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Impact of Varying the Component Assumptions on Projected Total Population and Age Structure in Canada

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Abstract

The objective of this paper is to study the relative impact of the range of component assumptions, namely; fertility, mortality, and immigration, on the projected total population and age structure, using Canadian population projections from 1993 to 2041. The effect of the high or low assumptions of each component on the variability in projected population size and age structure is measured as the deviation from the medium scenario, while controlling for the effect of the other two components. Two factors are found to have significant effect on the variation of the projected total population: the range of the component assumption, and the pace at which the assumption reaches its horizon value. Each component has its own unique effect on each age group. For example, immigration is the only component to have a significant effect across the age groups 0-14, 15-64 and 65+.

Résumé

Le Présent article a pour objet d'étudier l'incidence relative de l'étendue d'hypothèses relatives aux composantes -- fécondité, mortalité et immigration – sur les estimations de la population totale et de la pyramide des âges, d'après les projections de la population Canadienne de 1993 à 2041. L'effet des hypothèses se situant dans la partie inférieure on supérieure de la fourchette pour chaque composante est mesuré en fonction de l'écart par rapport au scénario moyen, l'effet des deux autres facteurs étant contrôlé. Il s'avère que deux facteurs ont un impact majeur sur la fluctuation des estimations démographiques : la fourchette de prévisions pour chaque composante et la vitesse à laquelle la valeur d'horizon est atteinte. Chaque composante produit son propre effet unique sur chaque groupe d'âges. Ainsi, l'immigration est le seut élément qui a un impact significatif sur tous les groupes d'âges de 0-14, 15-64 et 65+.

***Key Words**: projections, assumptions, fertility, mortality, immigration, impact.*

Introduction

Trends in national population size and age structure reflect the combined effects of fertility, mortality and international migration components. The effects of these components on the resulting population size and age structure over time depend upon the component level and pattern. Each component also affects various age groups differently, with greater or lesser impact. For example, based on the results of existing studies, the impact of the fertility component is likely to be greater on the younger ages, while that of mortality will have greater impact on the older ages (Lachapelle, 1992, George, Nault and Romaniuc, 1992). Long-term population projections or simulations provide the required data to study the relative impact of the separate and combined effects of the components on population size and age structure.

Following a similar approach to that employed in a U.S. study (Long, 1991), this paper analyses the relative demographic impact of the range of component assumptions, namely: fertility, mortality, and immigration, on the projected population size and age structure of Canada using the 1993 to 2041 population projections (Statistics Canada, 1994). The effect of the high and low assumptions of each component on the variability in projected population size and age structure is analyzed in terms of three broad age groups: 0-14; 15-64; and 65+.

Methods and Assumptions

Projection Method

The population projections model employed by Statistics Canada is the regional cohort component method[3]. The procedure starts with the base-year population distributed by age and sex. Age-and-sex specific survival ratios and age-specific fertility rates are applied to this distribution making allowance for immigration, emigration, returning Canadians, non-permanent residents, and interprovincial migration. The projections used in this study were generated using the low and high assumptions of each component (fertility, mortality, and immigration) employed in the 1993 base population projections (Statistics Canada, 1994). Thus, six projections were produced by combining either the high or low assumptions of each component with the medium assumption for all the other components. In addition, the medium scenario (medium fertility, mortality, and immigration assumptions) is used as a reference scenario for purposes of comparison. The time horizon of the projection covers 48 years, extending from 1993 to 2041. The utilization of longer-range projections enables us to assess the long-term growth and age-structure implications of the assumed demographic trends.

Component Assumptions

The component assumptions are summarized as follows:

Three Fertility Assumptions:

High:	The total fertility rate (TFR) is assumed to increase from 1.7 children per woman in 1993 to 1.9 by 2016 and remain constant thereafter.
Medium:	The TFR is assumed to remain constant at 1.7 children per woman throughout the projection period.
Low:	The TFR is assumed to decrease from 1.7 children per woman in 1993 to 1.5 by 2016 and remain constant until 2041.

Three Mortality (life expectancy) Assumptions:

High: The life expectancy at birth (e_0) is projected to reach 81 years for males and 86 years for females in 2016, and remain constant until 2041. In 1993, life expectancies at birth were 74.8 years for males and 81.3 years for females.

Medium: The life expectancy at birth is projected to reach 78.5 years for males and 84 years for females in 2016. Between 2016 and 2041, the life expectancy at birth for males and females is projected to remain constant.

Low: The life expectancy at birth is projected to reach 77 years for males and 83 years for females in 2016, and remain constant thereafter.

Three Immigration Assumptions:[2]

High: The annual immigration level is assumed to remain at 250,000 until 1995. This is the target set by the federal government for the years 1993 to 1995, inclusive. After 1995, annual immigration will increase gradually every five years reaching a level of 330,000 immigrants per year by 2005 and remain constant thereafter.

