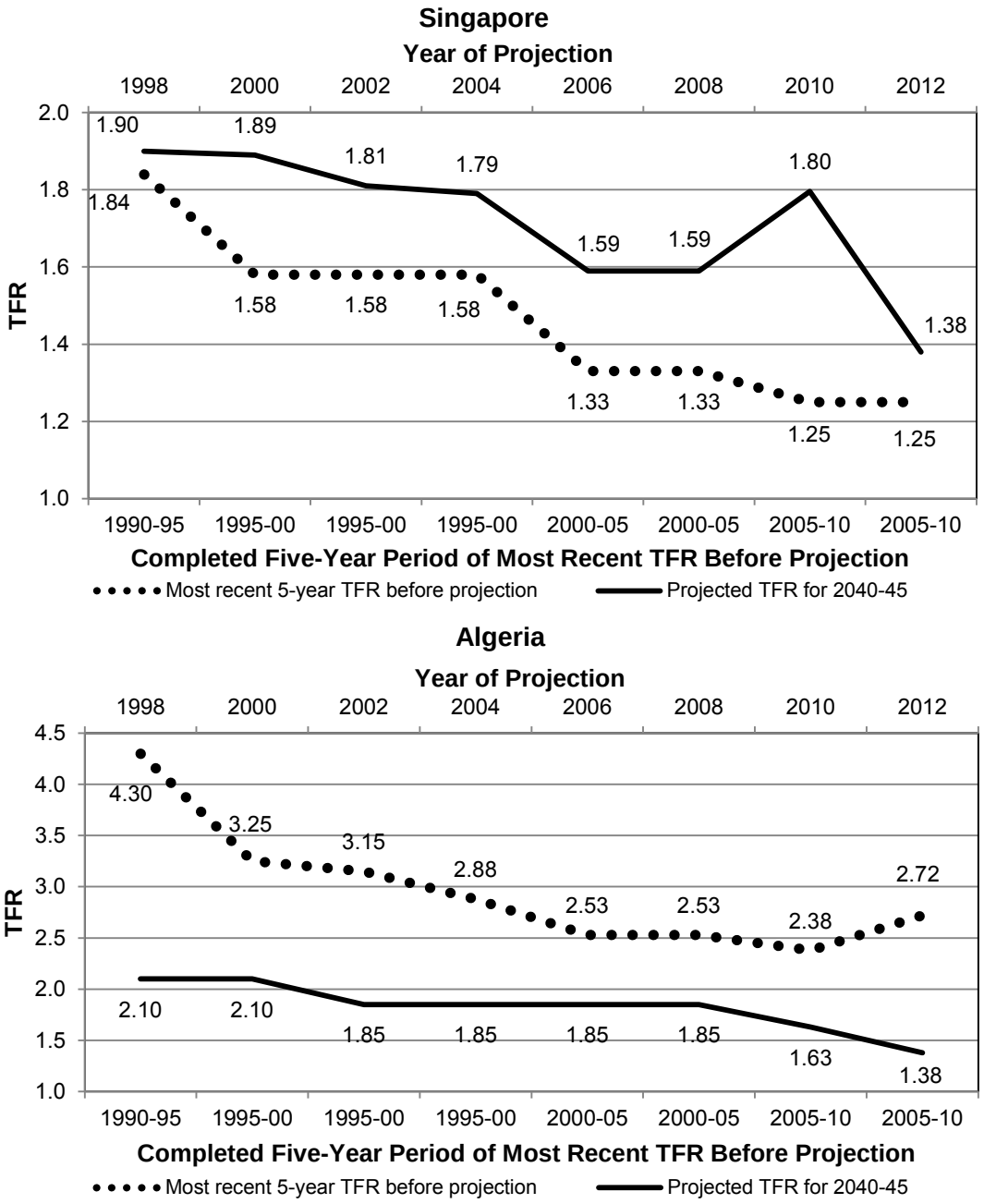

Figure 8 Projected TFR in Singapore and in Algeria for 2040-2045 as Projected in Different Years and Estimated TFR for Most Recent Five-Year Period before the Projection

We see in Table 1 that TFR in Singapore reached its lowest value to date in 2005-2010. The top panel of Figure 8 shows projected TFR for Singapore for 2040-2045 according to the United Nations *World Population Prospects* for 1998-2012 (United Nations, 1999, 2001, 2003,

2005, 2007, 2009, 2011a, 2013b).[13] The projected values are indicated by a solid line. The year of the projection is shown on the secondary horizontal axis at the top of the figure. The estimated TFR in the most recent five-year period with TFR published in *World Population Prospects* before the year of the projection is shown as a dotted line. The most recent five-year period before the year of the projection is shown on the primary horizontal axis at the bottom of the figure. Thus, the dotted line reflects what those preparing the projections would have known about the most recent TFR as they prepared their estimates.[14]

In the 1998 through 2008 *World Population Prospects*, projected TFR for 2040-2045 for Singapore generally changed in keeping with changes in the most recently observed TFR. However, while the most recently observed Singapore TFR declined between 2008 and 2010, projected TFR for 2040-2045 increased substantially. Also, there was no change in estimated TFR for 2005-2010 between the time projections were made in 2010 and 2012, but after the application of the 2012 country-specific adjustments, projected TFR for 2040-2045 fell to 1.38, much lower than in earlier projections.[15] For Singapore, projected TFR for 2040-2045 was always higher than recent estimated TFR, since even in 1990-1995, Singapore had below replacement fertility. However by the 2004 projection, TFR projected for 2040-2045 was lower than estimated TFR for 1990-1995.

The bottom panel of Figure 8 shows projected fertility for 2040-2045 for Algeria. It also shows the estimated Algerian TFR for the most recent five-year period before the time when the projection was produced. For Algeria, projected TFR for 2040-2045 was always lower than recent observed TFR because throughout 1990-2010, Algeria had above replacement fertility and in the 1998-2012 projections Algeria was expected to have at or below replacement fertility in 2040-2045. From 1998 through 2012, projected TFR for 2040-2045 tended to decline. Estimated TFR declined from 1990-1995 through 2000-2005. According to the estimates for 2005-2010 made in the *2010 World Population Prospects*, TFR was estimated to decline further between 2000-2005 and 2005-2010. However, from the values of TFR in 2005-2010 in the *2012 World Population Prospects*, Algerian TFR was estimated to have increased between 2000-2005 and 2005-2010. Thus, projected TFR for 2040-2045 increased from the 2010 to the 2012 editions of *World Population Prospects*, even as the estimate of recent TFR declined.

