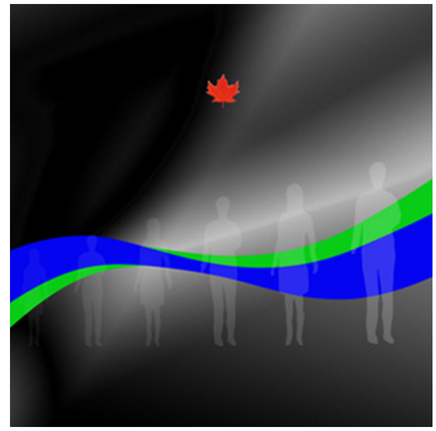
Catalogue no. 91-620-X
ISBN 978-0-660-31284-2

Population Projections for Canada (2018 to 2068), Provinces and Territories (2018 to 2043): Technical Report on Methodology and Assumptions



by Jonathan Chagnon, Patrice Dion, Nora Galbraith,
Elham Sirag and Yu Zhang

Release date: July 10, 2020

Statistics Canada Statistique Canada

Canada

How to obtain more information

For information about this product or the wide range of services and data available from Statistics Canada, visit our website, www.statcan.gc.ca.

You can also contact us by

Email at STATCAN.infostats-infostats.STATCAN@canada.ca

Telephone, from Monday to Friday, 8:30 a.m. to 4:30 p.m., at the following numbers:

- Statistical Information Service 1-800-263-1136
- National telecommunications device for the hearing impaired 1-800-363-7629
- Fax line 1-514-283-9350

Depository Services Program

- Inquiries line 1-800-635-7943
- Fax line 1-800-565-7757

Standards of service to the public

Statistics Canada is committed to serving its clients in a prompt, reliable and courteous manner. To this end, Statistics Canada has developed standards of service that its employees observe. To obtain a copy of these service standards, please contact Statistics Canada toll-free at 1-800-263-1136. The service standards are also published on www.statcan.gc.ca under "Contact us" > "Standards of service to the public."

Note of appreciation

Canada owes the success of its statistical system to a long-standing partnership between Statistics Canada, the citizens of Canada, its businesses, governments and other institutions. Accurate and timely statistical information could not be produced without their continued co-operation and goodwill.

Published by authority of the Minister responsible for Statistics Canada

An HTML version is also available.

Cette publication est aussi disponible en français.

Population Projections for Canada (2018 to 2068), Provinces and Territories (2018 to 2043)

Technical Report on Methodology and Assumptions

Report written by
Jonathan Chagnon, Patrice Dion, Nora Galbraith, Elham Sirag and Yu Zhang

Table of contents

Introduction 4

Acknowledgements 5

Chapter 1: General Approach to Assumption Building 6
- Introduction 6
- Building medium assumptions 6
- Building low and high assumptions 8
- Evolution of age-and-sex-specific rates 8
- Advantages of the current approach 8
- References 9

Chapter 2: *2018 Survey of Experts on Future Demographic Trends* 10
- Introduction 10
- New context, new goals for our elicitation protocol 11
- Elicitation protocol 12
- Target respondents and method of recruitment 17
- Aggregating the individual responses 19
- Acknowledgements 20
- References 20

Chapter 3: Projection of Fertility 22
- Introduction 22
- Fertility Trends 22
- Results of the *2018 Survey of Experts on Future Demographic Trends* 28
- Fertility assumptions and methodology 30
- References 33

Chapter 4: Projection of Mortality 35
- Introduction 35
- Analysis of trends 36
- Results of the *2018 Survey of Experts on Future Demographic Trends* 41
- Methodology 42
- Mortality assumptions 46
- References 48

Chapter 5: Projection of Immigration 51
- Introduction 51
- Arguments in support of an increase in immigration levels in the future 52
- Arguments in support of a stabilization or slight decrease in immigration levels in the future 55
- Results of the *2018 Survey of Experts on Future Demographic Trends* 58
- Immigration assumptions 60
- Appendix A5.1: Assumptions in the form of numbers instead of rates 64
- Appendix A5.2: The investigation of alternative assumptions for the distribution of immigrants by province, age and sex 65
- References 68

Chapter 6: Projection of Emigration ... 72
Introduction ... 72
Results of the *2018 Survey of Experts on Future Demographic Trends* ... 72
Emigration assumptions ... 73
Acknowledgements ... 76
References ... 76

Chapter 7: Projection of Non-Permanent Residents ... 77
Introduction ... 77
Note to users ... 77
Trends in the number of non-permanent residents ... 78
Methodology ... 78
Assumptions ... 80
Acknowledgements ... 82
References ... 82

Chapter 8: Projection of Interprovincial Migration ... 83
Introduction ... 83
Methodology ... 83
Assumptions ... 84
References ... 87

Introduction

This report describes the methodology used to calculate the projection parameters and develop the various projection assumptions for the *Population Projections for Canada (2018 to 2068), Provinces and Territories (2018 to 2043)*.

Following the inaugural edition of this technical report, this edition provides a detailed analysis of each the components of population growth as well as a description of the methodology and assumptions for each component. In particular, Chapter 1 details a new, general approach to assumption building which was utilized for the majority of the projection components. This revised general approach was motivated largely by improvements to the expert elicitation process which informed these projections, described in Chapter 2. Subsequent chapters 3 through 8 cover the various components of population growth, one by one, in the following order: fertility, mortality, immigration, emigration, non-permanent residents and interprovincial migration.

For a detailed description of the mechanics of the cohort-component population projection model, readers are encouraged to consult Chapter 1 of the technical report accompanying the 2013-based projections.[1]

The main report, containing the projection results (Statistics Canada catalogue no. 91-520-X), includes a summary of the projection assumptions and scenarios.

The results are described and analyzed in the analytical report: *Population Projections for Canada (2018 to 2068), Provinces and Territories (2018 to 2043)* (Statistics Canada catalogue no. 91-520-X).

Results can be obtained in the following tables:
Table 17-10-0057-01: projected population, by age, sex and province/territory.
Table 17-10-0058-01: components of projected population growth.

1 See Dion, P. 2015. "Chapter 1: Statistics Canada's cohort-component population projection model", in Bohnert et al. 2015. *Population Projections for Canada (2013 to 2063), Provinces and Territories (2013 to 2038): Technical Report on Methodology and Assumptions*, Statistics Canada catalogue no. 91-620-X.

Acknowledgements

The population projections for Canada, provinces and territories are the result of a close collaboration between Statistics Canada and numerous partners, including the Provincial and Territorial Focal Points, the Advisory Committee on Demographic Statistics and Studies as well as numerous federal departments. Moreover, the projection assumptions were largely developed from the responses provided by members of the Canadian demography community who graciously participated in our *2018 Survey of Experts on Future Demographic Trends*. I firmly believe that the contributions of all these partners strengthen the relevance of Statistics Canada's population projections as a neutral and objective source of information to support decision-making. I would therefore like to express my sincere gratitude to them.

I would also like to take this opportunity to thank the individuals whom contributed to the project in various ways: Julien Bérard-Chagnon, Arnaud Bouchard-Santerre, Éric Caron Malenfant, Jonathan Chagnon, Patrick Charbonneau, Carol D'Aoust, Hubert Denis, Nora Galbraith, Hélène Landry, Stéphanie Langlois, Laurent Martel, Stéphane Mongeau, Jean-Dominique Morency, François Sergerie, Elham Sirag, Peter Tarassoff, Stéphanie Tudorovsky, Gabriel Vesco, Samuel Vézina and Yu Zhang.

Patrice Dion

Chief, Demographic Projections Section
Demography Division
Statistics Canada

Chapter 1: General Approach to Assumption Building

by Patrice Dion and Elham Sirag

Introduction

This chapter describes the general approach used to derive projection assumptions for the majority of the demographic components: fertility, immigration, emigration, and non-permanent residents.[2] This approach was based around three general goals:

1. To take into consideration both short-term and long-term future outcomes in building projection assumptions;
2. To allow each province and territory to follow its own specific path in the short term, based on its own recent past;
3. To ensure that the provinces and territories follow a convergent pattern in the long term, reflecting the fact that despite differences in year-to-year trends, Canada's provinces and territories tend to follow a similar pattern over a long-term horizon.

The approach adopted permits each province and territory to follow their own individual assumptions in the short-term, then gradually converge toward the Canada-level long-term assumptions over the span of the projection horizon. This progression is intended to mimic the way demographic components within a country typically evolve over time: over a short horizon, differences between regions may be more pronounced, resulting in (potential) divergences in regional trends; while when observed over a longer period of time, these trends tend to converge more than they diverge.

This method is consistent with the traditional "hybrid bottom-up" approach often used in population projections: assumptions specific to each province and territory are constructed from assumptions initially developed at the national level, but the Canada-level projections exist only by summing the results for the provinces and territories individually. However, in comparison to previous editions, more consideration is given to the way provinces and territories attain the national targets over the course of the projection.

The next sections describe this method in greater detail.

Building medium assumptions

Briefly, medium assumptions for each component are derived as follows:

- Two distinct linear trajectories are produced for the period 2018 to 2043 for each of the provinces and territories: (1) a short-term trajectory based on the examination of historical trends, and (2) a long-term trajectory based on the results from the *2018 Survey of Experts on Future Demographic Trends*;
- These two linear trajectories are combined to obtain a single medium assumption, with the use of a logarithmic interpolation technique that allows for a smooth transition.

Short-term trajectory

The short-term trajectory assumes that recent year-to-year changes observed for a given demographic indicator over the last 10 years continue to apply in the future. More specifically, a weighted average of the year-to-year changes throughout the selected reference period (generally, 2007/2008 to 2017/2018) is computed, and is applied over the first 25 years of the projection (2018/2019 to 2042/2043). The weights were set to increase linearly so that the weight applied to the most recent year is twice that of the weight applied to the first year of the selected reference period. This allows changes in more recent years to have a larger influence on expected changes in the near future. This 'increasing' weighting scheme was also found to perform slightly better than no weighting in terms of short-term accuracy. Depending on whether the cumulative change is positive or negative, the projected indicator—for example, the projected period total fertility rate (PTFR)—follows either a linearly increasing or linearly decreasing path over the span of the 25-year projection period.

2. Assumptions for mortality and interprovincial migration are derived using alternative approaches, which are described briefly in their respective chapters.

Long-term Trajectory

For the long-term trajectory, results from the *2018 Survey of Experts on Future Demographic Trends*[3] are used to obtain medium target values of the PTFR, immigration and emigration rates and the stock of non-permanent residents in 2043. Targets consistent with each of the assumptions are derived in a way that makes use of the probabilistic nature of the information obtained from the survey. For each component, medium targets in 2043 are obtained by taking the median (50th percentile) of the aggregate probability distribution from the survey for that indicator. Values for the intermediary projection years (from 2019 to 2042) are the result of a linear interpolation between current levels and the medium targets in 2043.

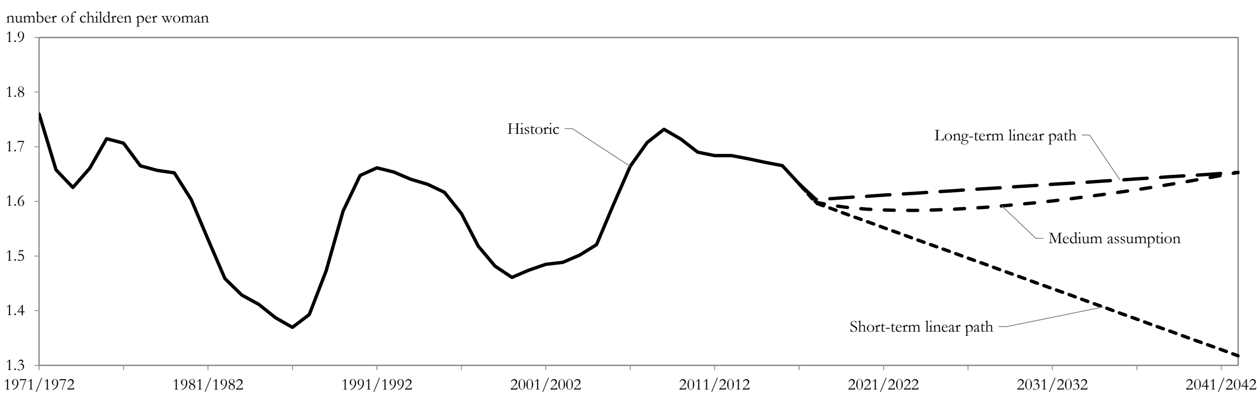
Targets are obtained for values at the Canada-level only, which are then used to derive the same proportional medium long-term targets, in terms of percentage growth, for each of the provinces and territories.

Final Assumptions

Final medium assumptions for the provinces and territories are obtained by combining the short- and long-term trajectories. Logarithmic interpolation of the two curves yields a single assumption, with weights selected so that the curve based on the short-term trajectory is given more weight earlier on in the projection years, and the curve based on the long-term trajectory is given more weight in the latter years.[4] The consequence is that in the short-term, assumptions for a given province will reflect mostly recently observed trends, whereas in the long-term, they will be more influenced by beliefs about future trends at the Canada-level. Using logarithmic interpolation, instead of linear interpolation for example, ensures that the short-term trajectory fades relatively quickly in favor of the long-term trajectory. This was deemed preferable given the generally poor performance of time series model in the long-term for demographic forecasting. After 2043, assumptions are held constant for the remainder of the projection (to 2068).