Medium: The annual immigration level remains constant at 250,000 immigrants per year over the projection period.

Low: The annual immigration level decreases every five year after 1995, declining to 150,000 immigrants per year by 2005 and remain constant thereafter.

The assumptions made for the levels of non-permanent residents and returning Canadians are the same in all projections. The rationale for the assumptions on each component used is described in detail in the report, Population Projections for Canada, Provinces and Territories, 1993-2016 (Statistics Canada, 1994).

Table 1 shows the summary of component assumptions underlying the seven scenarios employed in this study. Scenarios 1 and 2 are developed by combining the low and high fertility assumptions with the medium assumptions of the other components, respectively. Scenarios 3 and 4 are generated by combining the low and high life expectancy assumptions with the medium assumptions of fertility and immigration, respectively. Scenarios 5 and

Table 1.
Summary of Component Assumptions Underlying the Six Alternative and Medium Scenarios for Canada: 1993 to 2016

Scenario	Fertility TFR by 2016	Mortality (Life Expectancy) e0 by 2016	Immigration Level to 2016
(1) Fertility - Low	Low 1.5	Medium M: 78.5/ F: 84.0	Medium 250,000
(2) Fertility - High	High 1.9	Medium M: 78.5/ F: 84.0	Medium 250,000
(3) Life Expectancy - Low	Medium 1.7	Low M: 77.5/ F: 83.0	Medium 250,000
(4) Life Expectancy - High	Medium 1.7	High M: 81.0/ F: 86.0	Medium 250,000
(5) Immigration - Low	Medium 1.7	Medium M: 78.5/ F: 84.0	Low 150,000
(6) Immigration - High	Medium 1.7	Medium M: 78.5/ F: 84.0	High 330,000
(7) Medium	Medium 1.7	Medium M: 78.5/ F: 84.0	Medium 250,000

Note: The assumptions for emigration, non-permanent residents, and returning Canadians, respectively are the same for all projection series.

Source: Statistics Canada (1994). Population Projections for Canada, Provinces and Territories, 1993-2016. Catalogue No. 91-520 (Occasional).

6 represent the combination of low and high immigration assumptions with medium fertility and life expectancy assumptions, respectively. Lastly, Scenario 7 is the medium scenario: medium fertility, life expectancy, and immigration assumptions.

Effects of Components

The relative effects of the range in each component of population change are discussed in relation to the variation in projected total population size and variability by age groups. The effects of the range in each component of population change is measured as the deviation of the low or high assumptions from the medium scenario, while controlling for the effects of the other components.

In the following sections, the effects of the range of each component of population growth on the variation of projected total population are discussed first, then followed by the variation in age structure. The analysis focuses on three age groups: 0-14, 15-64, and 65 and over. Ages 0-14 roughly represent the child population, 15-64, the working age population, and age 65+, the elderly population.

Total Population

Fertility

Under the high fertility assumption, the total fertility rate reaches 1.9 births per woman, which is 12% above the medium assumption of 1.7. This is a modest rise in the TFR, from 1.7 in 1993. The present symmetrical range departs from the practice in past projections of fixing the high fertility assumption at the replacement level of 2.1 children per woman. As Ryder (1993) stated in a memorandum, there is "no basis for setting the high level at the replacement level. Any connection between a stable population measure like this, and reproduction behaviour, verges on the mystical". On the other hand, the low-fertility assumption is 1.5 children per woman, or 12% below the medium assumption. This level is slightly lower than the lowest TFR ever recorded nationally (1.57 children per woman in 1987).

By 2016 (23 years into the projection), the high- and low-fertility series yield projected populations of 38.0 million and 36.3 million, respectively, which are about 2.4% above and 2.2% below the medium scenario, for a total range of 1.7 million or 4.6%. By 2041 (48 years into the projection), the range will expand to about 5.8% above and below the medium series or a total range of 5.0 million or 11.6% between the high- and low-fertility series (Table 2, Figures 1, and 2).

Table 2.
Total Population of Canada according to the Seven Alternative Scenarios for Selected Years: 1993-2041

Year	Medium Series	Fertility		Life Expectancy (e_0)		Immigration	
		Low	High	Low	High	Low	High
1993	28.8	28.8	28.8	28.8	28.8	28.8	28.8
1996	30.0	29.9	30.0	30.0	30.0	29.9	30.0
2001	31.9	31.7	32.1	31.8	31.9	31.6	32.1
2006	33.7	33.3	34.1	33.6	33.8	33.0	34.2
2011	35.4	34.8	36.0	35.3	35.7	34.2	36.4
2016	37.1	36.3	38.0	36.9	37.5	35.3	38.6
2021	38.7	37.6	39.8	38.4	39.3	36.3	40.7
2026	40.1	38.7	41.5	39.7	40.8	37.0	42.5
2031	41.2	39.5	43.0	40.8	42.0	37.6	44.2
2036	42.1	40.1	44.3	41.6	43.1	37.8	45.6
2041	42.9	40.4	45.4	42.3	43.9	38.0	46.8

Source: Statistics Canada, Demography Division, Population Projections Section.