[13] Through the *2006 World Population Prospects*, projections were only published through 2050. In the 2010 and 2012 *World Population Prospects*, projections were published through 2100.

[14] The UN Population Division also can re-estimate TFR for the previous five-year period, based on newly available data, such as from new surveys or from analysis of previously available data.

[15] When the UN Population Division makes its projections, they use all currently available information, not just data for the most recent completed five-year period ending in a 0 or a 5. For example the projections made for the *2012 World Population Prospects*, which was published in 2013 would use any available data on a country's fertility for 2011 and 2012.

Deterministic and Probabilistic Fertility Projections

Another major change in United Nations projection methodology that occurred in the 2000s was a shift from a deterministic to a probabilistic approach. Through the *2008 World Population Prospects*, after the main TFR projection had been made for a given country, a high estimate was calculated which had a TFR of 0.5 more children and a low estimate was calculated which had a TFR of 0.5 less children. This was an arbitrary range. Thus, the UN Population Division was thinking about changing the way uncertainty in fertility projections would be incorporated through adopting a probabilistic approach.

Keilman, Pham and Hetland (2002) point out that there have been three bases for probabilistic forecasts:

1. Time series extrapolations – In this approach a model, including variability, is developed based on past experience of a selected set of populations
2. Expert judgment – in this approach expert opinion collects expected outcomes, and the range of expert opinion is used to estimate variability. Expert opinion can also be used to place bounds on estimates from the time series approach.
3. Extrapolation of historical forecast errors – in this approach, the mean values for prediction come from one of the first two approaches, but past error patterns are used to estimate future variability.

There was a large amount of work at the UN Population Division and elsewhere about how to produce probabilistic fertility projections with a more realistic range, or how to construct a pseudo-confidence interval. Gerland (2009) compared the medium variant of the 2008 deterministic TFR projections to the median probabilistic TFR projections based on the estimates available in 2008. The overall agreement of the two kinds of estimates was good. For 75% of the countries the projected TFR for 2048 differed by less than 15%. In the 2010 and 2012 projections, the range that included 80% of the projected TFR values and the range that included 95% of the projected TFR values was highlighted. However, for reasons that remain unclear, these semi-c0nfidence intervals have not been used to mark the high and low TFR projections, but the designation of 0.5 children above the median projection and 0.5 children below the median projection has been retained at the "High" and the "Low" TFR projections.

The *2010 World Population Prospects* changed mostly to probabilistic fertility projections, and the *2012 World Population Prospects* changed completely to probabilistic fertility projections.[16]

[16] There has also been extensive work to produce probabilistic mortality projections. This approach was not totally adopted in the *2012 World Population Prospects*, due to problems in projecting mortality in countries in which there is a high level of mortality from HIV/AIDS.

The issue of what assumptions to use in modelling the third stage of the fertility transition is a separate issue from whether a deterministic or a probabilistic approach is used. As discussed later in this paper, the adoption of a probabilistic approach was important in the changes between the 2010 and *2012 World Population Prospects* fertility projections but had little effect on the change between the 2004 and *2010 World Population Prospects* fertility projections.

The Basis of the Model of an Increase in TFR to About Replacement Fertility in Low Fertility Countries in the *2010 World Population Prospects* and to Adjustments of the Model in the *2012 World Population Prospects*

There was a major change in the fertility projection model between the *2008 World Population Prospects* and the *2010 World Population Prospects*, and there was a smaller change in the model between the *2010 World Population Prospects* and the *2012 World Population Prospects*.

First we look at the basis of change between the model used in the *2008 World Population Prospects* and the *2010 World Population Prospects*. In the Frequently Asked Questions for the *2010 World Population Prospects*, 21 below replacement fertility countries were listed in which there was an increase in below replacement TFR for at least two time periods. This constituted 54 increases in TFR from one five-year period to the next (Alkema, Raftery and Gerland, 2013). The behavior of these countries was the basis of the model of TFR increase in stage 3 of the fertility transition. This was applied both to countries with below replacement fertility in 2005-2010 and to countries once they were projected to fall to below-replacement fertility.

Table 2 shows data for these 21 countries. The table shows TFR for each of the 21 countries for every five-year period 1950-2010, based on the *2010 World Population Prospects*. The period with the lowest estimated TFR for a given country and subsequent five-year periods with a higher TFR are bolded. This yields 53 periods of TFR increase. There was no requirement of any minimum for the increase in TFR across five-year periods.

For some countries, there was an increase in TFR from some time since the 1980s for every five-year period. These countries include Belgium with TFR increases across every five-year period 1995-2010 and Netherlands with TFR increases in every five-year period 1980-2010. For other countries there is an increase for two or more periods and then a slight decline sometimes followed by another TFR increase. This includes the United States and Norway. However for other countries included in the model, TFR increases for two periods, and then TFR declines, sometimes reaching its lowest level in 2005-2010, such as for Singapore and sometimes

showing a TFR in 2005-2010 that is not the lowest value, but is much lower than seen in the period of TFR increase. This is the situation for the Channel Islands, Luxembourg and Singapore.[17]

Table 2 Twenty-one Countries on Which the Model of TFR Increase in Below Replacement Fertility was Based for the *2010 World Population Prospects*[18]