Figure 1.1 provides an example of the projected PTFR in Quebec according to the short-term trajectory, long-term trajectory and final medium assumption. The short-term trajectory projects a linear decrease in the PTFR based on the decreasing trend observed in the historical reference period. In the long-term trajectory, results from the *2018 Survey of Experts on Future Demographic Trends* indicate an expected increase in the PTFR for Canada as a whole in the long term; this expected increase is applied in proportion to Quebec. The final medium assumption reflects both of these possible trajectories with varying weights—in the short term, the assumption is more influenced by the decrease observed in the short-term curve, while in the medium- to long-term, it rises to reflect the anticipated increase envisioned by the experts.

Figure 1.1 Period total fertility rate, Quebec, historic (1971/1972 to 2016/2017) and projected (2017/2018 to 2042/2043)



Note: The 2017 data are considered preliminary.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 1971 to 2017, Survey 3231 and Demography Division.

3. See Chapter 2: *2018 Survey of Experts on Future Demographic Trends* for more information.
4. For instance, in a 25-year projection, the short-term trajectory would be given a weight of 0.787 in year 1, a weight of 0.663 in year 2, and so on, ending with a weight of 0 in year 25.

Building low and high assumptions

Low and high assumptions were built based on the medium assumption described above and targets reflecting the uncertainty of experts. The low assumption long-term target (for 2043), was computed by taking the 10th percentile of the aggregate probability distribution of experts, and the high long-term target, was computed by taking the 90th percentile. Thus, low and high long-term targets represent the bounds of an 80% prediction interval around the medium long-term target. To construct trajectories for the low and high assumptions, the medium assumption was modified to reach the desired target in 2043 so that the distance from the medium path increases following a logarithmic curve; faster at the beginning of the projection and slower as the projection advances. This approach was used to better mimic how uncertainty unveils in the short-term.[5]

Evolution of age-and-sex-specific rates

Historical data were not used solely to project the global path of a demographic indicator (e.g., PTFR), but also to project changes in the age- and sex- schedule of rates, or, in the case of immigration, in the geographic distribution of new immigrants. It is easy to translate the changes in the projected demographic indicators into changes at age-specific values because the former is simply the sum of the latter (for instance, the PTFR is the sum of age-specific fertility rates). Age-specific values are projected by forecasting age-specific patterns of changes in a manner so as to reflect historical changes in the beginning of the projection but becoming less and less informative over time and thus, restricting the extent of changes to the age schedule over the course of the projection. This means, for instance, that aging of the fertility schedule observed in recent years continues up to a point in the projection but does not continue indefinitely. This was done by using a logarithmic interpolation of two distinct vectors of age-specific patterns of change, similarly to the method used for construction of the medium assumption: one reflecting ten years of historical change, and one that is proportional to the age schedule of the rates. The result is that recent historical changes leave a diminishing mark on projected rates over time. Again, this method was used to take into account information from the recent past without giving it overdue importance for the long-term.[6]

Advantages of the current approach

One of the key advantages of this new approach to assumption-building is its consistency across components; with the exception of mortality and interprovincial migration, assumptions for all other demographic components are built in the exact same manner.[7] This leads to greater coherence in the resulting projection scenarios (which combine assumptions about the various components). For instance, across the majority of components, the long-term projection assumptions share the same probabilistic meaning: the “high” assumption represents the 90th percentile of the aggregate probability distribution of plausible future values for that indicator according to the experts who responded to the survey; the “medium” assumption represents the 50th percentile, and the “low” assumption the 10th percentile.

Another advantage of the current approach is that the way assumptions are derived in the short-term results in more plausible short-term evolutions for the individual provinces and territories, and evolutions of the patterns by age and sex. This follows best practices in projections (UNECE 2018) and results in more relevant projections for users most interested in projections of the short-term future and/or of a particular province or territory. By allowing for the continuation of recent provincial and territorial trends in the short term, with gradual convergence toward national targets in the long-term, the potential occurrence of “shocks”— i.e., abrupt changes in demographic behaviour such as sharp increases or decreases necessary to bring provincial/ territorial levels toward national targets over the span of the projection horizon—is greatly reduced. As a result, individual provinces and territories experience more plausible transitions over the course of the projection.

5. To illustrate this point, it is useful to consider how uncertainty propagates when a fully probabilistic process is used. In a probabilistic projection of PTFR for example, where a very large number of stochastic trajectories are ran (e.g., 100,000), a prediction interval constructed around the median PTFR tends to widen quickly in the early years of the projection and then more slowly over time. This reflects the fact over time, year-to-year fluctuations tend to cancel out to some extent (see Lee 1998 for an explanation of uncertainty propagation in demographic projections in light of autocorrelation structures).
6. Note that in some cases where the number of demographic events during the historical period were very rare (returning emigrants in Nunavut, for example)—that is, where historical trends in age-and-sex-specific rates were erratic/not meaningful, the choice was made to omit the historical change vector from the calculation and to use only the proportional change vector.
7. Although, in the case of mortality, the projection model has similar properties, leaving room for specific developments in the province and territories in the short-term, but ensuring national convergence in the long-term.

The approach also offers an improved representation of the uncertainty of the projections. Despite the fact that these projections are not probabilistic, the construction of deterministic low and high assumptions uses fully probabilistic information from the expert survey. The resulting range between low and high values reflect expert's possibly asymmetric views of their uncertainty about the future evolution of a demographic indicator. The methods implemented for these projections therefore provide an enriched and more plausible representation of uncertainty propagation for the different demographic components of growth.

Finally, the current approach facilitates the production of annual projection updates, a product which are in high demand by projection users. Every year, an additional year of historical data would simply shift the 10-year reference period forward one year, and the same long-term low, medium and high targets obtained from the 2018 survey could be applied one year later in the projection span. The re-computation of intermediary targets is straightforward, and follows exactly as is outlined above. This method thus allows for consistency in the way projections are produced on a quinquennial versus annual basis.

References

Lee, R.D. 1998. "Probabilistic approaches to population forecasting", *Population and Development Review*, volume 24, pages 156 to 190.

United Nations Economic Commission for Europe. 2018. "Recommendations on Communicating Population Projections", prepared by the Task Force on Population Projections, United Nations, New York and Geneva.

Chapter 2: *2018 Survey of Experts on Future Demographic Trends*

by Patrice Dion, Nora Galbraith and Elham Sirag

Introduction

In the previous edition of Statistics Canada's demographic projections (2013 to 2063), a formal consultation of expert Canadian demographers was undertaken to obtain their views on future demographic trends (Bohnert 2015). Although Statistics Canada already engaged in some external consultations on projection assumptions and methods, this more rigorous, formalized consultation process was done in an effort to improve the plausibility and credibility of the projection assumptions.

The approach adopted at the time was modeled largely on the techniques recently used by a number of other statistical agencies; principally, the British Office for National Statistics (Shaw 2008). A questionnaire was distributed to experts which asked them to provide a plausible range of quantitative estimates of future indicators of fertility, mortality and migration according to a specified level of confidence, as well as qualitative justifications for those numeric estimates.

The first venture into a formal surveying of Canadian demographers proved to be a fruitful exercise for Statistics Canada's Demographic Projections Program. The quantitative estimates received in the survey directly informed the assumption-building process. Equally important were the many arguments, methodologies and other evidence that were provided by experts via the open-ended comment sections of the survey. Given the observed benefits of the process to the credibility of the projections, it was determined that formal expert elicitation should continue in future editions of the demographic projections.

For the present edition of the projections, new goals were associated with the expert elicitation exercise. Principally, we wanted to use the elicitation exercise to improve how we characterize uncertainty in the projections; specifically, we sought to obtain complete probability distributions from experts regarding various future demographic indicators. Soliciting probabilistic information from survey respondents is a complex undertaking, and so we examined in greater depth the science of expert elicitation, a large and mature field in itself. The key findings of this review are described below, followed by a description of the new elicitation protocol devised for the current series of the demographic projections.

What is expert elicitation, and why use it?

Formal expert elicitation can be considered a structured approach to consulting experts on a subject for which there is insufficient knowledge or uncertainty is great (Knol et al. 2010). It is a way to gather and synthesize the knowledge and wisdom of experts. In the context of modeling uncertain events, elicitation can be used to translate someone's judgment about those uncertain events into something that can be usefully modeled (Gosling 2014).

Eliciting the views of experts is often the only viable option when a decision must be made in the absence of empirical data, or when the required data is limited, unreliable or prohibitively expensive (James et al. 2010; Runge et al. 2011). However, expert elicitation should not be viewed as a mere "last resort", as it offers several benefits. When properly structured and documented, expert elicitation provides greater transparency in addressing uncertainties than other conventional statistical techniques (Knol et al. 2010). It is also relatively quick and inexpensive to obtain (Knol et al. 2010; Gosling 2014). Further, in some cases, expert elicitation may be preferable over other methods such as time series extrapolation if it takes into consideration additional factors other than what has previously been observed. This possibility is particularly appealing for the projection of demographic phenomena, which often display ambiguous historical trends (in the case of fertility) and are highly affected by social, political or economic developments that can be very difficult to predict based purely on historical trends (in the case of immigration) (Lutz et al. 1998).

Producing population projections—whether deterministic or probabilistic— inevitably requires the producer to make numerous subjective judgment calls. Thus, 'expert opinion' is always utilized in the development of population projections. Typically, projection assumptions are developed by a small team of individuals who examine historical and recent trends and debate emerging issues. In this context, tendencies towards groupthink can arise. By expanding and diversifying the number of individuals involved in gathering expert opinion, including experts working in various capacities within the broader field of demography, the assumption-building process becomes more rigorous and transparent. It is our belief that the use of a formal expert elicitation improves the credibility of resulting projection assumptions.

While offering many benefits, the practice of eliciting expert views is also subject to numerous challenges, mostly related to the limitations of human estimation abilities. While expert judgments are valuable, being that they come from humans, they are susceptible to numerous heuristic devices that can create biases which impact both the reliability and validity of their estimations (Tversky and Kahneman 1974; Morgan and Henrion 1990; Hoffman et al. 1995; Kynn 2008; Lutz et al. 1998; Martin et al. 2011). The main types of bias that can hinder expert elicitation are *anchoring bias* (estimates are anchored to a natural starting point or benchmark and as a result, don't vary much from it) and *availability bias* (the estimated probability of an event is based on familiarity/cognitive availability rather than objective frequency). Numerous other factors can also impact elicitation exercises, including plain misinterpretation on the part of the respondent and phenomena as ephemeral as the respondent's mood or level of fatigue at the time of the elicitation (Grigore et al. 2017; Knol et al. 2010; Runge et al. 2011). Motivational biases, such as the desire to maintain or elevate their public image through the display of high confidence, can also arise among individuals considered to be leading experts in their field (Runge et al. 2011).

Furthermore, it has been found that humans, whether expert or not, have difficulty estimating probability, or constructing probability distributions, a task often requested of them in expert elicitation (Morgan and Henrion 1990; Lee 1998; Kynn 2008; Garthwaite et al. 2005). Lutz et al. (1998) and Lee (1998) both question whether experts can reasonably be expected to distinguish between values demarking the 85th versus 95th percentile, for example, as they are often called upon to do in elicitation exercises, noting that such estimations create a false sense of precision. Experts also tend to be overconfident in their judgments, regardless of elicitation technique, which can result in a systematic underestimation of uncertainty (Martin et al. 2011; Burgman et al. 2006; Speirs-Bridge et al. 2010; Goldstein and Rothschild 2014).

In sum, the use of expert elicitation is not without its challenges. The judgments of experts may be biased, unreliable, poorly calibrated or poorly communicated. As a result, expert elicitation should not be considered a precise science (Gosling 2014). Nevertheless, building projections requires that some form of expert judgment be made—whether on the choice of method or the assumptions about each projection component. The use of expert elicitation, when used with knowledge of its limitations, permits an enriched assumption-building process, particularly with regard to the treatment of uncertainty. Expert elicitation also provides a means of explicitly formalizing the contribution of experts in the assumption-building process.

New context, new goals for our elicitation protocol

Designing an elicitation protocol requires a balancing act: on one hand, we want to provide a pleasant, relatively undemanding elicitation experience for the respondent; on the other hand, we want to ensure that we capture his or her true belief to the greatest extent possible (Sperber et al. 2013). As seen in the preceding section, there has been much research completed on the challenges associated with expert elicitation. There have also been numerous studies completed on the best methods to counter or minimize those challenges. Readers can find comprehensive reviews of these topics in Garthwaite et al. (2005), O'Hagan et al. (2006) and Dias et al. (2018). Following our review of the science of expert elicitation, the new *2018 Survey of Experts on Future Demographic Trends* elicitation protocol implements many best practices in elicitation and several methodological innovations, permitting us to attain several new goals. These key goals for the 2018 elicitation exercise were the following.

Improved expression of uncertainty

In comparison to eliciting a single point estimate, obtaining complete probability distributions from experts allows for an expression of the uncertainty about the parameter of interest (Morris et al. 2014). Recent methodological innovations have facilitated the process of creating flexible probability density functions using only a small number of parameters elicited from experts. These innovations open up the possibility to achieve more accurate and coherent portrayals of respondent judgments about the future and could be used for the production of probabilistic demographic projections in the future (Lutz et al. 1998; Lutz and Scherbov 1998; Tuljapurkar et al. 2004).