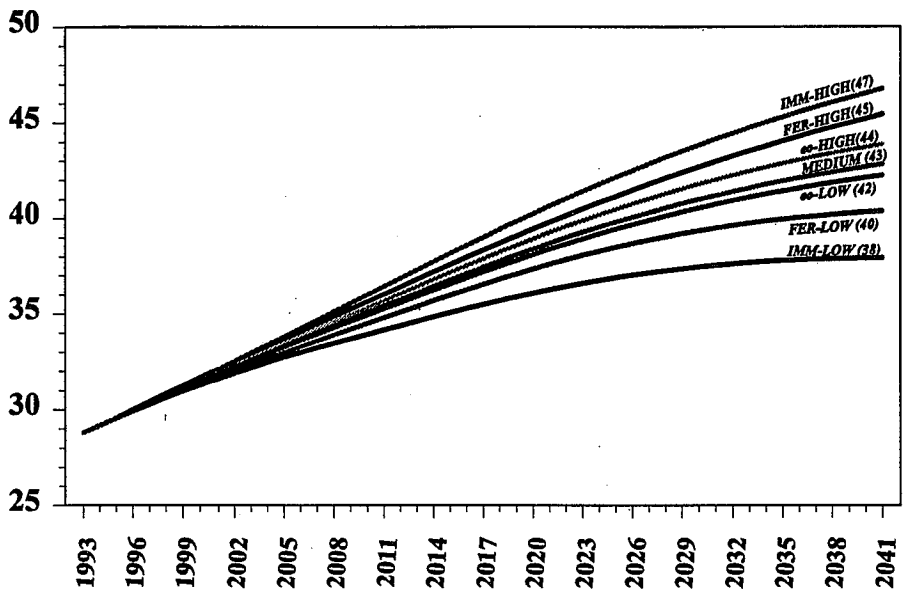
The range of variation in projected total population, as shown above, due solely to alternative fertility assumptions is rather narrow when compared to the projection results for the United States in Long's study. The current assumptions of fertility in this study might be interpreted as rather conservative, with a range of only 0.4 children per woman, between the high and low assumptions. On other hand, the range is almost double, 0.7 children per woman, in the U.S. projections. Consequently, the variability in the U.S. fertility assumptions creates a range in projected total population size which is relatively larger (22%) than that in the Canadian projections (11.6%), by around 50 years into the projection period. This shows that the larger the range between the high- and low-fertility assumptions, the larger is the range of variation in projected total population.

Mortality

In developed countries like Canada and the United States, unlike fertility and immigration, the mortality trend is stable. Furthermore, deaths are heavily concentrated in the oldest ages, and each deferred death will add to the future total population for only a few years until the person eventually dies (Long, 1991). Given the relative stability of mortality and its limited effect on future

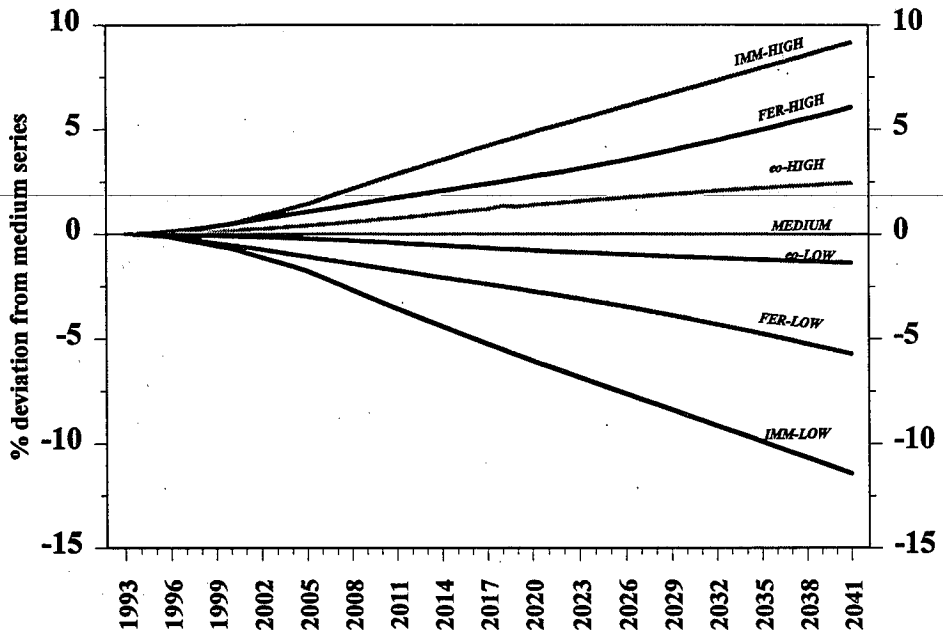
population, alternative scenarios for mortality have much less effect on the long-term projected total population size.