	1950-55	1955-60	1960-65	1965-70	1970-75	1975-80	1980-85	1985-90	1990-95	1995-00	2000-05	2005-10
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Belgium	2.34	2.50	2.64	2.39	2.02	1.71	1.60	1.56	1.61	1.60	1.69	1.79
Bulgaria	2.48	2.27	2.18	2.15	2.17	2.17	2.01	1.92	1.51	1.22	1.25	1.46
Channel Is.	2.06	2.22	2.56	2.36	1.86	1.52	1.44	1.45	1.46	1.40	1.41	1.42
Czech Rep.	2.68	2.37	2.24	1.96	2.19	2.32	2.00	1.93	1.66	1.18	1.19	1.41
Denmark	2.55	2.55	2.58	2.27	1.96	1.68	1.43	1.54	1.75	1.76	1.76	1.85
Estonia	2.06	1.99	1.94	2.02	2.15	2.06	2.09	2.20	1.63	1.33	1.39	1.64
Finland	3.00	2.77	2.66	2.19	1.62	1.66	1.69	1.66	1.82	1.74	1.75	1.84
France	2.76	2.70	2.85	2.65	2.31	1.86	1.87	1.80	1.71	1.76	1.88	1.97
Germany	2.16	2.30	2.49	2.32	1.64	1.52	1.46	1.43	1.30	1.34	1.35	1.36
Ireland	3.42	3.58	4.07	3.77	3.82	3.25	2.76	2.18	1.91	1.94	1.97	2.10
Italy	2.36	2.29	2.47	2.52	2.35	1.94	1.54	1.34	1.28	1.22	1.25	1.38
Latvia	2.00	1.95	1.85	1.81	2.00	2.00	2.00	2.09	1.63	1.17	1.25	1.41
Luxembourg	1.98	2.23	2.40	2.19	1.72	1.49	1.47	1.47	1.66	1.72	1.65	1.62
Netherlands	3.05	3.10	3.17	2.80	2.06	1.60	1.52	1.56	1.58	1.60	1.73	1.75
Norway	2.60	2.84	2.90	2.72	2.25	1.81	1.69	1.80	1.89	1.86	1.81	1.92
Russia	2.85	2.82	2.55	2.02	2.03	1.94	2.04	2.12	1.55	1.25	1.30	1.44
Singapore	6.61	6.34	5.12	3.65	2.82	1.84	1.59	1.70	1.84	1.58	1.33	1.25
Spain	2.53	2.70	2.81	2.84	2.85	2.55	1.88	1.46	1.28	1.19	1.29	1.41
Sweden	2.21	2.23	2.32	2.16	1.89	1.66	1.65	1.91	2.01	1.56	1.67	1.90
UK	2.18	2.49	2.81	2.57	2.01	1.73	1.78	1.84	1.78	1.74	1.66	1.83
USA	3.45	3.71	3.31	2.55	2.02	1.79	1.80	1.89	1.99	1.96	2.04	2.07

Bold indicates time periods of increase in below-replacement TFR. Grey shading indicates data used to construct the model of TFR increase in below-replacement situations.

For every country in Table 2, all changes in TFR from one five-year period to the next after the first increase in TFR from one five-year period to the next are included in the model. This means that the changes in TFR for Singapore 1995-2010 are included in the model. This was done to build some variability into the model of increase from below-replacement fertility (Gerland, 2013).

There were 49 countries in the *2010 World Population Prospects* with estimated TFR<=1.8 in 1995-2000, but only 21 were reported as having an increase in TFR across two time periods. Thus, the model of fertility increase in 2010 was based on the experience of less than half of the low fertility countries.

[17] In United Nations (2011d), it was misstated what was the five-year period of lowest fertility. This was clarified in Gerland (2013).

[18] Data in Columns 2-13 are from United Nations (2011a).

The set of countries that were used to model the TFR increase for the *2012 World Population Prospects* is shown in Table 3. The 2012 projections were based on 25 countries. The newly-added countries are shown in bold **Times New Roman** font. For the 2012 model, estimates of TFR for the 2010-15 time period were also used (Gerland, 2013). Even though most of that five-year period was yet to occur, it was thought that enough of the period had occurred by the time the 2012 *World Population Prospects* results were published in 2013 to use the 2010-15 estimates. Canada and Lithuania were added due to inclusion of the 2010-2015 TFR, while Barbados and Hong Kong were added due to reestimates of TFR between the 2010 and 2012 *World Population Prospects*.

Table 3 Twenty-five Countries on Which the Model of TFR Increase in Below Replacement Fertility was Based for the *2012 World Population Prospects*[19]

	1950 -55	1955 -60	1960 -65	1965 -70	1970 -75	1975 -80	1980 -85	1985 -90	1990 -95	1995 -00	2000 -05	2005 -10	2010 -15
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Barbados	4.42	4.30	4.27	3.53	2.72	2.16	1.92	1.77	1.73	1.74	1.80	1.83	1.85
Belgium	2.34	2.50	2.65	2.39	2.01	1.71	1.60	1.56	1.61	1.60	1.68	1.82	1.85
Bulgaria	2.53	2.30	2.22	2.13	2.16	2.19	2.02	1.95	1.55	1.20	1.24	1.43	1.53
Canada	3.65	3.88	3.68	2.61	1.98	1.73	1.63	1.62	1.69	1.56	1.52	1.63	1.66
Channel Islands	2.06	2.22	2.56	2.36	1.86	1.52	1.44	1.45	1.46	1.40	1.41	1.42	1.46
China, Hong Kong SAR	4.44	4.72	5.31	3.65	3.29	2.31	1.72	1.36	1.24	0.87	0.96	1.03	1.13
Czech Rep.	2.68	2.38	2.24	1.99	2.19	2.32	2.01	1.93	1.66	1.18	1.19	1.43	1.55
Denmark	2.55	2.55	2.58	2.27	1.96	1.68	1.43	1.54	1.75	1.76	1.76	1.85	1.88
Estonia	2.06	1.99	1.94	2.02	2.15	2.06	2.09	2.20	1.63	1.33	1.39	1.64	1.59
Finland	3.00	2.77	2.66	2.19	1.62	1.66	1.69	1.66	1.82	1.74	1.75	1.84	1.85
France	2.75	2.69	2.83	2.64	2.30	1.86	1.87	1.81	1.72	1.76	1.88	1.97	1.98
Germany	2.13	2.29	2.47	2.36	1.71	1.51	1.46	1.43	1.30	1.35	1.35	1.36	1.42
Ireland	3.42	3.58	4.07	3.77	3.82	3.25	2.76	2.18	1.91	1.94	1.97	2.00	2.00
Italy	2.36	2.29	2.47	2.52	2.35	1.94	1.54	1.34	1.28	1.19	1.29	1.41	1.48
Latvia	2.00	1.95	1.85	1.81	2.00	1.88	2.03	2.13	1.63	1.17	1.29	1.49	1.60
Lithuania	2.71	2.66	2.43	2.30	2.30	2.10	2.04	2.06	1.82	1.47	1.28	1.42	1.51
Luxembourg	1.98	2.23	2.40	2.19	1.72	1.49	1.47	1.47	1.66	1.72	1.65	1.62	1.67
Netherlands	3.05	3.10	3.17	2.80	2.06	1.60	1.52	1.56	1.58	1.60	1.73	1.75	1.77
Norway	2.60	2.84	2.90	2.72	2.25	1.81	1.69	1.80	1.89	1.86	1.81	1.92	1.93
Russia	2.85	2.82	2.55	2.02	2.03	1.94	2.04	2.12	1.55	1.25	1.30	1.44	1.53
Singapore	6.61	6.34	5.12	3.65	2.82	1.84	1.59	1.70	1.73	1.57	1.35	1.26	1.28
Spain	2.53	2.70	2.81	2.84	2.85	2.55	1.88	1.46	1.28	1.19	1.29	1.41	1.50
Sweden	2.24	2.25	2.31	2.17	1.91	1.67	1.64	1.91	2.01	1.56	1.67	1.89	1.92
UK	2.18	2.49	2.81	2.57	2.01	1.73	1.78	1.84	1.74	1.74	1.66	1.88	1.89
USA	3.33	3.67	3.40	2.58	2.02	1.77	1.80	1.91	2.03	2.00	2.04	2.06	1.97