Improved approach to the aggregation of individual responses components

After eliciting the views of numerous experts, it is necessary to combine their views in some manner. A benefit of using probability distributions to quantify experts' beliefs is that, for each demographic component, the individual distributions can be combined in such a way that the aggregate result is also a probability distribution. This provides a statistically coherent expression of aggregate beliefs and, within a deterministic framework, allows for the use of different summary statistics – such as select quantiles of the aggregate distribution, for example – to derive projection assumptions. Such a technique can also be utilized within a probabilistic framework, since a single representative probability distribution is required for each of the components.

Visual feedback via a graphical user interface

It has been suggested that providing visual representations of experts' quantitative judgments can greatly aid in the elicitation process, allowing the expert to assess, confirm or revise their judgments if desired, thus improving their calibration and accuracy (Garthwaite et al. 2005; Kynn 2008; Speirs-Bridge et al. 2010; Morgan 2013; Goldstein and Rothschild 2014). It was therefore a priority to design the elicitation tool in a manner so as to provide the respondent an interactive graphical user interface with which they could visually assess how their estimates translated into a probability distribution. The interface is flexible enough to accommodate different types of distributions (for instance, left-or right-skewed, bounded or unbounded), allowing respondents to provide nuanced responses.

More user-friendly remote elicitation experience

In the 2013-based elicitation exercise, a survey was distributed remotely to experts in the form of a modifiable Adobe PDF document. This procedure brought challenges: some respondents did not have the required software, others had outdated versions that did not perform in the anticipated way.

For the new edition, we investigated the potential of a number of web-based survey tools, but none could incorporate the specifications we required for the elicitation tool. Instead, it was determined that the design of a MS Excel spreadsheet-based tool offered numerous benefits: the software is widely used by respondents and is easily modifiable to our custom requirements including the incorporation of a graphical user interface and the acceptance of both textual and numerical inputs.

These principal goals, combined with our current knowledge of best practices in elicitation, guided the design of the 2018 expert elicitation protocol, described in the following section.

Elicitation protocol

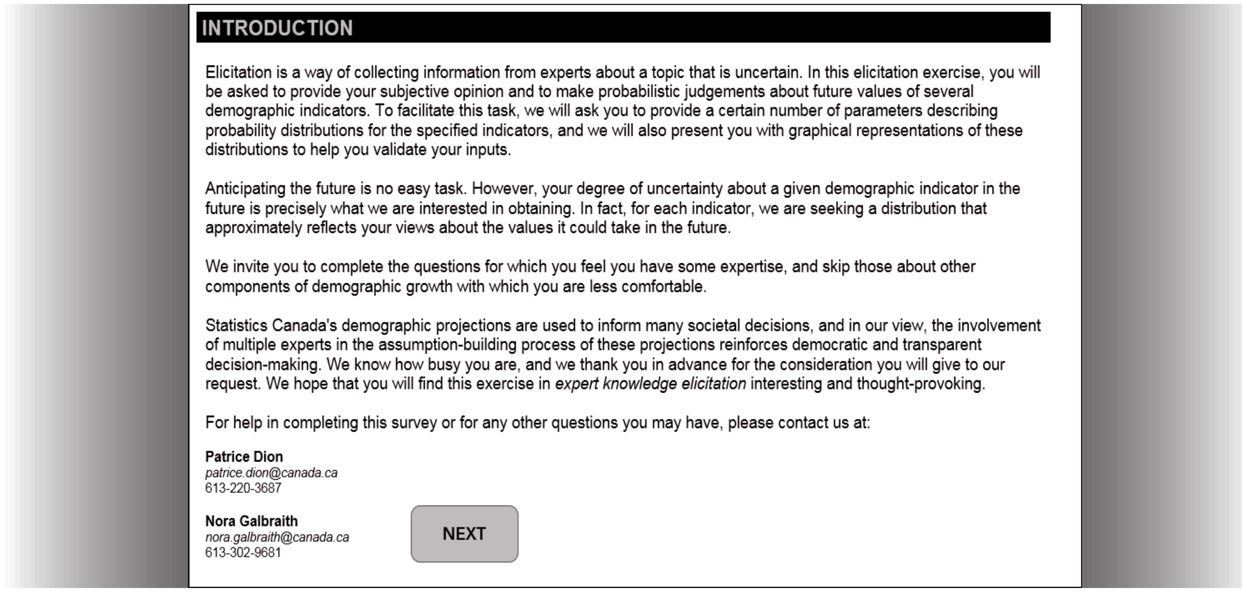
Our new elicitation protocol is inspired principally by the spreadsheet-based remote elicitation tools developed by Sperber et al. (2013) and Grigore et al. (2017). It also profits greatly from the recent development of the Metalog algorithm by Keelin (2016, 2018) which permitted us to create a graphical user interface with which the expert could review how their parameter estimates translate into a flexible continuous probability distribution.

Introduction to the survey

On opening the survey, respondents were first provided with a brief description of the task at hand (Figure 2.1). The difficulty/impossibility of predicting the future is acknowledged, and respondents are encouraged to embrace and communicate their level of uncertainty. Respondents are also instructed to skip the sections related to demographic components for which they feel they do not have sufficient expertise (Morgan and Henrion 1990; Lee 1998; Lutz et al. 1998). Finally, respondents are encouraged to contact us in the event that they had any questions or issues in completing the survey.

Following the introduction to the survey, respondents are asked several questions about their background: years of experience; level of expertise in fertility, mortality, international migration and demographic projections; and current domain of work (Figure 2.2). This information is collected for two purposes: firstly, to assess whether the group of respondents is suitably diverse (as recommended by Morgan and Henrion 1990 and Aspinall 2010, among others); and secondly, the information is used for the purpose of weighting responses during aggregation, described in more detail later.

Figure 2.1 Screenshot from the *2018 Survey of Experts on Future Demographic Trends*: Introduction



INTRODUCTION

Elicitation is a way of collecting information from experts about a topic that is uncertain. In this elicitation exercise, you will be asked to provide your subjective opinion and to make probabilistic judgements about future values of several demographic indicators. To facilitate this task, we will ask you to provide a certain number of parameters describing probability distributions for the specified indicators, and we will also present you with graphical representations of these distributions to help you validate your inputs.

Anticipating the future is no easy task. However, your degree of uncertainty about a given demographic indicator in the future is precisely what we are interested in obtaining. In fact, for each indicator, we are seeking a distribution that approximately reflects your views about the values it could take in the future.

We invite you to complete the questions for which you feel you have some expertise, and skip those about other components of demographic growth with which you are less comfortable.

Statistics Canada's demographic projections are used to inform many societal decisions, and in our view, the involvement of multiple experts in the assumption-building process of these projections reinforces democratic and transparent decision-making. We know how busy you are, and we thank you in advance for the consideration you will give to our request. We hope that you will find this exercise in *expert knowledge elicitation* interesting and thought-provoking.

For help in completing this survey or for any other questions you may have, please contact us at:

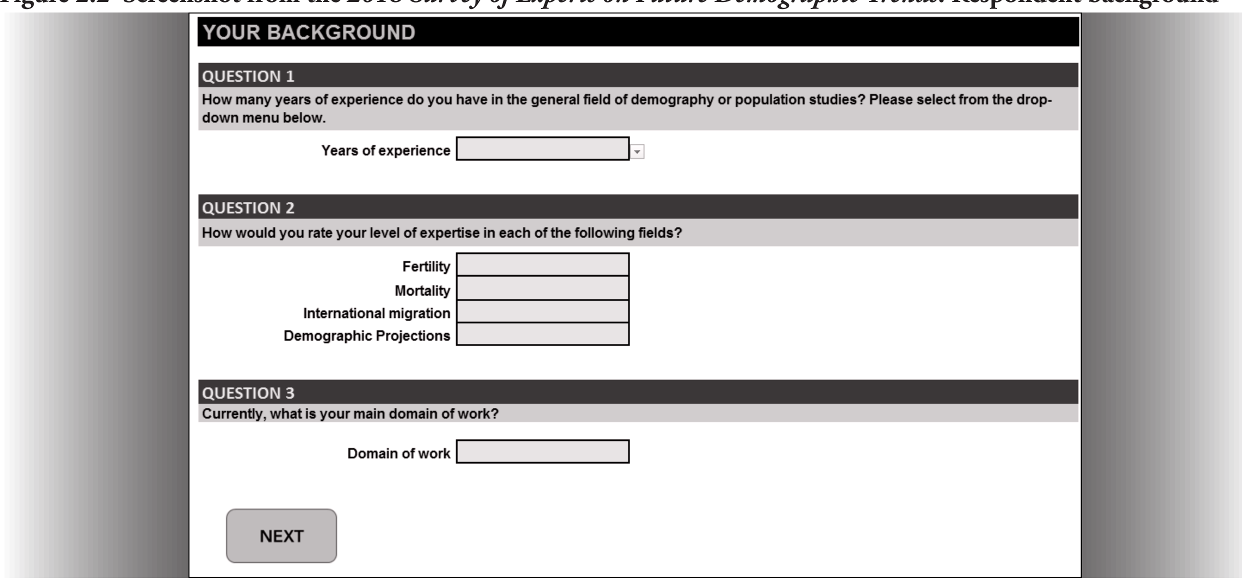
Patrice Dion
patrice.dion@canada.ca
613-220-3687

Nora Galbraith
nora.galbraith@canada.ca
613-302-9681

NEXT

Source: Statistics Canada, Demography Division.

Figure 2.2 Screenshot from the *2018 Survey of Experts on Future Demographic Trends*: Respondent background



YOUR BACKGROUND

QUESTION 1

How many years of experience do you have in the general field of demography or population studies? Please select from the drop-down menu below.

Years of experience

QUESTION 2

How would you rate your level of expertise in each of the following fields?

Fertility
Mortality
International migration
Demographic Projections

QUESTION 3

Currently, what is your main domain of work?

Domain of work

NEXT

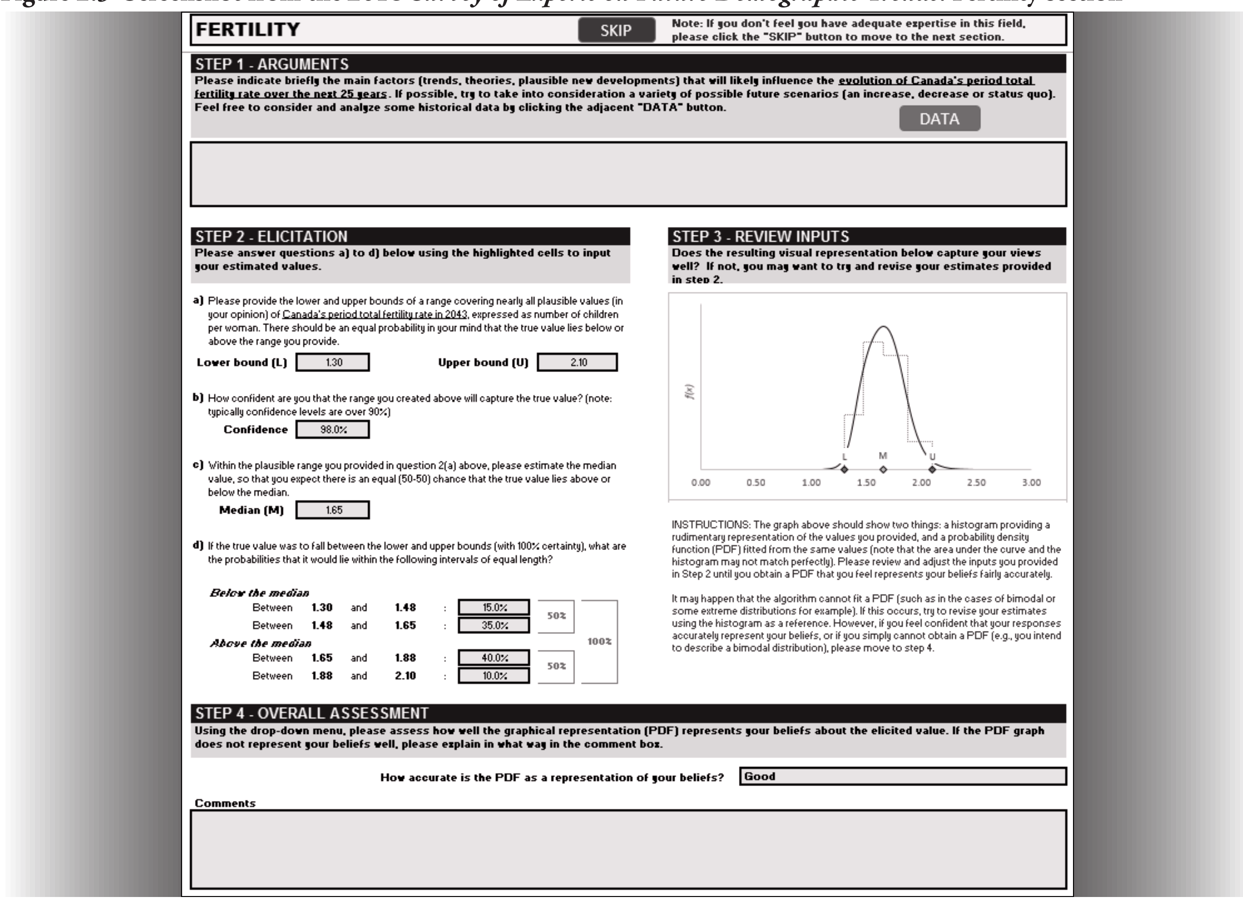
Source: Statistics Canada, Demography Division.