Figure 1
Total Population of Canada
Seven Scenarios, 1993 - 2041



Under the high life expectancy at birth series, males would reach 81 years in 2016 or 3.2% above the medium series of 78.5 years. The low life expectancy at birth series is 77 years, or 1.9% below the medium series. The range is similar for females, 2.4% above (86.0 years) and 1.2% (84.0 years) below the medium series. This variation in life expectancy gives a population which is either 0.5% below or 1.1% above the medium projection, for a total range of 1.6% in 2016. In absolute numbers, the high- and low-life expectancy series will produce projected populations of 37.5 million and 36.9 million, respectively, for a range of 0.6 million. Even in the year 2041, the effect of the alternative mortality series remains small, yielding a projected population with high life expectancy of about 2.3% above the medium projection, and with low life expectancy, about 1.4% below, for a total range of 3.7% or 1.6 million in absolute numbers (Table 2, Figures 1 and 2).

Figure 2
Range of Alternative Scenarios from Medium Series, Canada, 1993 - 2041



The Canadian data reinforces the findings of the U.S. study that the effects of mortality are quite small relative to the effects of the alternative fertility series. Currently, the life expectancy level in both countries is approaching 80 years. Further marked increases or decreases in life expectancy are unlikely without sudden medical breakthroughs or a major epidemics. Given the limited variability in mortality assumptions, the resulting projected total population falls within a relatively narrow range.

Immigration

Table 2 and Figure 1 show that immigration is an important factor affecting the growth of the Canadian population, among the three components of change. According to the six alternative scenarios, the largest population will be attained under the high-immigration series at 38.6 million in 2016, and 46.8 million in

2041. The low-immigration series, on the other hand, will generate the smallest population in 2016 and 2041, among these six alternative projection series, at 35.3 million and 38.0 million, respectively.

The high-immigration assumption assumes that annual immigration will reach 330,000 by 2005, which is 32% above the medium series of 250,000 per year. This assumed level implies that the current annual proportion of immigrants to the total population remains constant over the projection period at the 1993 level (0.86%). This is slightly lower than the 1% level set in the Red Book (The Liberal Party of Canada, 1993). The low-immigration assumption assumes a decline to a level of 150,000 by 2005, 40% below the medium series. This reflects the average annual number of immigrants observed in the recent six years (1985-1986 to 1990-1991), immediately preceding the recent upturn in immigration.

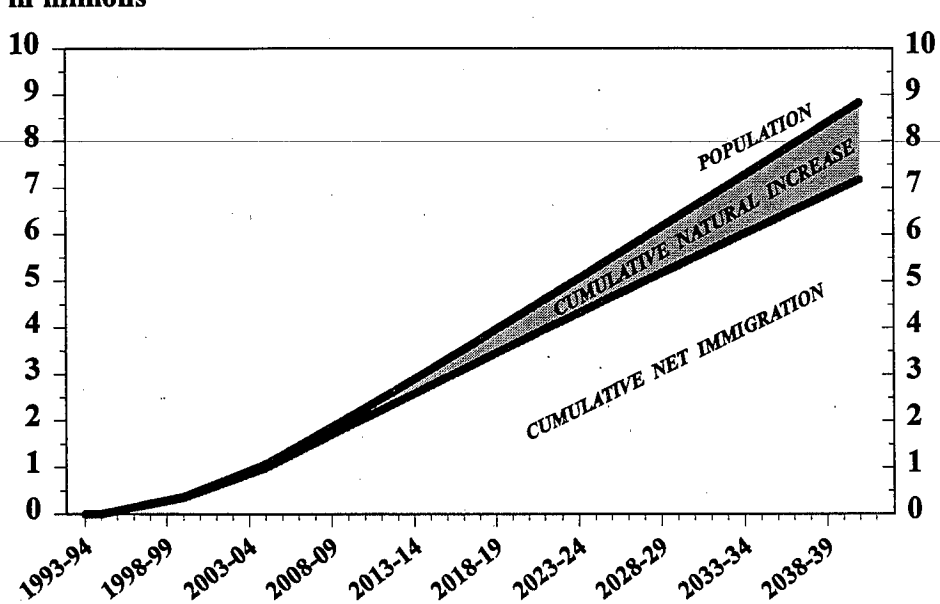
By 2016, the high- and low-immigration series will produce a population close to 4.0% above and about 4.9% below the medium series - for a total range of 3.3 million or close to 9%. By 2041, the range in total population size between the high-immigration and medium series will increase to 9.1%, and between the low-immigration and medium series will increase to 11.4%, for a total range of 20.5% or 8.8 million (Figures 1 and 2). The range in total population size due to the range in the immigration assumptions is the largest at the end of the projection period, compared to that of fertility and mortality, 11.6% and 3.7%, respectively.