Bold with grey shading indicates time periods of increase in below-replacement TFR. Grey shading indicates data used to construct the model of TFR increase in below-replacement situations. Newly-added countries are shown in **Times New Roman bold**.

[19] Columns 2-14 are from United Nations (2013a).

In the *2012 World Population Prospects* it was estimated that in 1995-2000 there were 48 countries where TFR<= 1.8, and 25 countries were identified as having experienced an increase in TFR. Of the 25 countries used to model TFR increase, only 3 had TFR>1.8 in 1995-2000. Thus in both 2010 and 2012, a model of fertility recovery from substantially below replacement fertility was applied to all countries, based on observed experience of about half of the countries with non-trivially below replacement fertility.

Projections of TFR in Different Categories of Countries

Next we look at estimated and projected TFR in some countries that fall into three categories. These categories with examples of countries in each category are:

Group 1: Low fertility countries with little or no sign of a fertility increase in the 2000s:

- Singapore
- Japan
- China
- Republic of Korea
- Germany
- Austria

Group 2: Countries with above replacement fertility in 2005-2010:

- Algeria
- India
- Bangladesh
- Laos
- El Salvador

Group 3: Low fertility countries where TFR noticeably increased in the 2000s:

- Sweden
- Russia
- France
- Netherlands

Figure 9 shows estimated TFR 1950-2010 for one country from each group, to indicate the different trajectories among the groups. Sweden has long had low fertility, but was close to replacement by 2005-2010, Singapore fell from high fertility to below-replacement fertility since 1975-1980, and although Algeria had a substantial fertility decline since 1980, it still had above replacement fertility in 2005-2010.

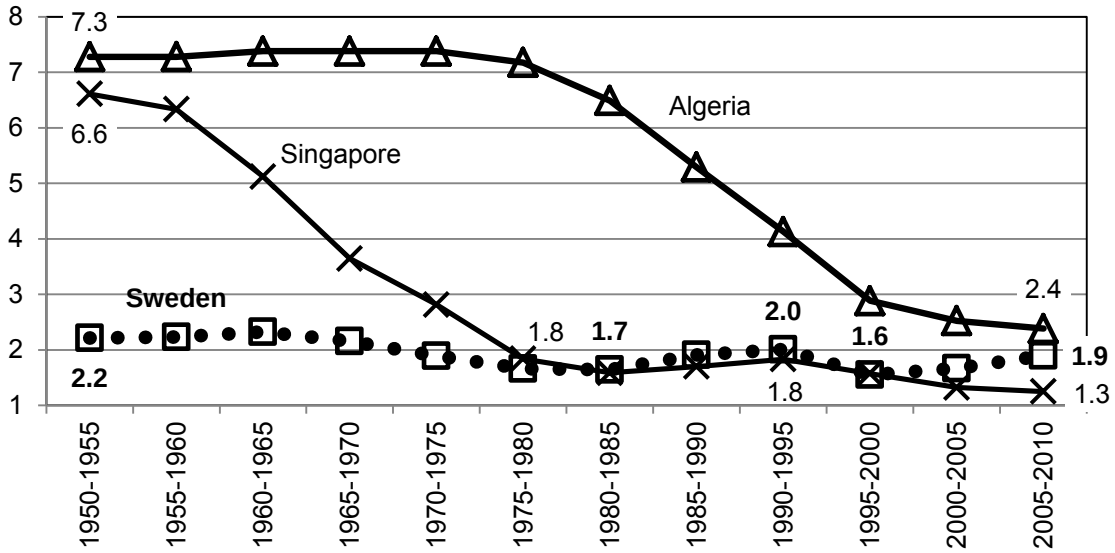

Figure 9 Estimated TFR in Three Countries from *2010 World Population Prospects*

Table 4 shows projected TFR for all the countries listed above. Projected TFRs for 2015-2020 and 2045-2050 are shown from the 2000, 2008, 2010 and 2012 *World Population Prospects*. Projected TFR for 2095-2100 is also shown from the 2010 and 2012 estimates. The latest date for which TFR projections were shown in the 2000 and 2008 *World Population Prospects* was 2045-2050 because these projections were only published through 2045-2050Also, for each group of countries, the average value of projected TFR for the given year for the group of countries is shown.

Table 4 Estimated and Projected TFR: 2000, 2008, 2010 and 2012[20]