Eliciting probability distributions for indicators of fertility, mortality and immigration in Canada in 2043

The main part of the survey consists of the elicitation of qualitative arguments and quantitative estimates regarding the evolution of selected indicators of fertility (period total fertility rate), mortality (life expectancy at birth for males and for females) and immigration (number of immigrants per thousand population) in Canada in 2043.[8] We describe the process using the fertility component as an example. Figure 2.3 provides a screen shot from the tool, showing the various steps of the elicitation procedure for the fertility section.

In Step 1, we ask for qualitative arguments that are likely to influence the future path of the total fertility rate in Canada between now and 2043. For this task, experts can consult a series of tables and figures showing historical trends for various fertility indicators. Experts are invited to think about a variety of possible future scenarios (increase, decrease, status quo) when formulating their arguments. Besides providing critical information for putting into context their later quantitative estimates, this procedure is recommended as it encourages experts to think about the substantive details of their judgements and consider a whole range of possibilities, thus reducing potential overconfidence (Morgan and Henrion 1990; Kadane and Wolfson 1998; Garthwaite et al. 2005; Kynn 2008).

Figure 2.3 Screenshot from the *2018 Survey of Experts on Future Demographic Trends*: Fertility section



Source: Statistics Canada, Demography Division.

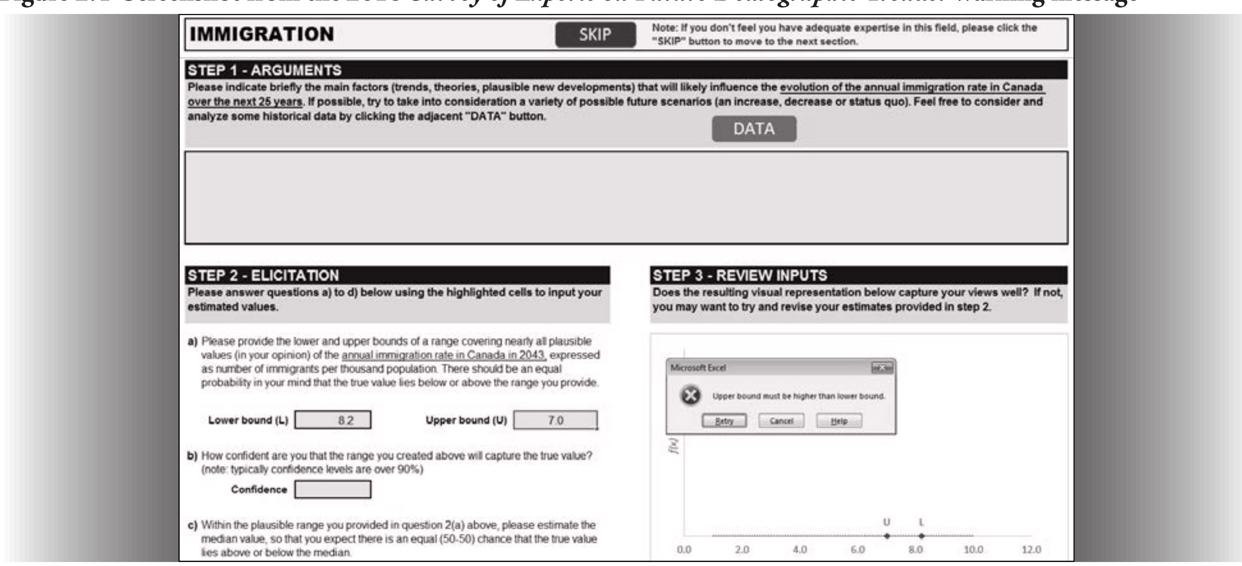
8. The year 2043 was chosen as the target year since it represented the final year in the eventual projection of the provinces and territories (while Canada as a whole will be projected for 50 years, up to 2068). Having a target year 25 years in the future was also deemed to be a good point of balance, forcing experts to think past the short-term evolutions which are likely to follow recent trends, but not so far into the future as to be inconceivable (i.e., we do not ask experts to predict the major demographic behaviors of generations not yet born at the time of the survey).

Step 2 is modeled in large part by the step-based procedures utilized by Speirs-Bridge et al. (2010), Sperber et al. (2013) and Grigore et al. (2017).

- In Step 2(a), experts were first asked to provide the lower and higher bounds of a range covering nearly all plausible[9] values of the period total fertility rate in Canada in 2043. This is an intentional practice used to minimize potential overconfidence (Speirs-Bridge et al. 2010; Sperber et al. 2013; Oakley and O'Hagan 2016; Grigore et al. 2017; Hanea et al. 2018). Indeed, asking experts to first provide a single central estimate such as a mean or a median tends to could trigger *anchoring* to that value in subsequent responses.
- In Step 2(b), experts were then asked to report how confident they are that the true value will fall within the range they just specified. Allowing experts to determine their own level of confidence has been found to reduce overconfidence in comparison with asking them to identify the low and high bounds of an interval to some pre-determined confidence level (Speirs-Bridge et al. 2010). That said, we impose the restriction that the respondent must choose a confidence level of at least 90% or higher; experts are asked to revise their range if they are confident at a level less than 90%.[10]
- In Step 2(c), experts are asked to estimate the median value of the plausible range they provided in Step 2(a), so that they expect an equal (50-50) chance that the true value lies above or below the median.
- In Step 2(d), the range of values between the lower bound and the median is split in two segments of equal length and the same is done for values between the median and the upper bound. The respondent is then asked to assign to each segment the probability that the true value falls within each of these segments. Note that each half below and above the median has by definition 50% probability of occurrence, so it is a matter of redistributing that 50% to each segment.[11]

Throughout Step 2, several "checks", in the form of pop-up warning signs, were built into the elicitation tool in order to prevent illogical inputs in various forms (Figure 2.4 provides an example in the case where a respondent provides an upper bound estimate that is lower than their lower bound estimate). This is following best practices in remote elicitation (Sperber et al. 2013; Grigore et al. 2017).

Figure 2.4 Screenshot from the *2018 Survey of Experts on Future Demographic Trends*: Warning message



Source: Statistics Canada, Demography Division.

9. The term "plausible" was arrived at after much careful consideration. As illustrated by Morgan (2013), terms such as "probable", "likely", or "possible" may be interpreted very differently by different respondents.
10. This minimum confidence level is required because at lower confidence levels, the tails of the probability distribution often become too large, making it difficult to fit and therefore graph a valid probability density function.
11. This represents the *fixed interval method*. We found in testing that it performed better than the *variable interval method* in minimizing the range-principle effect (see Parducci 1963), a problem that has been reported in other elicitation tasks (e.g., Sperber et al. 2013; Gosling 2014). In comparison with the variable interval method, respondents found the task easier and more intuitive with the fixed interval method, and their responses were more plausible.

Moving next to a key and innovative feature of our protocol: in Step 3, respondents are provided with a visual representation of the parameter estimates they provided in Step 2, in the form of a histogram and probability density function.

While there have been several tools developed for the purpose of providing experts with visual representations of their estimates (see Sperber et al. 2013; Morris et al. 2014; Grigore et al. 2017), none of these existing tools fit our exact requirements, which were the following:

- The visualization can be implemented within MS Excel (in a remote elicitation setting);
- The visualization appears to the expert instantaneously upon entering their parameter estimates;
- The visualization is flexible enough to work with bounded, unbounded or semi-bounded probability distributions, left or right-skewed or otherwise 'irregular' distributional shapes.

Fortunately, Keelin (2016, 2018) recently developed a very flexible algorithm which permits the calculation of probability density functions for many possible parameter combinations (as an example, see the PDF displayed in Figure 2.2 corresponding to a fictitious respondent's parameter estimates and confidence level inputs for the total fertility rate in Canada in 2043).

The metalog distribution – short for "meta-logistic" – belongs to the larger class of Quantile-Parameterized Distributions (QPDs) developed by Keelin and Powley (2011), and refers to any continuous probability distribution that can be fully parameterized in terms of its quantiles. The appeal of using QPDs in modeling uncertainty is that modifications can be made to their quantile functions (through the addition of extra shape parameters, for example), enabling them to represent a broader range of beliefs. The quantile function of the logistic distribution (a QPD) is an example of one that can be modified with relative ease due to it being linear in its parameters.

The "meta" in metalog is a term used by Keelin to describe distributions whose original parameters have been substituted in order to incorporate a greater number of shape parameters. In theory, there is no limit to the number of shape parameters the metalog distribution can have, meaning it can be used to model distributional characteristics such as right- or left-skewness, varying levels of kurtosis, and multi-modality. However, the inclusion of additional shape parameters requires the elicitation of a greater number of quantiles. The procedure described in Step 2 is designed to elicit five quantiles, enabling the algorithm to fit unbounded metalog distributions with up to a maximum of five shape parameters. In the event that experts' inputs describe a semi-bounded or bounded distribution, log- or logit-transforms are applied to the metalog quantile function, respectively, in order to restrict its range accordingly.

Despite being highly flexible, there can be instances where our version of the metalog algorithm (having a maximum of 5 shape parameters) is unable to compute a probability density function given the inputs provided. This can occur for example if an expert envisions a largely bimodal probability density function. For this reason, a rudimentary histogram is also presented to the expert which, despite not showing the tails of the distribution, still reflects in a crude manner the inputs of experts, allowing them to recognize any possible mistake they may have made, or possible biases they may have fell into. When a probability density function cannot be computed, experts are informed and instructed to go to the next step if they nevertheless feel comfortable with their inputs.[12]

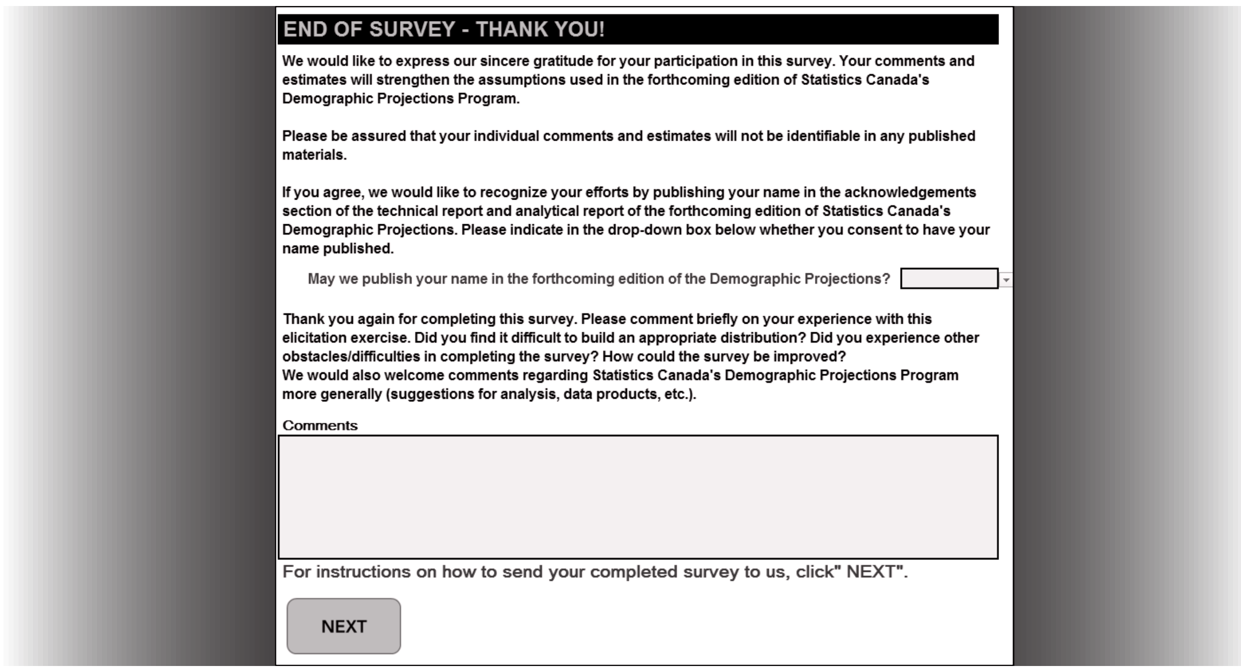
Once experts have reviewed the graphed densities and are satisfied with their inputs, they are invited to comment on the results in Step 4. They are also asked to indicate to what extent the resulting PDF represents an accurate description of their beliefs (i.e., very accurate, good, poor). Lastly, experts who answered that the visualization of the results did not provide a coherent representation of their beliefs are asked to provide further explanation.

12. The idea is that since an infinite number of distributions could correspond to their inputs, their inputs may be faithful to their assessments of the future, even though a visual representation could not be produced. The histogram remains useful as a way to validate their inputs.