The effects of immigration on total population growth can be discussed in terms of direct and indirect effects. Figure 3 shows the differences between high- and low-immigration scenarios in terms of population size, cumulative net international migration, and cumulative natural increase. The cumulative indices were derived by cumulating the differences in the projected numbers of natural increase and net international migration for each year, according to the low- and high-immigration projections.

The annual variation in population size between the high- and low-immigration series is the combined effect of cumulative net international migration and cumulative natural increase. In 2016, the cumulative difference between the two extreme scenarios would be 2.9 million for net international migration, and 0.4 million for natural increase. This yields a total difference of 3.3 million in the projected population. The corresponding numbers for 2041 are 7.2, 1.6, and 8.8, million respectively. The variations between the high and low projected populations are thus mostly attributable to the direct effect of projected immigration and secondarily, to the indirect effects of births and deaths occurring to immigrants. The indirect effects of net migration increases from around 12% in 2016, to about 19% by 2041.

The immigrant population, thus, contributes to the population growth of the host countries through the addition of the immigrants themselves and through their subsequent fertility, which is often higher than that of the nonimmigrant population (Espanshade, 1987; Wolf, Wils, Lutz and Scherbov, 1988). In

Figure 3
Difference between High and Low Scenarios in Projected Population,Net International Migration, and Natural Increase (of Immigrants)



Canada, Ram and George (1990) indicate in their study that the fertility of foreign-born women tends to be higher than that of the Canadian-born women, at least during the initial years of their arrival. In some European countries, Espenshade (1987) notes that the immigrant population may account for nearly all of a nation's natural growth. He cited two examples, West Germany and France. In 1975, immigration and natural increase among immigrants were the only source of demographic growth in West Germany. Since 1975, nearly all of the growth in the French population has been due to higher birth rates among North African immigrants.

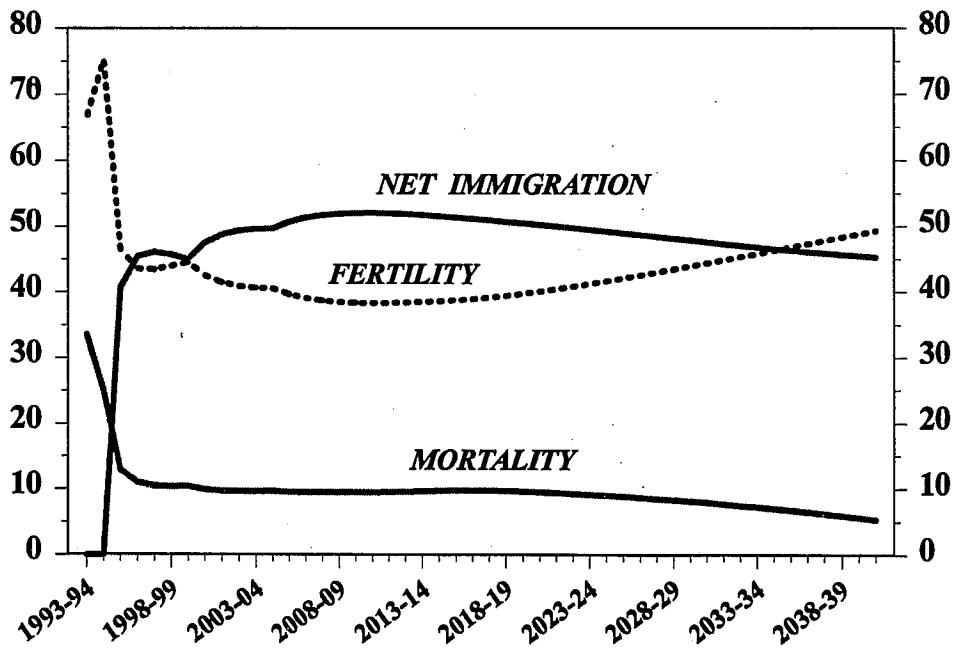
Although immigrant fertility tends to be higher, in developing the projections used in this analysis, it has been assumed that their fertility level and pattern are the same as those of the Canadian-born population.[4]

Combined Effects

The relative effect of each component of change on the total population variation is shown in Figure 4. In interpreting the results shown in this figure, it should be noted that immigration alternatives of the 1993-based projections are not assumed to take full effect in the first year of the projections, instead the annual immigration level is assumed to remain constant at 250,000 in the first 2 years. After 1995, the annual immigration level will either increase or decrease gradually to reach the low or high immigration assumption by 2005.

Due to the aforesaid nature of the immigration assumption, fertility is the most important factor in the variation of the total population during the first three

Figure 4
Percentage of Population Projection Range due to Each Component of Change, Canada, 1993-94 – 2040-2041



years of the projection period. Then the effect of immigration begins to show but it is not much larger than that of fertility during the years 1996-97 to 1999-2000. From 2000-01 onwards, the effect of immigration on total population variation begins to predominate. For 17 years, 2005-06 to 2021-22, immigration has more than a 50% effect on total population variation.