		Projection for Five-Year Period		
		2015-2020	2045-2050	2095-2100
Group 1: Low fertility countries with little or no sign of a fertility increase in the 2000s				
Singapore	Projected 2000	1.53	1.90	N.A.
	Projected 2008	1.34	1.64	N.A.
	Projected 2010	1.47	1.84	2.04
	Projected 2012	1.31	1.40	1.47
Japan	Projected 2000	1.48	1.75	N.A.
	Projected 2008	1.30	1.60	N.A.
	Projected 2010	1.51	1.85	2.04
	Projected 2012	1.48	1.72	1.85
China	Projected 2000	1.90	1.90	N.A.
	Projected 2008	1.84	1.85	N.A.
	Projected 2010	1.51	1.77	2.01
	Projected 2012	1.69	1.81	1.88
Republic of Korea	Projected 2000	1.74	2.10	N.A.
	Projected 2008	1.29	1.59	N.A.
	Projected 2010	1.48	1.83	2.03
	Projected 2012	1.39	1.68	1.84
Germany	Projected 2000	1.35	1.61	N.A.
	Projected 2008	1.39	1.69	N.A.
	Projected 2010	1.55	1.87	2.05
	Projected 2012	1.46	1.64	1.76
Austria	Projected 2000	1.29	1.65	N.A.
	Projected 2008	1.46	1.76	N.A.
	Projected 2010	1.36	1.74	2.01
	Projected 2012	1.52	1.74	1.85
Group 1 Average	Projected 2000	1.55	1.82	N.A.
	Projected 2008	1.44	1.69	N.A.
	Projected 2010	1.48	1.77	2.03
	Projected 2012	1.48	1.67	1.78
Group 2: Countries with above replacement fertility in 2005-2010				
Algeria	Projected 2000	2.10	2.10	N.A.
	Projected 2008	2.16	1.85	N.A.
	Projected 2010	1.96	1.66	1.97
	Projected 2012	2.55	1.93	1.90
India	Projected 2000	2.10	2.10	N.A.
	Projected 2008	2.30	1.85	N.A.
	Projected 2010	2.38	1.87	1.88
	Projected 2012	2.37	1.92	1.84
Bangladesh	Projected 2000	2.60	2.10	N.A.
	Projected 2008	2.10	1.85	N.A.
	Projected 2010	1.98	1.58	1.92
	Projected 2012	2.05	1.69	1.82
Laos	Projected 2000	3.33	2.10	N.A.
	Projected 2008	2.91	2.07	N.A.
	Projected 2010	2.24	1.60	1.91
	Projected 2012	2.72	1.88	1.83
El Salvador	Projected 2000	2.31	2.10	N.A.
	Projected 2008	2.13	1.85	N.A.
	Projected 2010	2.03	1.67	1.91
	Projected 2012	2.35	1.75	1.82
Group 2 Average	Projected 2000	2.49	2.10	N.A.
	Projected 2008	2.32	1.90	N.A.
	Projected 2010	2.12	1.68	1.92
	Projected 2012	2.41	1.83	1.84
Group 3: Low fertility countries where TFR noticeably increased in the 2000s				
France	Projected 2000	1.85	1.90	N.A.
	Projected 2008	1.85	1.85	N.A.
	Projected 2010	2.00	2.06	2.09
	Projected 2012	1.98	1.99	1.99
Netherlands	Projected 2000	1.57	1.81	N.A.
	Projected 2008	1.81	1.85	N.A.
	Projected 2010	1.84	1.99	2.08
	Projected 2012	1.79	1.86	1.90
Sweden	Projected 2000	1.45	2.01	N.A.
	Projected 2008	1.85	1.85	N.A.
	Projected 2010	1.95	2.04	2.08
	Projected 2012	1.94	1.98	2.00
Russia	Projected 2000	1.27	1.75	N.A.
	Projected 2008	1.53	1.83	N.A.
	Projected 2010	1.61	1.89	2.05
	Projected 2012	1.60	1.81	1.90
Group 3 Average	Projected 2000	1.54	1.85	N.A.
	Projected 2008	1.76	1.85	N.A.
	Projected 2010	1.85	2.00	2.08
	Projected 2012	1.83	1.91	1.95

[20] Estimated TFR is from United Nations (2011a). Projections are from United Nations (22001, 2009, 2011a, 2013c).

For most **Group 1** countries projected TFR for 2045-2050 declines between the 2000 and the 2008 projections, consistent with the change in asymptotic TFR from 2.07 to 1.86. Between the 2008, 2010 and 2012 projections projected TFR for 2045-2050 increases and then decreases, except for China and Austria. The 2095-2100 projections decrease from the 2010 to the 2012 projections, since the Group 1 countries were substantially affected by their history of little or no TFR increase from below replacement. All of the **Group 2** countries show declines in projected TFR for 2045-2050 from 2000 through 2010 and then an increase in the 2012 projections. This is because in the 2010 projections, the Group 2 countries were in a period of substantial below replacement fertility based on the 2010 model, which was relaxed in the 2012 projections. Nonetheless, for 2095-2100. projected TFR is always lower in the 2012 than in the 2010 projections. For most **Group 3** countries, there was lower projected TFR for 2045-2050 in the 2008 than in the 2000 projections. Projected fertility for 2095-2100 was always lower in the 2012 than in the 2010 projections.

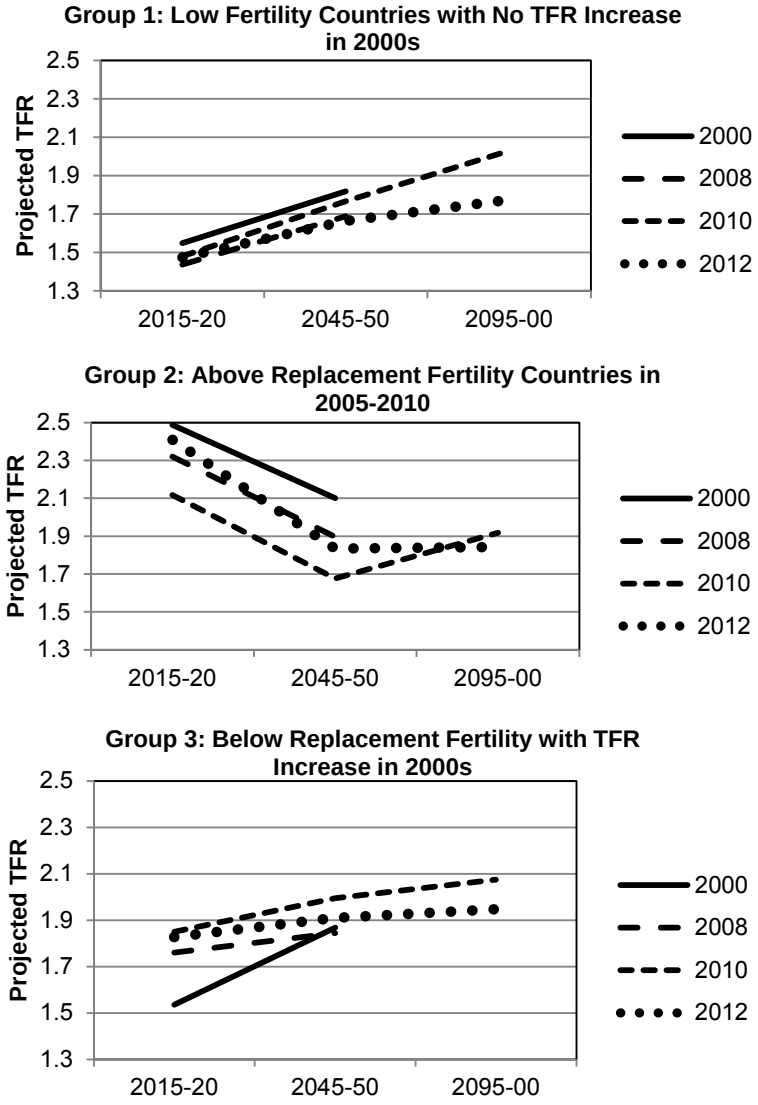

Figure 10 Projected TFR for 2015-2020, 2045-2050 and 2095-2100, as Projected in 2000, 2008, 2010 and 2012, for Three Groups of Countries