End of survey

At the end of the survey, experts are asked to confirm whether they would like their names to be acknowledged in future Statistics Canada's demographic projections products, while maintaining anonymity in their individual responses (Figure 2.5). This 'limited anonymity' has been found to be important in limiting any possible motivational biases and permitting respondents to be as unconstrained as possible in their responses (Knol et al. 2010; Morgan 2013). Finally, experts are encouraged to comment on their experience with the elicitation, as well as to provide any general comments or suggestions regarding Statistics Canada's demographic projections program. Allowing the expert to give feedback on the elicitation exercise increases the chances that their knowledge and views are captured accurately (Gosling 2014; Runge et al. 2011; Martin et al. 2011).

Figure 2.5 Screenshot from the *2018 Survey of Experts on Future Demographic Trends*: End of survey


END OF SURVEY - THANK YOU!

We would like to express our sincere gratitude for your participation in this survey. Your comments and estimates will strengthen the assumptions used in the forthcoming edition of Statistics Canada's Demographic Projections Program.

Please be assured that your individual comments and estimates will not be identifiable in any published materials.

If you agree, we would like to recognize your efforts by publishing your name in the acknowledgements section of the technical report and analytical report of the forthcoming edition of Statistics Canada's Demographic Projections. Please indicate in the drop-down box below whether you consent to have your name published.

May we publish your name in the forthcoming edition of the Demographic Projections?

Thank you again for completing this survey. Please comment briefly on your experience with this elicitation exercise. Did you find it difficult to build an appropriate distribution? Did you experience other obstacles/difficulties in completing the survey? How could the survey be improved?
We would also welcome comments regarding Statistics Canada's Demographic Projections Program more generally (suggestions for analysis, data products, etc.).

Comments

For instructions on how to send your completed survey to us, click" NEXT".

NEXT

Source: Statistics Canada, Demography Division.

Target respondents and method of recruitment

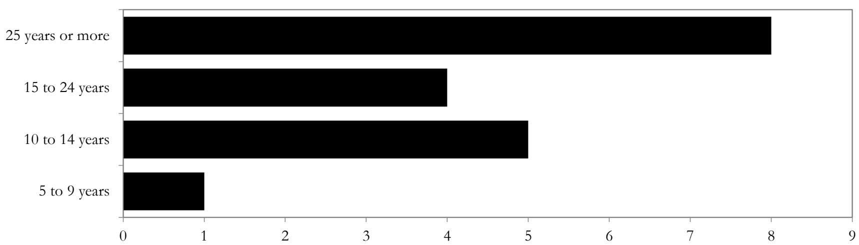
With the assistance of the council members of Canada's two demography associations, an email invitation to participate in the *2018 Survey of Experts on Future Demographic Trends* was sent to all members of the Canadian Population Society (CPS) and l'Association des démographes du Québec (ADQ). Remote elicitation greatly improves the number of potential respondents that can be accessed while keeping costs minimal. Additional personal email invitations were sent to a number of individuals with well-known expertise in fertility, mortality, immigration or demographic projections.

In the context of an elicitation on the topic of Canadian demography—a very small field of academic discipline, narrowed further by the fact that we were asking specifically about the *future*, requiring some level of familiarity with demographic projections—experts are a fairly scarce resource. That said, it has been suggested that in fact only a small number of experts—around six to fifteen—are required to obtain robust elicitation results, beyond which results should not change substantially (Hogarth 1978; Aspinall 2010; Knol et al. 2010). In total we received 18 responses to the 2018 elicitation exercise. The characteristics of the respondents are described in the next section.

Respondent characteristics

The 18 respondents to the *2018 Survey of Experts on Future Demographic Trends* were found to represent a fairly well-balanced mix of expertise (Figure 2.6), general years of experience in the field (Figure 2.7), and current domain of work (Figure 2.8). The majority of respondents (10 out of 18) reported having high levels of expertise in demographic projections.

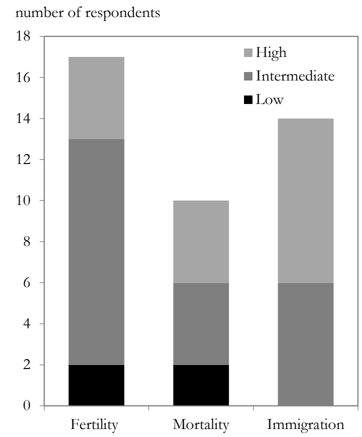
Figure 2.7 Years of experience in the field of demography among respondents to the *2018 Survey of Experts on Future Demographic Trends*



Source: Statistics Canada, Demography Division.

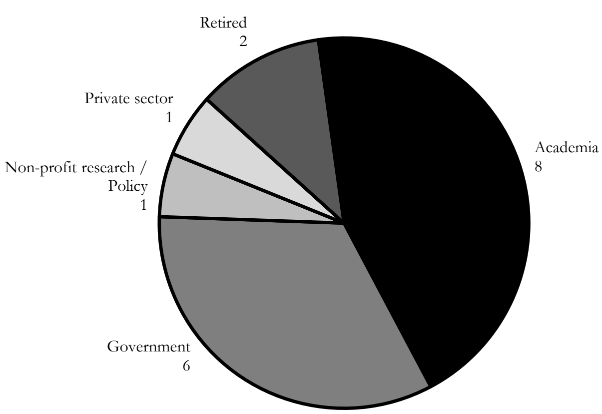
By and large, respondents reporting low or no expertise in a given component elected to skip the questions relating to that component, as was expected. While nearly all respondents completed the section on fertility, response rates were lower for the sections on immigration and particularly mortality where there were a relatively low number of respondents with self-rated high expertise (Figure 2.6).

Figure 2.6 Number of respondents for each section of the *2018 Survey of Experts on Future Demographic Trends*, according to their self-rated level of expertise in each specific field



Source: Statistics Canada, Demography Division.

Figure 2.8 Current domain of work of respondents to the *2018 Survey of Experts on Future Demographic Trends*



Source: Statistics Canada, Demography Division.

Aggregating the individual responses

The choice of aggregation method was made with the goal of capturing as much information as possible from the experts' individual beliefs (i.e. avoiding a "compromise"), while ensuring that the aggregate result is itself a valid probability distribution from which relevant summary statistics – such as the mean, median, and quantiles –can be derived. For this reason, we adopted a mixture model approach (referred to as a "linear opinion pool" when applied to the context of expert elicitation) in which the aggregate distribution for each component can be thought of as a weighted average of the individual expert distributions.

The most commonly adopted weighting scheme in mixture models is an equal-weights scheme. The aggregate distribution is then simply the arithmetic mean of the component distributions. Another commonly used scheme is to weight expert distributions based on some additional criteria, such as subject matter expertise. A scheme that assigns greater relative weight to distributions belonging to experts with more expertise has an intuitive appeal, especially in the context where we solicit a large number of experts in demography with varying levels of expertise in the areas of fertility, mortality, immigration. Moreover, some respondents considering themselves as having a low level of expertise may have accepted to answer the survey confident that they warned us and that we will take this information into consideration.

While there are good reasons to believe that experts reporting higher levels of expertise are likely to exert better judgement, past experimentations show that this is not true under all circumstances (Morgan and Henrion 1990; Tetlock 2005; Martin et al. 2011; Sperber et al. 2013). This pattern may reflect the fact that respondents familiar with the considerable challenges and 'inaccuracies' inherent to the field of demographic projections may be less confident in their ability to accurately assess the future evolution of Canada's fertility, mortality and immigration, and therefore be less prone to be overconfident.

We chose therefore to implement an additive weighting scheme that assigns weights to expert distributions based on their expertise in each of the three components and population projections, as well as their years of experience in the general field of demography. It is described as follows:

1. Experts are assigned partial weights between 1 and 4 based on whether their self-rated expertise level in the areas of fertility, mortality, and immigration is reported as "none," "low," "intermediate," or "high";[13]
2. Experts are then assigned a similar partial weight (between 1 and 4) based on their self-rated expertise in the area of demographic projections;
3. Experts are also assigned a partial weight between 1 and 5 based on their self-reported years of experience in demography or population studies: less than 5 years, 5 to 9 years, 10 to 14 years, 15 to 24 years, or 25 or more years;
4. For each component, the partial weights in (1)-(3) are then summed (and normalized) to derive the final weights assigned to each expert in the three mixture distributions.

Despite the fact that experts' responses are parametrized by metalog distributions,[14] the resulting mixture distributions for fertility, mortality, and immigration are not metalog distributions, and do not belong to any defined parametric family. Characteristics such as central moments and quantiles are derived using empirical methods.

Summaries of the survey responses and mixture distributions for each of the three components are provided in their respective chapters of this report.

13. Note that the weight for self-rated expertise in immigration is only applied to the respondent's estimates for immigration, and so on.
14. While the majority of experts provided us with inputs that could be used to fit a four- or five-parameter metalog distribution, there were a smaller number of cases in which the inputs could not be used to generate a valid metalog density function. In each of these cases, rudimentary analysis of the inputs revealed that a three-parameter metalog (which was not included in the survey algorithm) could be fit, and could reflect experts' beliefs with an acceptable degree of accuracy. For the sake of being able to include these results in the aggregation procedure, three-parameter metalog distributions were fit to the inputs prior to inclusion.

Acknowledgements

We would like to express our deep gratitude to the following experts who graciously volunteered their time to complete the *2018 Survey of Experts on Future Demographic Trends*: Roderic Beaujot, Alain Bélanger, Julien Bérard-Chagnon, Éric Caron Malenfant, Gustave Goldmann, Michael Haan, Daniel Heibert, Nan Li, Rachel Margolis, Guillaume Marois, Jean-Dominique Morency, François Nault, Doug Norris, François Pelletier, Étienne Poulin, Claudine Provencher and Luc Roy, as well as one anonymous expert.

We would also like to sincerely thank Michael Haan, President of the Canadian Population Society, Benoît Laplante, President of l'Association des démographes du Québec, and Laurent Martel, Director, Demography Division, Statistics Canada, for facilitating the recruitment of expert respondents, as well as numerous colleagues within the Demography Division who assisted us in the testing of the tool.

References

Aspinall, W. 2010. "A route to more tractable expert advice", *Nature*, volume 463, pages 294 to 295.

Bohnert, N. 2015. "Chapter 2: Opinion Survey on Future Demographic Trends", in Bohnert, N., J. Chagnon, S. Coulombe, P. Dion and L. Martel. 2015. *Population Projections for Canada (2013 to 2063), Provinces and Territories (2013 to 2038): Technical Report on Methodology and Assumptions*, Statistics Canada catalogue no. 91-620-X.

Burgman, M., F. Fidler, M. McBride, T. Walshe and B. Wintle. 2006. *Eliciting expert judgment: Literature review*, Australian Center of Excellence for Risk Analysis, round 1, project 11.

Dias, L., A. Morton and J. Quigley (editors). 2018. *Elicitation: the science and art of structuring judgment*, Springer, New York.

Garthwaite, P.H., J.B. Kadane and A. O'Hagan. 2005. "Statistical methods for eliciting probability distributions", *Technical Paper 1-2005*, Carnegie Mellon University Research Showcase.

Goldstein, D.G. and D. Rothschild. 2014. "Lay understanding of probability distributions", *Judgment and Decision Making*, volume 9, issue 1, pages 1 to 14.

Gosling, J.P. 2014. *Methods for eliciting expert opinion to inform health technology assessment*, Medical Research Council, UK.

Grigore, B., J. Peters, C. Hyde and K. Stein. 2017. "Explicit: A feasibility study of remote expert elicitation in health technology assessment", *BMC Medical Informatics and Decision Making*, volume 17, issue 131.

Hanea, A.M., M. Burgman and V. Hemming. 2018. "Chapter 5: IDEA for Uncertainty Quantification", in Dias, L., A. Morton and J. Quigley (editors). 2018. *Elicitation: the science and art of structuring judgment*, Springer, New York.

Hoffman, R.R., N.R. Shadbolt, M.A. Burton and G. Klein. 1995. "Eliciting knowledge from experts: A methodological analysis", *Organizational Behavior and Human Decision Processes*, volume 62, issue 2, pages 129 to 158.

Hogarth, R.M. 1978. "A note on aggregating opinions", *Organizational Behavior and Human Performance*, volume 21, issue 1, pages 40 to 46.

James, A., S. Low Choy and K Mengersen. 2010. "Elicitator: an expert elicitation tool for regression in ecology", *Environmental Modelling & Software*, volume 25, issue 1, pages 129 to 145.

Kadane, J. and L.J. Wolfson. 1998. "Experiences in Elicitation", *Journal of the Royal Statistical Society: Series D (The Statistician)*, volume 47, issue 1, pages 3 to 19.

Keelin, T.W. 2016. "The Metalog Distributions", *Decision Analysis*, volume 13, issue 4.

Keelin, T.W. 2018. "The Metalog Distributions – Excel workbook", http://www.metalogdistributions.com/excelworkbooks.html.

Keelin, T.W. and B.W. Powley. 2011. "Quantile-parameterized distributions", *Decision Analysis*, volume 8, issue 3, pages 206 to 219.

Knol, A.B., P. Slottje, J.P. van der Sluijs and E. Lebret. 2010. "The use of expert elicitation in environmental health impact assessment: a seven step procedure", *Environmental Health*, volume 9, issue 19.

Kynn, M. 2008. "The 'heuristics and biases' bias in expert elicitation", *Journal of the Royal Statistical Society, Series A (Statistics in Society)*, volume 171, issue 1, pages 239 to 264.

Lee, R.D. 1998. "Probabilistic approaches to population forecasting", *Population and Development Review*, volume 24, pages 156 to 190.