Eventually, the cumulative effects of fertility prevail, fertility then becomes the most important factor in the variation of the total population from 2035-36 onwards. The limited impact of mortality on total population variation is evident, for a majority of the time, its effect is below 10%. By the end of the projection period, the relative effect of fertility, immigration, and mortality on the variation in total population is 49.3%, 45.3%, and 5.4%, respectively.

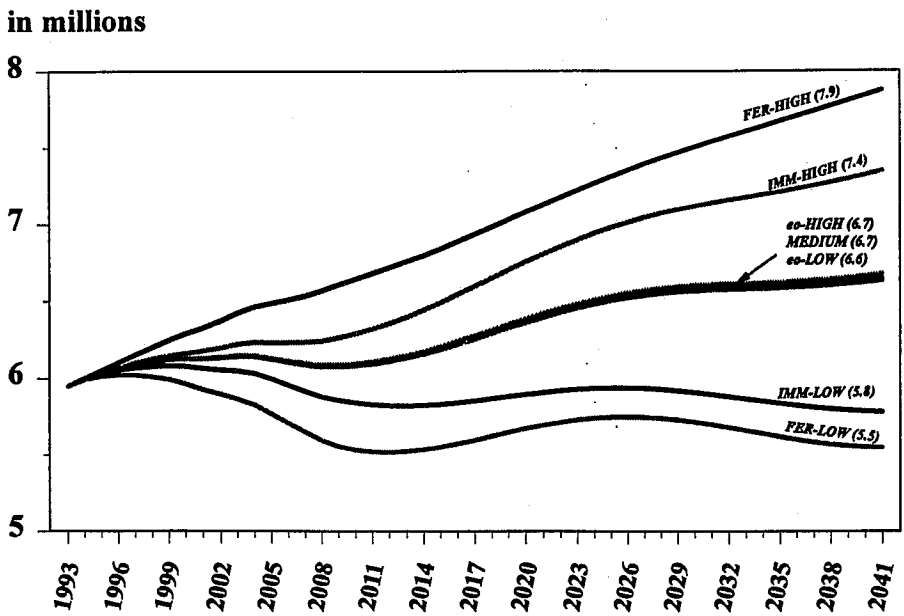
In Long's study (1991) based on 1986-based projections for the United States, the full range of the effect of immigration on total population variation occurs in the first year of the projection period, as the assumed low- and high-immigration levels are to occur in that year. In this study, immigration is the most important factor in the variation for total population by seven years into the projection period, around 2010-2011, the assumed annual immigration level remains constant between 1993 and 1995. However, the relative predominance of fertility effect by the end of the projection period is similar to that of the U.S. experience. "Fertility has a greater cumulative effect on population growth because each extra births adds not only to the next year's population but to the projected population for the person's entire lifespan roughly 75 years" (Long, 1991, p. 507).

Age Structure

The Population Aged 0-14

In Canada, mortality is largely concentrated in the elderly population, thus changing mortality levels will only have significant effects on the increased survival of the seniors. As shown in Figure 5, throughout the projection period, the number of children aged 0 to 14, are similar in the high- and low-mortality series. On the other hand, alternative fertility assumptions cause considerable variability in the young ages. In 2016, there will be 5.6 million children according to the low-fertility assumption and 6.9 million under the high-fertility assumption, a difference of 1.3 million or 21%. The difference will increase to 2.3 million or 35% if the projection is extended for another 25 years. Besides fertility, alternative immigration assumptions also have a noticeable impact on projected child population size. The difference in projected population aged 0 to 14 between the low- and high-immigration series will be 0.7 million or 11.2% in 2016 and will double to 1.6 million or 23.6% by 2041.

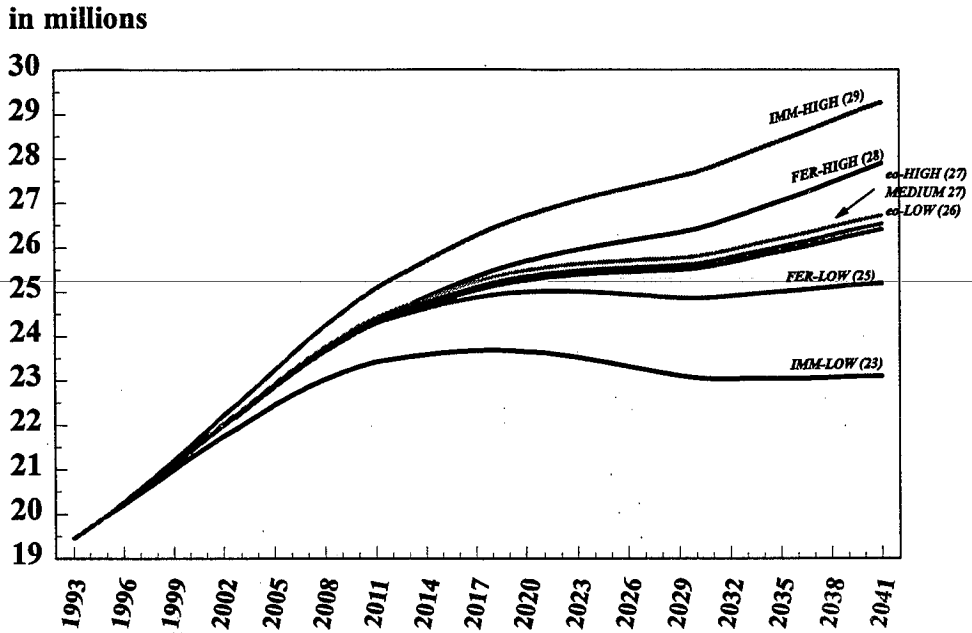
Figure 5
Projected Population Aged 0-14 Years
Canada, 1993-94 – 2040-2041