Figure 10 graphs the average projected TFR values for all the countries considered in each group. The effects of the shift in projecting TFR to move toward 2.07 from before 2004 to TFR moving toward 1.85 in 2004 is shown in the change from the projections in 2000 to the projections done in 2008. In Group 1 and Group 2 there are lower projected values from 2008 than in 2000. In Group 3, the slope of increase in the 2000 projections is greater than in the 2008 projections.

The shift in assumptions from 2004 to 2010, when TFR was again seen to move toward 2.07 is shown in Group 1 and Group 3 in the higher values in the 2010 projections than in the 2008 projections. In Group 2, the line for 2010 is below that for 2008 through 2045-2050 and then increases sharply. This is because the 2010 projections assumed that above replacement fertility countries would fall substantially below replacement and then move toward replacement fertility. In their description and discussion of the 2010 projections, Alkema *et al.(*2013) note the projected decline to below replacement followed by an increase in Group 2 countries, illustrating this with the example of India. They also state that there is a great deal of uncertainty about future fertility in Group 2 countries.

The shift in assumptions between 2010 and 2012 is indicated by the lower projected values from 2012 than from 2010 in Group 1 and Group 3. In Group 2, the projected values from 2010 are below those from 2012 for 2045-2050 but rise above those from 2012 by 2095-2100. This is because the 2010 projections assumed a sharp decline in above replacement fertility to substantially below replacement, before fertility rose toward replacement, while more gradual changes were assumed in 2012.

Table 5 Five-Year Period of Lowest TFR 1950-2100 as Estimated and Projected 2095-2100 TFR from 2010 and 2012 *World Population Prospects*: Selected Countries[21]

(1)	(2)	(3)	(4)	(5)
	2010 World Population Prospects		***2012 World Population Prospects***	
	Lowest TFR 1950-2100	**Projected TFR 2095-2100**	**Lowest TFR 1950-2100**	**Projected TFR 2095-2100**
Group 1: Low Fertility Countries with Little or No Sign of a Fertility Increase in the 2000s from *2010 WPP*				
Singapore	1.2	2.0	1.3	1.5
Japan	1.3	2.0	1.3	1.9
China	1.5	2.0	1.6	1.9
Republic of Korea	1.2	2.0	1.2	1.8
Germany	1.3	2.0	1.3	1.8
Austria	1.3	2.0	1.4	1.9
Average	**1.3**	**2.0**	**1.4**	**1.8**
Group 2: Countries with Above Replacement Fertility in 2005-2010 from *2010 WPP*				
Algeria	1.6	2.0	1.9	1.9
India	1.8	1.9	1.8	1.8
Bangladesh	1.6	1.9	1.7	1.8
Laos	1.6	1.9	1.8	1.8
El Salvador	1.7	1.9	1.8	1.8
Average	**1.7**	**1.9**	**1.8**	**1.8**
Group 3: Low Fertility Countries where TFR Noticeably increased in the 2000s from *2010 WPP*				
Sweden	1.6	2.1	1.6	2.0
Russia	1.3	2.0	1.3	1.9
France	1.7	2.1	1.7	2.0
Netherlands	1.5	2.1	1.5	1.9
Average	**1.5**	**2.1**	**1.5**	**2.0**

Table 5 looks further at the effects of the change in fertility projection assumptions between 2010 and 2012. It shows the five-year period with the lowest estimated or projected TFR 1950-2010 and the lowest TFR value as reported in the *2010 World Population Prospects* and the lowest TFR value as reported in the *2012 World Population Prospects*. The average value of the lowest TFR is also shown for countries in each of the three groups as reported in both 2010 and 2012. Projected TFR in 2095-2100 is shown for the projections from 2010 and from 2012.

The values in Table 5 make clear that the *2010 World Population Prospects* estimates produced wider swings in projected TFR than did the *2012 World Population Prospects* estimates. For every country the lowest estimated or projected TFR 1950-2100 from the *2010 World Population Prospects* was less than or equal to that in the *2012 World Population Prospects* . Also the projected TFR for 2091-2100 from the *2010 World Population Prospects* is greater than or equal to the projected value from the *2012 World Population Prospects*.

Specifically, in the second group of countries, TFR is projected to dip further below replacement in the 2010 projections than in the 2012 projections.

[21] Estimated TFR is from United Nations (2011a). Projections from 2008 are from United Nations (2009), for 2010 from United Nations (2011a), for 2012 from United Nations (2013c).

For every group, the lowest projected or estimated TFR 1950-2010 is lower and the projected TFR for 2095-2100 is higher in the 2010 projections than in the 2012 projections, indicating the greater fluctuations in projected TFR in 2010 than in 2012.

Estimates and Projections 2005-2100 for Three Countries

Figure 11 shows TFR values for 2005-2100 from the *2010 World Population Prospects* and the *2012 World Population Prospects* for the three countries shown in Figure 11, one from each group. The same vertical scale is shown for each country. The 2005-2010 values had been observed by the time the *2010 World Population Prospects* were published. For Singapore and Sweden the estimated values for 2005-2010 are almost identical in the 2010 and the 2012 estimates and projections. For Algeria, the estimate of TFR 2005-2010 that appeared in the *2012 World Population Prospects* was higher than the 2005-2010 TFR estimate in the *2010 World Population Prospects*, probably due to the high number of births in Algeria reported for 2011 (United Nations, 2013e). The lowest projected TFR for Algeria from the *2010 World Population Prospects* was 1.63 in 2035-2045, while in the *2012 World Population Prospects*, the lowest value is 1.89 which is maintained 2060-2095, with a slight uptick to 1.90 in 2095-2100

These three countries illustrate the observations made for the larger group of countries in Figure 10 and Tables 4 and 5. There are lower projected values in 2012 than in 2010 in Singapore from Group 1, there is more variation in projected TFR in 2010 than in 2012 in Algeria from Group 2, and there are similar projected values in 2010 and in 2012 in Sweden from Group 3, although for Sweden the 2012 projected values are slightly lower than the 2010 projected values.