Lutz, W., W.C. Sanderson and S. Scherbov. 1998. "Expert-based probabilistic population projections", *Population and Development Review*, volume 24, pages 139 to 155.

Lutz, W. and S. Scherbov. 1998. "An expert-based framework for probabilistic national population projections: The example of Austria", *European Journal of Population*, volume 14, pages 1 to 17.

Martin, T.G., M.A. Burgman, F. Fidler, P.M. Kuhnert, S. Low-Choy, M. McBride and K. Mengersen. 2011. "Eliciting expert knowledge in conservation science", *Conservation Biology*, volume 26, issue 1, pages 29 to 38.

Morgan, M.G. and M. Henrion. 1990. *Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis*, Cambridge University Press.

Morgan, M.G. 2013. "Use (and abuse) of expert elicitation in support of decision making for public policy", *PNAS Perspective*, volume 111, issue 20, pages 7,176 to 7,184.

Morris, D.E., J.E. Oakley and J.A. Crowe. 2014. "A web-based tool for eliciting probability distributions from experts", *Environmental Modelling and Software*, volume 52, pages 1 to 4.

Oakley, T. and A. O'Hagan. 2016. *Shelf: the Sheffield elicitation framework (version 3.0)*, accessible at: http://www.tonyohagan.co.uk/shelf/SHELF3.html.

O'Hagan, A., C.E. Buck, A. Daneshkhah, J.R. Eiser, P.H. Garthwaite, D.J. Jenkinson, J.E. Oakley and T. Rakow. 2006. *Uncertain Judgements: Eliciting Experts' Probabilities*, Chichester, Wiley.

Parducci, A. 1963. "The Range-Frequency Compromise in Judgment", *Psychological Monographs*, volume 77, issue 2, pages 1 to 50.

Runge, M.C., S.J. Converse and J.E. Lyons. 2011. "Which uncertainty? Using expert elicitation and expected value information to design an adaptive program", *Biological Conservation*, volume 144, pages 1,214 to 1,223.

Shaw, C. 2008. "The National Population Projections Expert Advisory Group: Results from a questionnaire about future trends in fertility, mortality and migration", *Population Trends*, volume 134, pages 42 to 53.

Sperber, D., D. Mortimer, P. Lorgelly and D. Berlowitz. 2013. "An expert on every street corner? Methods for eliciting distributions in geographically dispersed opinion pools", *Value in Health*, volume 16, issue 2, pages 434 to 437.

Speirs-Bridge, A., F. Fidler, M. McBride, L. Flander, G. Cumming and M. Burgman. 2010. "Reducing overconfidence in the interval judgments of experts", *Risk Analysis*, volume 30, issue 3, pages 512 to 523.

Tetlock, P.E. 2005. *Expert Political Judgment: How Good Is It? How Can We Know?*, Princeton University Press.

Tuljapurkar, S., R.D. Lee and Q. Li. 2004. "Random scenario forecasts versus stochastic forecasts", *International Statistical Review*, volume 72, issue 2, pages 185 to 199.

Tversky, A. and D. Kahneman. 1974. "Judgment under uncertainty: heuristics and biases", *Science*, volume 185, issue 4,157, pages 1,124 to 1,131.

Chapter 3: Projection of Fertility

by Nora Galbraith, Patrice Dion and Elham Sirag

Introduction

Of all the components of population growth, fertility tends to have the largest impact on the size of the population (Kaneda and Bremner 2014). Three assumptions of fertility (low, medium and high) are created based on:

- The qualitative comments and quantitative estimates provided by the respondents of the *2018 Survey of Experts on Future Demographic Trends*;
- An examination of historical and recent trends both within and outside of Canada;
- A review of recent academic and international literature on the topic of fertility.

Fertility Trends

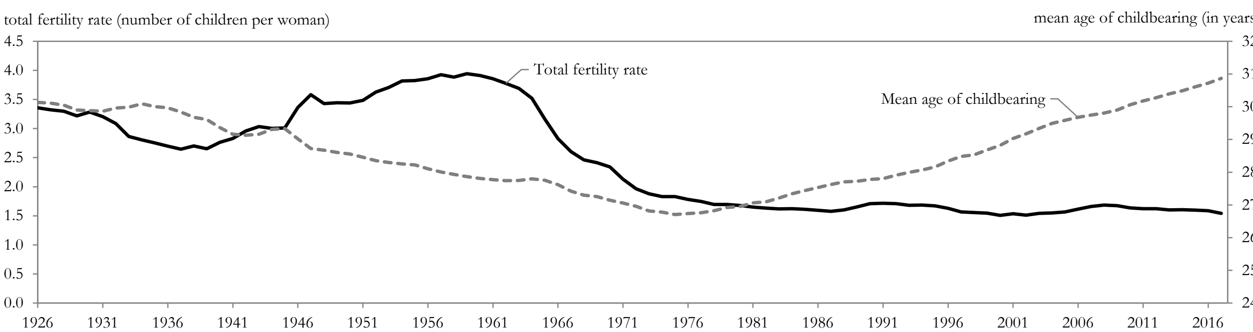
In this section, trends in Canadian fertility are examined from various perspectives: period, age, cohort, and parity, followed by a discussion.

In recent years, Canada's period total fertility rate[15] (PTFR) has been declining slowly but continuously, from 1.68 children per woman in 2009 to 1.54 in 2017—nearly the lowest level observed in Canada's history.[16] Over the same period, the mean age of women at the birth of their child has continued its long term increase, reaching 30.9 years in 2017 (Figure 3.1).

These long-term changes in the timing of births have resulted in shifts in the predominant ages of childbearing: Since 2005, women aged 30 to 34 have had higher fertility than those aged 25 to 29; since 2010, women aged 35 to 39 have had higher fertility than those aged 20 to 24 and since 2014, women aged 40 and older have had higher fertility rates than those aged 15 to 19 (Figure 3.2).

Figure 3.3 shows how the combined patterns of fertility postponement at younger ages and recuperation at older ages have modified the fertility schedule over the last 40 years in Canada. In 1977, the majority (60.2%) of all first births were to mothers aged 24 or under. By 2017, women in this age group were responsible for only one-fifth (19.7%) of all first births.

Figure 3.1 Period total fertility rate and mean age of childbearing, Canada, 1926 to 2017

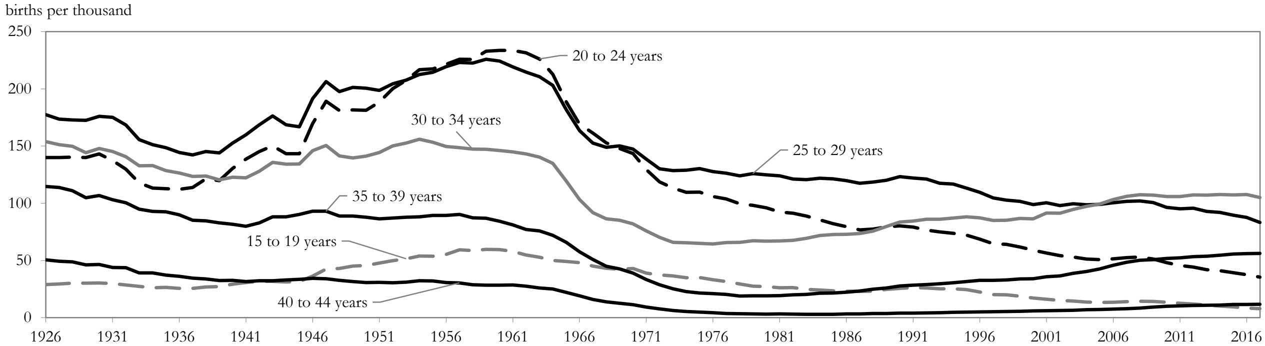


Notes: The mean age of childbearing's calculation is based on age-specific rates (and not actual number of births). The 2017 data are considered preliminary. The calculation for Canada in 2017 excludes Yukon.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 1926 to 2017, Survey 3231 and Demography Division, Demographic Estimates Program.

15. Sobotka and Lutz (2010) lament for numerous reasons the fact that the period total fertility rate (PTFR) is the most-used indicator of fertility levels and trends by policy makers. Relying on the PTFR alone can result in: misguided assumptions that fertility levels have significantly increased or decreased; an overestimation of the fertility of immigrants; and the incorrect attribution of family policies or programs to real changes in fertility when in reality they are nearly always tempo effects. Instead, to analyze average childbearing intensity in a given year, they recommend using parity progression ratios which partly reduce the distorting influence of age structure and tempo effects. In particular, age-specific parity-conditional fertility measures would provide a much better understanding of policy effects on fertility in comparison with the period total fertility rate. Unfortunately, such information cannot currently be derived from the Canadian Vital Statistics system.
16. Canada's lowest recorded PTFR was 1.51 children per woman in 2000 and 2002.

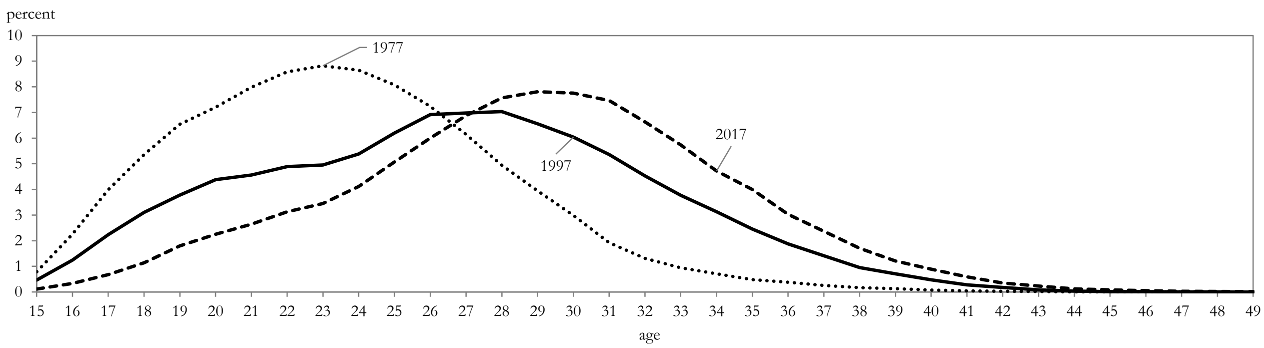
Figure 3.2 Fertility rate by age group, Canada, 1926 to 2017



Notes: Births to mothers for whom the age is unknown were prorated. The 2017 data are considered preliminary. The calculation for Canada in 2017 excludes Yukon.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 1926 to 2017, Survey 3231 and Demography Division, Demographic Estimates Program.

Figure 3.3 Distribution (percent) of first births by age of mother, Canada, 1977, 1997 and 2017



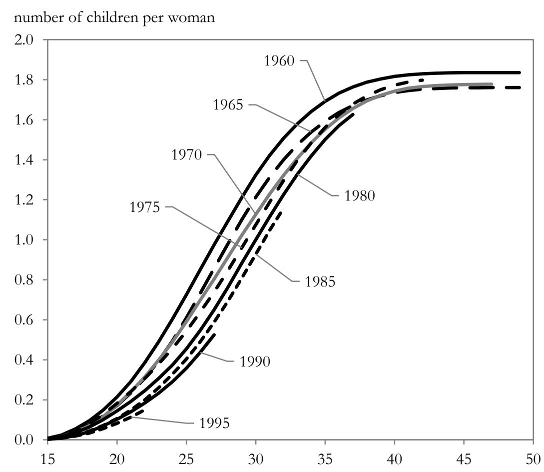
Notes: The 2017 data are considered preliminary.The calculation for Canada in 2017 excludes Yukon.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 1977 to 2017, Survey 3231 and Demography Division, Demographic Estimates Program.

Taking next a cohort perspective which reflects the completed fertility of various generations, the increasing delayment of childbearing is shown in Figure 3.4. It can be seen that the process of delayment in the 20s followed by recuperation in the 30s has evolved differently for various cohorts of Canadian women. The cohort total fertility rate (CTFR) of women born in 1970 ultimately surpassed the earlier 1965 cohort's CTFR, despite the fact that they experienced considerably lower fertility up to age 34. The same is true for the 1975 cohort of women who, with a CTFR of 1.80 children per woman by age 42, have already surpassed the fertility of the 1965 and 1970 cohorts.

In contrast with the 1975 cohort who made steep gains in their fertility in their late 30s, the 1980 cohort appears on track to end their childbearing years with a CTFR below 1.80 children per woman. They experienced considerably lower fertility in their 20s than the 1975 cohort, making it much more difficult to "catch up" to the same degree in their 30s. Similarly, the 1990 and 1995 cohorts are showing even lower fertility in their 20s to date compared to previous cohorts, making it seemingly unlikely that they will be able to recover at such intensity at later ages as to reach a CTFR of 1.80 children per woman.

Figure 3.4 Cumulated fertility rate by age, selected cohorts of Canadian women



Notes: The 2017 data are considered preliminary. The calculation for Canada in 2017 excludes Yukon.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 1926 to 2017, Survey 3231 and Demography Division, Demographic Estimates Program.

As noted by Sobotka (2017) and Billari et al. (2007), this shift in the onset of childbearing to older ages, seen across all post-demographic transition societies, represents an unprecedented change in human history. Sobotka (2017) identifies four key interrelated forces that have contributed to the current patterns of delayed, unstable and low fertility observed in many developed countries, each discussed below.