The Working Age Population, Age 15-64

Immigrants are generally concentrated in the young working age group between 20 and 44. According to immigration statistics for the period 1990 to 1992, (Statistics Canada, 1996) over half of all immigrants (57%) are in the age group 20-44. The proportion of those under 20 (26%), is greater than that of those over 45 (17%), and there are very few individuals over 65 (5%). Due to the age structure of the immigrant population, the significant effects of immigration on the adult ages are apparent in Figure 6. If the proportion of immigrants to the total population remains constant over the projection period at the 1993 level (high-immigration scenario), the working age population will increase steadily from 19.5 million in 1993, to 26.1 million by 2016, and 29.3 million by 2041. This is 4.3% and 10.3% higher than the medium series of 25.0 million and 26.5 million in 2016 and 2041, respectively. Conversely, the low-immigration series will produce a working age population that is about 5.4% below the medium series in 2016, and 12.9% below the medium series by 2041. This implies a total range between the low- and high-immigration series of 9.7% and 23.2% in 2016 and 2041, respectively.

Figure 6
Projected Population Aged 15-64 Years
Canada, 1993-94 – 2040-2041



The effect of alternative mortality assumptions on the 15 to 64 age group is relatively limited, the range in population size of this age group between the high- and low- mortality assumptions is only 0.7% in 2016 and increases slightly to 1.2% in 2041.

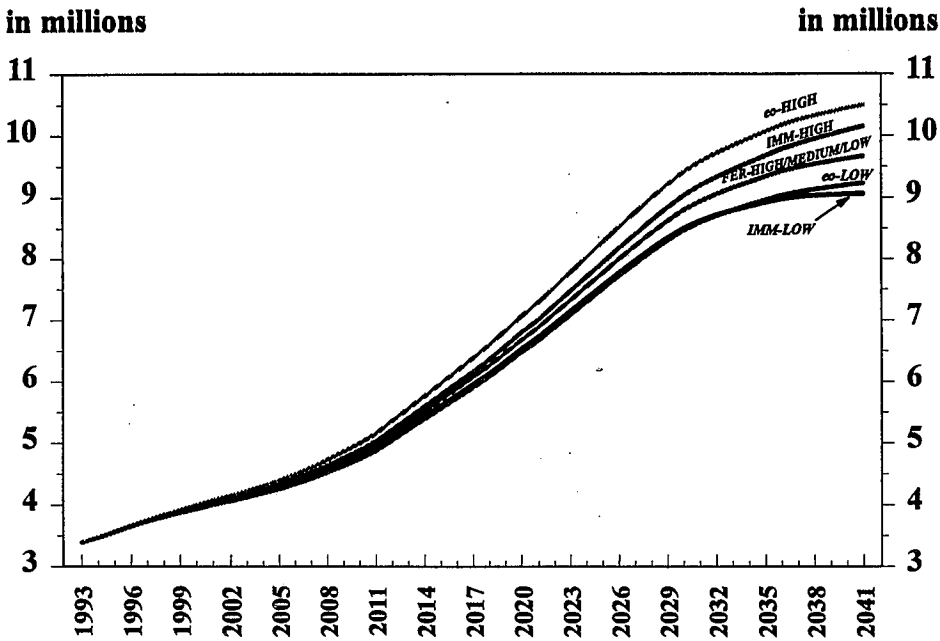
The impact of alternative fertility assumptions on the working age population will be nil before 2009. Only as the cohort born after the base year of theprojection period slowly moves into the working age population, will the curves shown for the alternative fertility assumptions start to deviate from the medium series (Figure 6). By the end of the projection period, the working age population in the low- and high-fertility series will be 5.0% below and 5.2% above the medium series, for a range of 10.2%.