Cohort and Period Fertility and Assumptions about the Shape of Age-Specific Fertility Schedules

Examination of age-specific fertility rates can show whether childbearing has shifted to an older age in the recent past and whether it is projected to shift to an older age in the future. The countries upon which stage 3 fertility change was modeled have generally had a shift to older ages of childbearing. In some age-specific fertility rates have increased at older ages. Has childbearing been observed to shift from the Time 1 to the Time 2 pattern and has it or is it expected to shift to the Time 3 pattern shown in Figure 1?

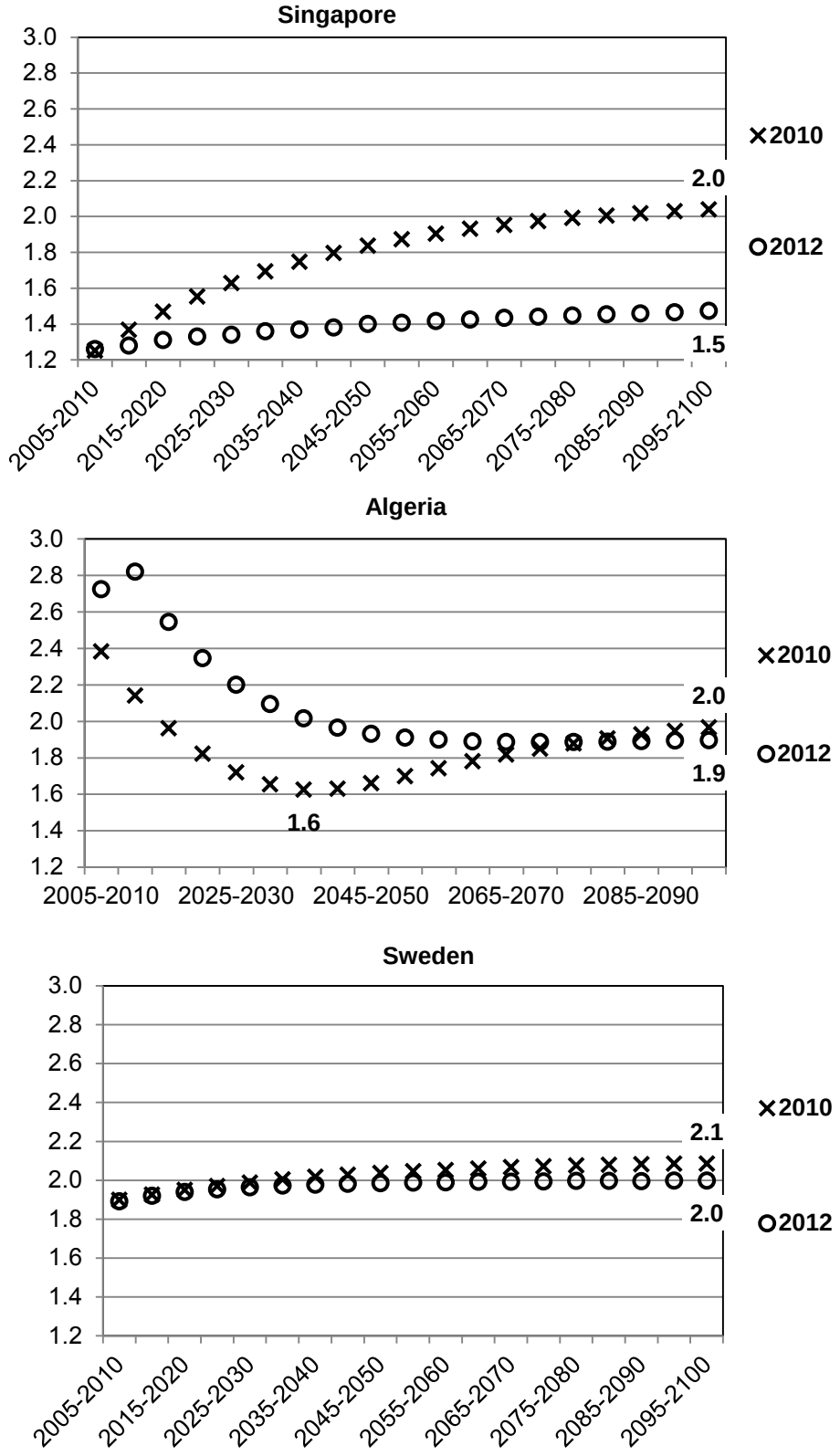

Figure 11 Estimated and Projected TFR 2005-2100 in Three Countries from 2010 and 2012 *World Population Prospects*[22]

[22] Data for 2010 are from United Nations (2011a); data for 3012 are from United Nations (2013c).