The rapid growth of postsecondary education

Educational expansion might be considered the primary force in the postponement of childbearing. Specifically, increases in the average age at leaving education have been found to explain the majority of the shift to later first-birth timing in the United Kingdom and France (Ní Bhrolcháin and Beaujouan 2012). Generally, women wait until they have completed their education until they commence childbearing, and as the share of women pursuing tertiary increases, so has the average age at which women have their first child (Bui and Cain Miller 2018; Livingston 2015). It is thought that rising education attainment increases the opportunity costs associated with childbearing for women, particularly for those in their 20s (Ní Bhrolcháin and Beaujouan 2012).

The deteriorating economic position of young adults and growth of precarious work

Deterioration in the economic and labour position of young adults in most economically advanced countries such as Canada has resulted in conditions which make it challenging to form families at these ages (Sobotka 2017). Quoting Matysiak et al. (2018, page 31): "*In many countries, an increasing number of people – the emerging class of "precariat" – are facing uncertain lives, moving in and out of low-paid "stopgap" jobs that may give little meaning to their lives…Economic uncertainty has become an intrinsic feature of the contemporary globalizing world, and the relationship between economic conditions and family dynamics is to remain a major topic of public interest in the years to come*".

The dual trends of increasing education and deteriorating economic positions of young adults have contributed in part to the fact that more and more of them are residing in the parental home, where it is less likely that they will partner and have a child of their own (Hallman et al. 2017). Billari (2018) documents the paradoxical pattern that it is in countries characterized by stronger family ties where fertility rates are lowest, whereas in societies with younger ages at leaving the parental home, fertility rates are relatively higher. He expects that the relative position of youth in lowest-low fertility societies could deteriorate further in the future as their relative demographic weight decreases and the political will to improve their lot wanes.

The rise of women's paid employment and resulting changes in gender roles

The relationship between women's labour force participation and fertility has changed over time and varies between countries and age groups. A detailed exploration of this relationship, described as "complex and inconsistent" by Brehm and Englehardt (2015, page 709), is outside the bounds of this chapter. In general however, women in their late 20s have experienced the largest decreases in fertility, likely because this is this group for whom there is the greatest level of incompatibility between labour market activity and fertility (Brehm and Englehardt 2015).

Shifts in the values attached to partnership and marriage

Along with increases in union instability, postponement of union formation and living alone, there is evidence that the proportion of women who remain childless is rising in Canada (Brauner-Otto 2016; Provencher et al. 2018). Current patterns around family formation can have a strong influence on future fertility, creating a feedback loop of corresponding changes in cultural values and norms related to having and raising children (Huinink et al. 2014; Zeman et al. 2018). The 'low fertility trap' theory posits that once fertility falls below a certain critical threshold it is unlikely to reverse course, due to a gap in aspired versus actual material situation of young people which negatively impacts their ideal family size (Lutz et al. 2006). Similar to the idea of the low fertility trap, there are theories about the role of social networks, or social contagion, on fertility patterns: the childbearing behaviour of significant others such as family members or other peers like work colleagues has the ability to affect the childbearing intentions and behaviour of individuals (Bernardi and Klarner 2014). Taken together, these theories would suggest that fertility postponement and permanent childlessness may continue to increase in the future, resulting in a decrease to some extent in the total fertility rate in Canada.

On the other hand, some scholars have suggested that a societal shift towards greater gender egalitarianism, via increased involvement of men in childcare and homemaking, could generate a reversal in trends towards higher fertility and stabilization in the quantum of childbearing (McDonald 2013; Frejka 2017). Indeed, there is some evidence that fathers' use of parental leave has a positive impact on subsequent childbearing, at least in settings with high levels of gender egalitarianism such as Norway and Sweden (Duvander and Andersson 2006; Duvander et al. 2010). Yet a recent analysis of historical data from 35 countries concludes that there is no clear pattern between female political empowerment (an indicator of gender equality) and fertility, likely due in part to within-country heterogeneity (Kolk 2019). This recent finding calls into question previous assertions about a U-shaped pattern in the relationship between gender equality and fertility, particularly in Nordic countries; Kolk finds that these countries have had sustained high fertility which predates (and therefore did not raise in response to) increasing gender egalitarianism. In the Canadian context, it remains to be seen whether there will be any sustained positive impact on fertility quantum resulting from new dedicated leave provisions for the second parent in a childbearing couple.[17]

Implications of continued fertility postponement

The steady march towards an older age profile of fertility begs the question: how much older could the average age of childbearing become, and what impact might this have on the overall level of fertility in the population? Sobotka (2017) hypothesizes that the shift to later childbearing could continue for two to three more decades, given the fact that the trends of economic instability, conjugal instability and higher postsecondary education among young adults are expected to continue. It is certainly possible that the fertility rates among women of advanced reproductive age (ages 40 and older) could increase more: Billari et al. (2007) find that the fertility rates at these ages observed recently in various countries are considerably lower than those observed prior to the demographic transition or the baby boom where applicable.

For individual women and couples, postponement is likely to result in a growing proportion who face age-related infertility and miscarriage due to the biological limits of fecundity, with negative implications resulting for their wellbeing; as noted by Billari et al. (2007), the inability to have at least one child is substantially different than underachieving one's desired fertility at higher parities. However, the potential positive impact of assisted reproductive technologies (ART) such as in vitro fertilization (IVF) on the age profile and level of fertility in Canada could improve the prospects of women of advanced reproductive age who desire a(nother) child.

With the increasing demand and use of ART, it is possible that women who choose to delay childbearing may be more likely to achieve their desired total family size. To date, however, it has been found that any impact of ART is very small (Te Velde et al. 2012) and could only have a substantive impact on the total fertility rate if used more by women at younger, not advanced, reproductive ages (Kocourkova et al. 2014; Habbema et al. 2019). Impacts of ART on fertility levels have occurred to a noticeable degree only in countries such as Denmark and Belgium which offer accessible, free treatments and which have also not demonstrated fertility postponement to the same degree as many other countries. Indeed, Billari et al. (2007) suggest that the increased availability of ART may be a double-edged sword, possibly generating false confidence in individuals about the probability of successful pregnancy at advanced reproductive ages despite the high failure rates of IVF at these ages to date.

With the increasing use of effective contraceptives, some scholars have predicted a 'rectangularization' of the age profile of childbearing; however, to date there has been little evidence of such mass concentration in the ages of childbearing (Kocourkova et al. 2014). Nor has there been any evidence of a 'rescaling' of the fertile period of women's lives, that is, an increase in the age of menopause as a response to increased life expectancy (Billari et al. 2007).

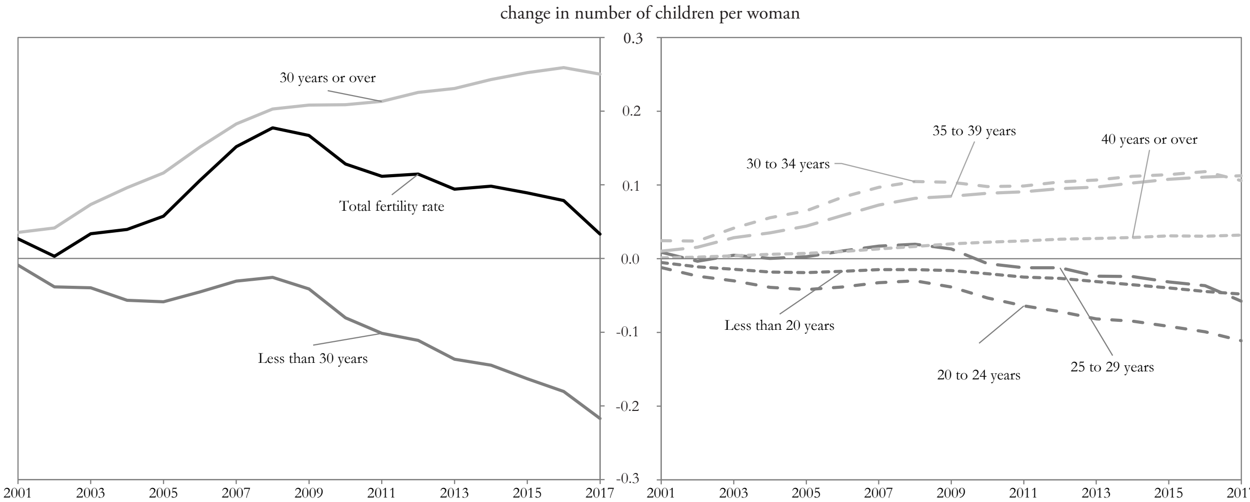
The impact of the economic climate on fertility

Fertility has generally been found to follow and react to economic cycles to a small degree, mainly through changes in the timing of childbearing rather than overall quantum (Sobotka et al. 2010). Specifically, increases in unemployment and precarious work are most likely to impact young adults, thus explaining in part the downward pressure recessions have on fertility. Additionally, highly educated women may perceive a higher opportunity cost to childbearing during recession periods, leading to their postponement of childbearing, particularly first births. For example, across industrialized countries, the pace of fertility postponement slowed in the early 2000s during a period of relatively good economic times but accelerated following the recent Great Recession (Lanzieri 2013, Matysiak et al. 2018).

17. Announced in the 2018 Canadian federal budget. The province of Quebec has had dedicated second parent leave since 2006, https://www.budget.gc.ca/2018/docs/themes/growth-croissance-en.html.

This pattern can be observed in Canada by comparing the changes in fertility rates of age groups and period total fertility rates since 2000 (Figure 3.5). Two distinct patterns of age-group-specific fertility trends can be observed over the period, one prior to the year 2008 and another post-2008. From 2000 to 2008, the fertility of women aged 30 and over increased sharply, while that of women in their late 20s was fairly stable and even slightly increased between 2005 and 2008. As a result, the total fertility rate increased over this period. After 2008, the fertility rates of women in their 30s stabilized or increased at a much slower pace. At the same time, the fertility rates of younger women (aged less than 30 years) declined sharply year-over-year from 2008 to 2017. These patterns combined to result in steady decreases in the total fertility rate from 2008 to 2017.

Figure 3.5 Change in period fertility rate for selected age groups of women and change in total period fertility rate, Canada, 2001 to 2017 compared to 2000

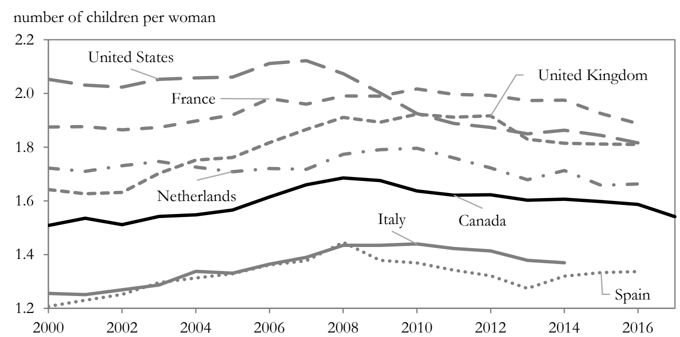


Notes: The 2017 data are considered preliminary. The calculation for Canada in 2017 excludes Yukon.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 2000 to 2017, Survey 3231 and Demography Division, Demographic Estimates Program.

Similar shifts in period fertility trends resulting from accelerated postponement behaviour have been observed in the United States, France, Spain, Italy, the United Kingdom and the Netherlands around the same time (Figure 3.6). Matsyiak et al. (2018) note that typically, such fertility reactions are for a limited time period only and are thus unlikely to impact completed fertility of cohorts unless high unemployment becomes a long-term situation. However, fertility shifts following the 2008 economic downturn appear to be fairly sustained in Canada and other countries, continuing nine years after its arrival with little sign of turnaround. Shifts in fertility have also been widespread in the sense that they have occurred among all childbearing age groups of women. As a result, it is expected that the 2008 recession will have at minimum a small negative impact on the completed fertility of women currently in the mist of the reproductive period, particularly those at more advanced ages for whom recuperation is less possible.

Figure 3.6 Period total fertility rate, selected countries, 2000 to 2017



Notes: The 2017 data are considered preliminary. The calculation for Canada in 2017 excludes Yukon.

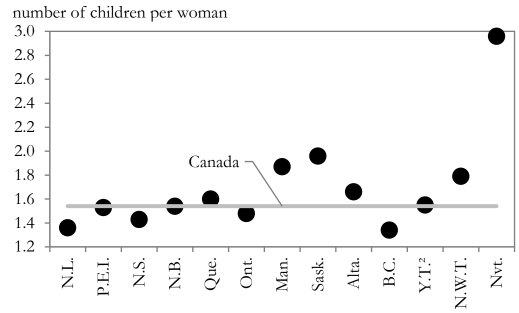
Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 2000 to 2017, Survey 3231 and Demography Division, Demographic Estimates Program. Human Fertility Database. Max Planck Institute for Demographic Research (Germany) and Vienna Institute of Demography (Austria). Available at www.humanfertility.org.

Subnational fertility trends in Canada

Differences in fertility across Canada's provinces and territories can impact the future evolution of the national portrait. For example, if one province has particularly high fertility rates, this could result in the demographic weight of the country shifting more heavily to that particular province in the coming years. This phenomenon has already been observed for Alberta in particular in recent years (Bohnert, Chagnon and Dion 2015).