The Population Aged 65 and Older

Under all of the seven scenarios, the number of elderly people will grow dramatically during the projection years. Mortality will generate the largest range in the elderly population. According to the high-mortality scenario, the

65 and over age group will almost double between 1993 and 2016, from 3.4 million to 6.2 million, and will expand to 10.5 million by 2041 (Figure 7). This translates into 4.9% and 8.6% above the medium series of 5.9 million and 9.7 million by 2016 and 2041, respectively. Under the low- mortality assumption, the number of seniors will increase to 5.7 million and 9.2 million by 2016 and 2041, respectively, or 2.6% and 4.5% below the medium series. Thus, the range between the low- and high-mortality series will be 0.4 million in 2016, and 1.3 million by 2041, or 7.5% and 13.1%, respectively.

Figure7
Projected Population Aged 65 Years and Over
Canada, 1993-94 – 2040-2041



Since a majority of the immigrants are between the ages of 20 and 44, the range of elderly population between the low- and high-immigration scenarios will be relatively narrow in 2016, 0.2 million or 3.3%. The range will broaden substantially after 25 years, as the immigrants would age through the projection years, it will be 1.1 million or 11.3% by 2041.

Alternative fertility scenarios will not affect the future size of the elderly population as only cohorts born after the base year of the projection (1993 in this

case) can be affected by differential fertility assumptions. Since there is no difference between the high- and low-fertility series for population aged 65 and over, the two fertility series are shown as one line in Figure 7.

Conclusion and Discussion

This paper has examined the relative effect of the range in component assumptions on projected total population size and age structure. The effect is studied as the deviation in total population size or age structure generated by the low or high assumptions of each component from the medium series, while controlling for the effect of the other two components. The effect of the component assumptions on age groups 0-14, 15-64, and 65+ have been discussed. It has been shown that the variations in the emerging total population size and age structure under the high and low scenarios of each component increases with time.

Two factors are found to have a significant effect on total population variations: the range of the component assumption and the pace at which the assumption reaches its horizon value. In Long's study of U.S. projections, the full range of variation due to alternative immigration assumptions is felt in the first year of the projection, since the horizon value of the immigration assumptions was reached in that year.

In this study, the shape of the curves differs from the U.S. projection results, since the immigration assumption is formulated differently. The immigration level is assumed to be the same across all the assumptions during the first 3 years of the projection period, thus, fertility is the most important factor in the variation of total population during those years. As the immigration level gradually increases or decreases to reach its horizon value by 2005, the effect of immigration slowly increases overtime until it reaches its peak around 2010. For 39 years, 1996 to 2034, the immigration component is the dominant factor affecting the variance. From 2035 onwards however, as the cumulative effect of fertility becomes more apparent, fertility has the largest effect.

The analysis also shows that the effects of the variability in the three components across the age spectrum are not uniform. Even though the range between the low and high fertility assumptions is relatively narrow, alternative fertility assumptions generate the largest range in the 0-14 age group, 21% and 35% in 2016 and 2041, respectively. For the working age population, 15-64, the range of variation due to alternative fertility and mortality assumptions is relatively narrow. On the other hand, the range of variation is relatively large between low- and high-immigration assumptions, 9.7% by 2016 and 23.2% by 2041. Though the range of variation for ages 0-14 and 15-64 between alternative mortality assumptions is relatively narrow, mortality is an important factor affecting the future size of the elderly population. The range of variation in the 65+ population due to low- and high-mortality assumptions is 7.5% in 2016 and 13.1% by 2041. These findings of the pattern of component effects on age structure are consistent with those based on the U.S. projections (Long, 1991).

Thus, among the three components of growth, Immigration has a significant effect across the entire age spectrum. However, the effect of immigration is stronger at the young adult ages due to the age structure of the immigrants. Alternative mortality assumptions only have a significant effect at the higher ends of the age pyramid since mortality is largely concentrated in the elderly population. Alternative fertility scenarios have the greatest impact on the unborn child population, but no effect on the population existing at the time of the projection. From the point of view of the forecasters and users of projections, the results indicate the degree of uncertainty in the 1993-based projections in terms of the three component assumptions, namely: fertility, mortality and immigration. It is evident, for example, that for the working age population 15-64, the variability of the 1993-based projections due to immigration is plus or minus 23% for a forecast horizon of about 50 years. For a shorter horizon of 23 years, however, the level of uncertainty in projecting the working age population due to immigration decreases to 9%.

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Endnotes:

1. For a detailed discussion of the method, see George, 1994.

2. The immigration target level has recently been adjusted to between 200,000 and 210,000 per year. This revised level has been taken into account in the latest short-term projections to the year 2001 (Statistics Canada, 1997, Catalogue No. 91-213). However, long-term projections based on the revised level have not yet been produced to enable us to use them in this study.

3. The reason for not assuming differential fertility assumptions for Canadian born and immigrants is because high fertility levels tend to decline over time, and the impact on the projection results of assuming differential fertility assumptions will be negligible since newly arrived immigrants constitute less than 1% of the total population.

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