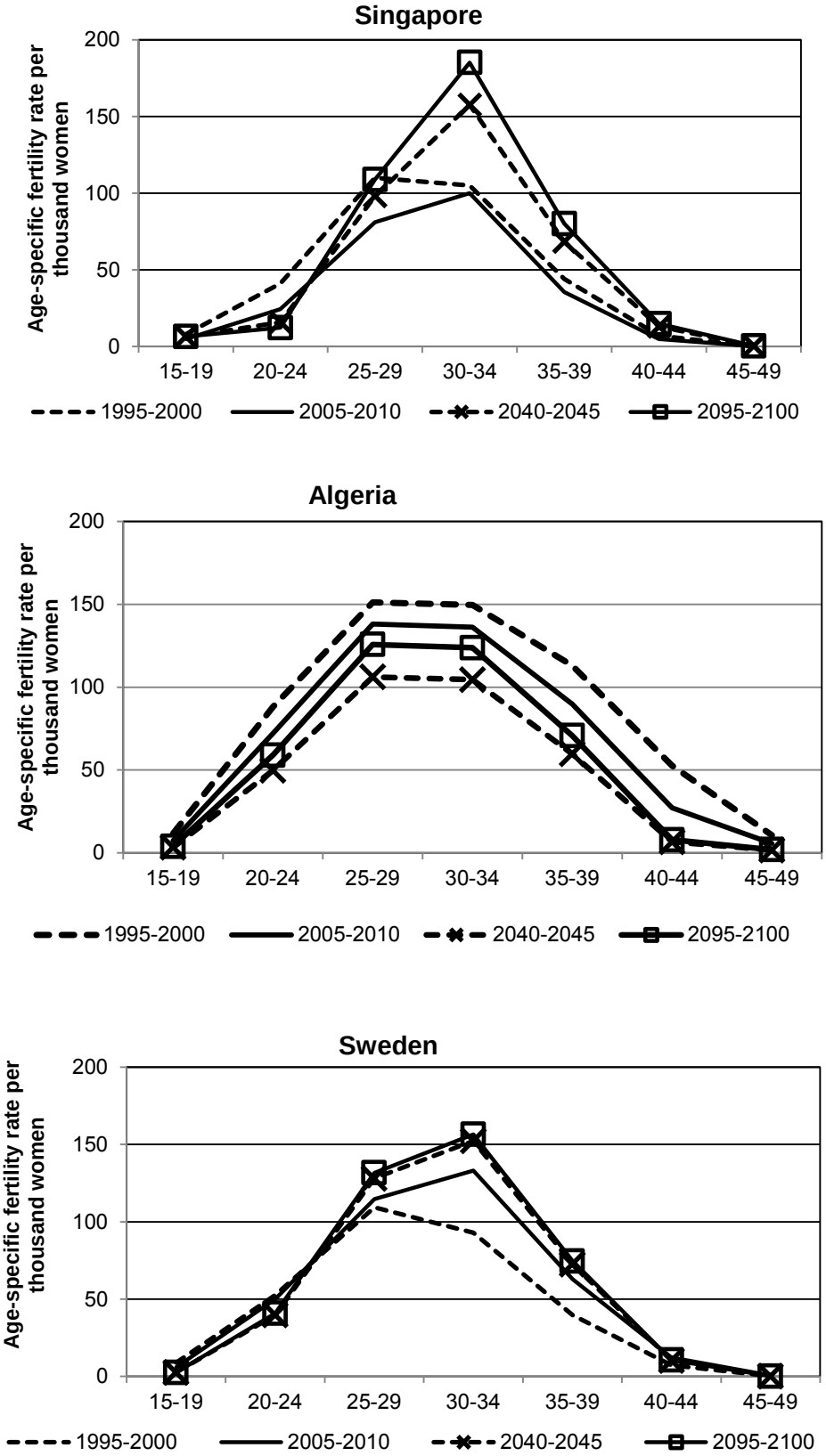

Figure 12 Estimated and Projected Age-Specific Fertility Rates in Singapore, Algeria and Sweden, Based on *2010 World Population Prospects*

Figure 12 shows estimated age-specific fertility rates for each country in 1995-2000 and 2005-2010.[23] From these two time periods, one can see what the trend has been in in the shape of the fertility schedule. Figure 12 also shows projected age-specific fertility rates for 2040-2045 and for 2095-2100 as estimated in *2010 World Population Prospects*. Table 6 shows the mean age of childbearing in each country at the four dates from *2010 World Population Prospects* (United Nations, 2011a).

Table 6. Mean Age of Childbearing in Singapore, Algeria and Sweden, Based on *2010 World Population Prospects*

Time Period	Singapore	Algeria	Sweden
1995-2000	30.0	31.5	29.5
2005-2010	30.5	31.0	30.6
2040-2045	31.8	30.4	31.0
2095-2100	32.0	30.4	31.0

In Singapore fertility shifted to an older age between 1995-2000 and 2005-2010. By 2040-2045 fertility is projected to become older and to become more concentrated in the 30-34 age group. Fertility in 2095-2100 is also projected to be concentrated in the 30-34 age group, but at a higher level, which is consistent with the higher projected TFR in Singapore in 2095-2100 than in 2040-2045, as shown in Figure 11. Mean age of childbearing in Singapore in 2095-2100 is expected to be 32.

In Algeria, age-specific fertility rates fell between 1995-2000 and 2005-2010 with little change in the shape of the fertility schedule. The rates as projected for 2040-2045 in 2010 fell at all ages, with little change in the fertility schedule's shape. The projected values for 2095-2100 are higher than for 2040-2045, consistent with the projected rise in TFR in Algeria between 2045-2050 and 2095-2100 as shown in Figure 11, but there is little projected change in the age pattern of fertility and some decline in the expected mean age of childbearing. Thus, although Algeria was projected in the 2010 World Population Prospects to attain below replacement fertility by 2095-2100, it was not assumed that the age pattern of fertility would shift to older ages, unlike that seen in Second Demographic Transition countries.

In Sweden, fertility shifted considerably to older ages between1995-2000 and 2005-2010. Even in 2005-2010, a Time 3 age pattern of fertility had emerged in Sweden. The shift to older ages is projected to continue through 2095-2100.

[23] Data from United Nations (2011a).

Conclusions

In a rapidly changing world, with fertility levels that have not been seen before, it is difficult to project the future. However, the changes since the early 2000s in the UN Population Division assumptions about future TFR have been large. The changes between 2004, 2010 and 2012 are striking.

One can question whether the change in 2004 to TFR declining to 1.86 was made before this was prudent. This large shift down in 2004 was probably premature and set up the 2010 and 2012 shifts to look unnecessarily dramatic. For countries non-trivially above replacement fertility, keeping the 2.07 TFR target could have been wise. The change in the fundamental assumption about the future of fertility from a stationary population future before 2004, to a below replacement future in 2004 and back to a stationary population future in 2010 represents substantial fluctuation in thinking about the future.

The change to a U-shaped assumption of the trajectory in TFR in the 2010 projections after replacement fertility was attained resulted in a puzzling pattern of decline and increase in some countries that were above replacement fertility in 2005-2010.

The changes between 2010 and 2012 in TFR projections address some criticisms of the 2010 results, but at this point, the predictive power of the 2012 model is unknown, and fertility trends in low fertility countries still seem extremely sensitive to economic shifts. Hopefully, the continual incorporation of the most current available data into new models will result in more stable and plausible projections.

The changes in fertility assumptions 2004-2012 resulted in large changes in projected TFR. It would be prudent:

1) To make clearer the substantive reasoning behind changes in fertility assumptions in addition to the degree of fit to recent empirical changes.
2) To consider whether conditions and relationships in countries that have experienced fertility change are likely to be the same in all other countries in the future.
3) To have a longer observation period of new empirical patterns before major fertility projection assumptions are changed.

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