The relative fertility levels of the various provinces and territories have been quite stable in recent years, and overall variation between the regions has decreased over time.[18] That said, Canada's provinces and territories do continue to demonstrate considerable differences in their fertility level, possibly reflecting the varied sociocultural and institutional settings associated with Canada's federalist political system (Beaujot and Wang 2010; Brauner-Otto 2016). As seen in Figure 3.7, fertility is higher than the national average in the Prairie provinces (Manitoba, Saskatchewan and Alberta)—often attributed to their stronger economies and more rural populations—and to a lesser extent, Quebec, where strong social welfare institutions may have contributed to a recent resurgence in period fertility rates (Brauner-Otto 2016; Moyser and Milan 2018).

Figure 3.7 Period total fertility rate, Canada, provinces and territories, 2017[1]



1. The 2017 data are considered preliminary. The calculation for Canada in 2017 excludes Yukon.
2. Data on births that occurred in Yukon or to residents of Yukon in other provinces or territories are not available for 2017. Therefore, the period total fertility rate for Yukon for 2017 is actually 2016.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 2016 and 2017, Survey 3231 and Demography Division, Demographic Estimates Program.

In turn, the provinces with some of the lowest period fertility rates—Newfoundland and Labrador, Nova Scotia—tend to register relatively high unemployment rates (Brauner-Otto 2016). Economic conditions may also contribute in part to the consistently lower fertility observed in British Columbia and Ontario: the high cost of housing in particular in the metropolitan areas of these two provinces has been linked elsewhere to lower and postponed fertility (Rindfuss et al. 2016).

As a result of these varied fertility levels across Canada's regions, the national period total fertility rate has tended to fall around 1.5 to 1.6 children per woman in recent years, making it an anomaly among economically advanced countries whom have otherwise demonstrated increasingly polarized fertility regimes. As noted by Rindfuss et al. (2016) and Brauner-Otto (2016), Canada currently stands alone between the higher-fertility regimes of Northwestern Europe, United States and Oceania (around 1.9 children per woman) and the lower fertility regimes of Central, Southern and Eastern Europe, and East and Southeast Asia (around 1.3 children per woman).

The shift to older ages of childbearing has occurred across all of the provinces and territories. In 2011, it was only in the provinces of Ontario, Alberta and British Columbia that the majority of births occurred to women aged 30 and older. By 2017, this was also the case for Newfoundland and Labrador, Nova Scotia, Prince Edward Island, Quebec and Yukon (Table 3.1).

18. For more details, see Figure 3.6 of Bohnert and Dion (2015).

Table 3.1 Distribution (percent) of births by age group of mother, Canada, provinces and territories, 2017[1]

Region	Age group of mother								
	19 years and under	20 to 24 years	25 to 29 years	30 to 34 years	35 to 39 years	40 to 44 years	45 years and over	Total	Aged 30 years and over
	percent								
Newfoundland and Labrador	3.4	15.8	29.4	33.3	15.2	2.7	0.1	100.0	51.3
Prince Edward Island	2.9	14.1	31.9	34.2	14.1	2.8	0.0	100.0	51.0
Nova Scotia	3.4	16.1	28.8	32.3	16.6	2.6	0.2	100.0	51.7
New Brunswick	3.8	20.0	31.8	29.4	12.7	2.1	0.1	100.0	44.3
Quebec	1.5	11.6	31.6	33.8	17.7	3.5	0.2	100.0	55.2
Ontario	1.7	9.7	26.3	37.5	20.3	4.2	0.3	100.0	62.3
Manitoba	4.7	16.3	29.6	31.6	14.9	2.8	0.1	100.0	49.4
Saskatchewan	4.7	15.9	32.4	31.5	13.3	2.2	0.1	100.0	47.1
Alberta	2.2	11.6	28.6	36.5	17.6	3.3	0.2	100.0	57.6
British Columbia	1.4	8.9	24.7	38.0	22.2	4.5	0.3	100.0	65.0
Yukon[2]	1.6	14.1	21.4	34.3	24.8	3.4	0.5	100.0	63.0
Northwest Territories	7.3	14.7	29.2	29.3	16.8	2.4	0.3	100.0	48.9
Nunavut	17.7	30.4	25.8	15.8	9.4	0.9	0.0	100.0	26.1
Canada[3]	2.1	11.3	28.3	35.7	18.7	3.7	0.3	100.0	58.4

1. The 2017 data are considered preliminary.
2. Data on births that occurred in Yukon or to residents of Yukon in other provinces or territories are not available for 2017. Therefore, the rates for Yukon for 2017 are actually 2016.
3. The calculations for Canada in 2017 excludes Yukon.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 2016 and 2017, Survey 3231 and Demography Division, Demographic Estimates Program.

Results of the *2018 Survey of Experts on Future Demographic Trends*[19]

In total, 17 experts provided their views on the future evolution of fertility in Canada. Experts were first asked to describe the arguments, trends or possibilities they considered when formulating their views about the probable distribution of the period total fertility rate in Canada in 2043.

By and large, experts expressed the view that in 2043, Canada's period total fertility rate is likely to remain at a level similar to those observed in recent years. This view was rooted in the observation that while there have been annual fluctuations, Canada's period total fertility rate has remained fairly stable for the last 25 years, around 1.6 to 1.7 children per woman. Experts commonly mentioned that the trends of higher educational attainment, stronger labour force attachment among women, increasing individualism, union instability as well as poorer economic integration of young adults, all contribute to the postponement in the age of childbearing observed in recent decades. In the view of many of the experts, these trends are likely to continue in the coming decades, and with continued decreasing fertility levels among women in their 20s, the extent of 'recuperation' of fertility at older ages will become limited (suggesting large increases in fertility are unlikely to occur).

Many experts remarked that within Canada, there has been a gradual improvement in the scope and generosity of policies aiming to support parents in combining paid work. That said, experts differed in their assessment of the outcome of such policies on the total fertility rate. Some thought there could be a small positive impact on fertility levels, while others felt the impact of social policies was likely to be marginal in the absence of a major initiative such as a national universal subsidized daycare system. As was noted by one expert, such a development in social policy is impossible to predict.

While several experts thought any impacts of new immigrants on the total fertility rate are likely to be minimal, others thought that given the recently-announced sizeable increases in admissions targets, there could be a short-term positive impact on fertility levels which would those new immigrant women's behaviour gradually merges with those of other Canadian women— at minimum, this could prevent the PTFR from decreasing further. Some experts mentioned that while the Indigenous population is growing, this population is unlikely to have a substantial impact on the total fertility rate due to their relatively small size and the fact that their fertility is slowly converging with the national rate.

The respondents to the survey also noted factors which could lead to a decrease in Canada's fertility rate by 2043: climate change and associated environmental deterioration could lead to increased levels of childlessness by choice, if individuals feel increased uncertainty about the future. The observed trend of rising childlessness rates was also mentioned, and its role in fostering a 'culture of low fertility' which could maintain a continued inhibiting effect.

19. For more information on the survey protocol, see Chapter 2: The *2018 Survey of Experts on Future Demographic Trends*.

Following their qualitative arguments, experts were asked to communicate their views about the likely evolution of the period total fertility rate in Canada in 2043 quantitatively; that is, by building a probability distribution that exemplified their opinion, and level of uncertainty, regarding what values the PTFR could take in 25 years. More specifically, each expert was asked to estimate the following parameters:

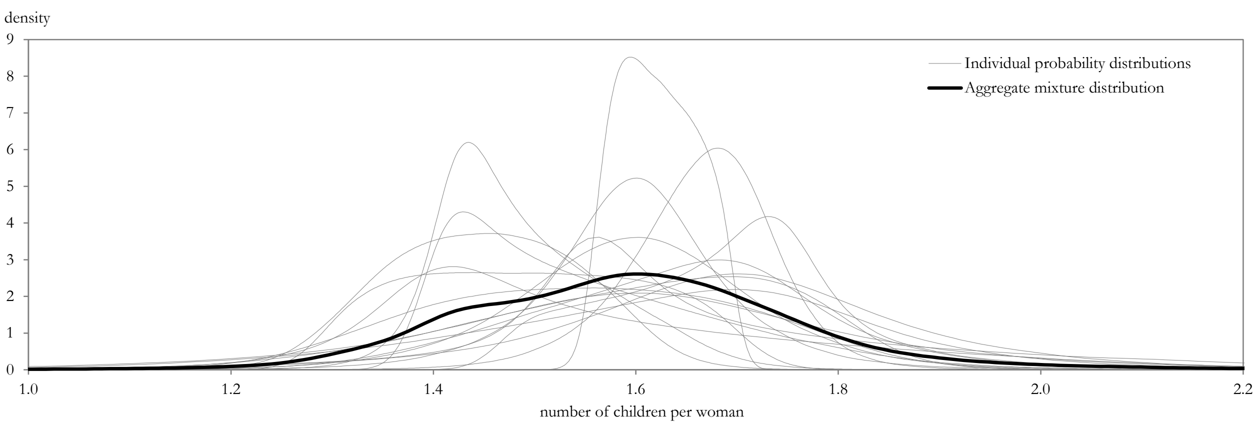
a. Lower and upper bounds of a range covering nearly all plausible values of the PTFR in Canada in 2043;
b. Their level of confidence (expressed in percent, with a minimum of 90% imposed) that the true value of the PTFR in 2043 will fall within the range specified in Step (a);
c. The median value of the plausible range provided in Step (a), such that they expect an equal (50-50) chance that the true value of the PTFR lies above or below the median;
d. Probabilities that the PTFR in 2043 will fall below and above the mid-points between:
    - the lower bound of the plausible range provided in Step (a) and the median provided in Step (c); and
    - the median provided in Step (c) and the upper bound of the plausible range provided in Step (a).[20]

Using these parameters, a visual representation of the resulting probability distribution was displayed to the experts using Keelin's (2016; 2018) metalog algorithm, and the expert was then encouraged to modify their inputs until they arrived at a satisfactory representation of their beliefs. The individual probability distributions of the 17 experts regarding their views about the probable PTFR in Canada in 2043 are displayed in Figure 3.8 (grey lines).

The experts generally constructed probability distributions which tended to fall within the bounds of the levels observed over the last several decades in Canada, though previously-unseen lower rates (below 1.50) were almost always considered to be within the realm of possibility.

The individual probability distributions of the 17 experts were aggregated via a mixture distribution,[21] the result of which is shown in the thicker black line of Figure 3.8. This aggregation resulted in an asymmetrical, nearly bimodal probability distribution, with a median of 1.59 children per woman, and the 10th and 90th percentiles of the distribution represented by 1.40 and 1.79 children per woman, respectively.

Figure 3.8 Period total fertility rate, Canada, 2043: Individual probability distributions and aggregate mixture distribution of the respondents of the *2018 Survey of Experts on Future Demographic Trends*



Source: Statistics Canada, Demography Division.

20. For each of the intervals in Step (d), the expert was asked to imagine that the entire interval sums to 50%.
21. For more information on the aggregation procedure, see Chapter 2: The *2018 Survey of Experts on Future Demographic Trends*.

Fertility assumptions and methodology

Description of method

Provincial and territorial assumptions on the PTFR were derived using the methods described in Chapter 1: General Approach to Assumption Building. Briefly, short-term trajectories of PTFR in each province and territory were obtained by extrapolating trends in the changes in age-specific fertility rates observed in the period between 2007 and 2017. Long-term trajectories were derived by applying the national PTFR targets in 2043 obtained from the *2018 Survey of Experts on Future Demographic Trends* to each of the provinces and territories proportionally. More specifically, the median of the aggregate distribution of the PTFR in 2043 was used to obtain a medium target for Canada (1.59 children per woman), the 90th percentile to obtain a high target (1.79) and the 10th percentile to obtain a low target (1.40). This corresponds to growth rates of 3.2%, 16.1%, and -9.2% in the PTFR, respectively, between 2017 (1.54) and 2043. These growth rates are then applied to each of the provinces and territories to obtain long-term low, medium, and high targets. After 2043, rates are held constant for the remainder of the projection.

The short- and long-term trajectories are combined in a manner that allows each province and territory to follow its own path in the earlier projection years, while in the long term, each experiences a growth rate between 2018 and 2043 identical to that envisioned at the Canada level by the expert survey respondents, according to each of the assumptions (low, medium, and high).

Regarding the evolution of provincial and territorial age-specific fertility rates, in the short-term, age-specific patterns are governed largely by recent historical movements in age-specific rates. Over the course of the projection, however, the age-structure eventually becomes fixed, and rates are simply scaled up or down so that the PTFR reaches the appropriate target in a given year for the remaining years of the projection. This ensures that recent trends in the age structure of fertility are incorporated in the short-term projection horizon, but that they are not assumed to continue indefinitely. More details on the methodology to project age-specific fertility rates can be found in Chapter 1: General Approach to Assumption Building.

Assumptions

Figure 3.9 displays the observed (1990 to 2017) and projected (2018 to 2043) levels of the PTFR for each of the provinces and territories for the low, medium and high fertility assumptions. Table 3.2 also provides the observed PTFR in 2017 along with the projected rates in 2043 according to each assumption. The results demonstrate that the projected PTFR varies widely between regions; according to the medium assumption, for example, the projected PTFR in Nunavut in 2043 is approximately 3.06 children per woman, while in British Columbia, the corresponding rate is 1.38.

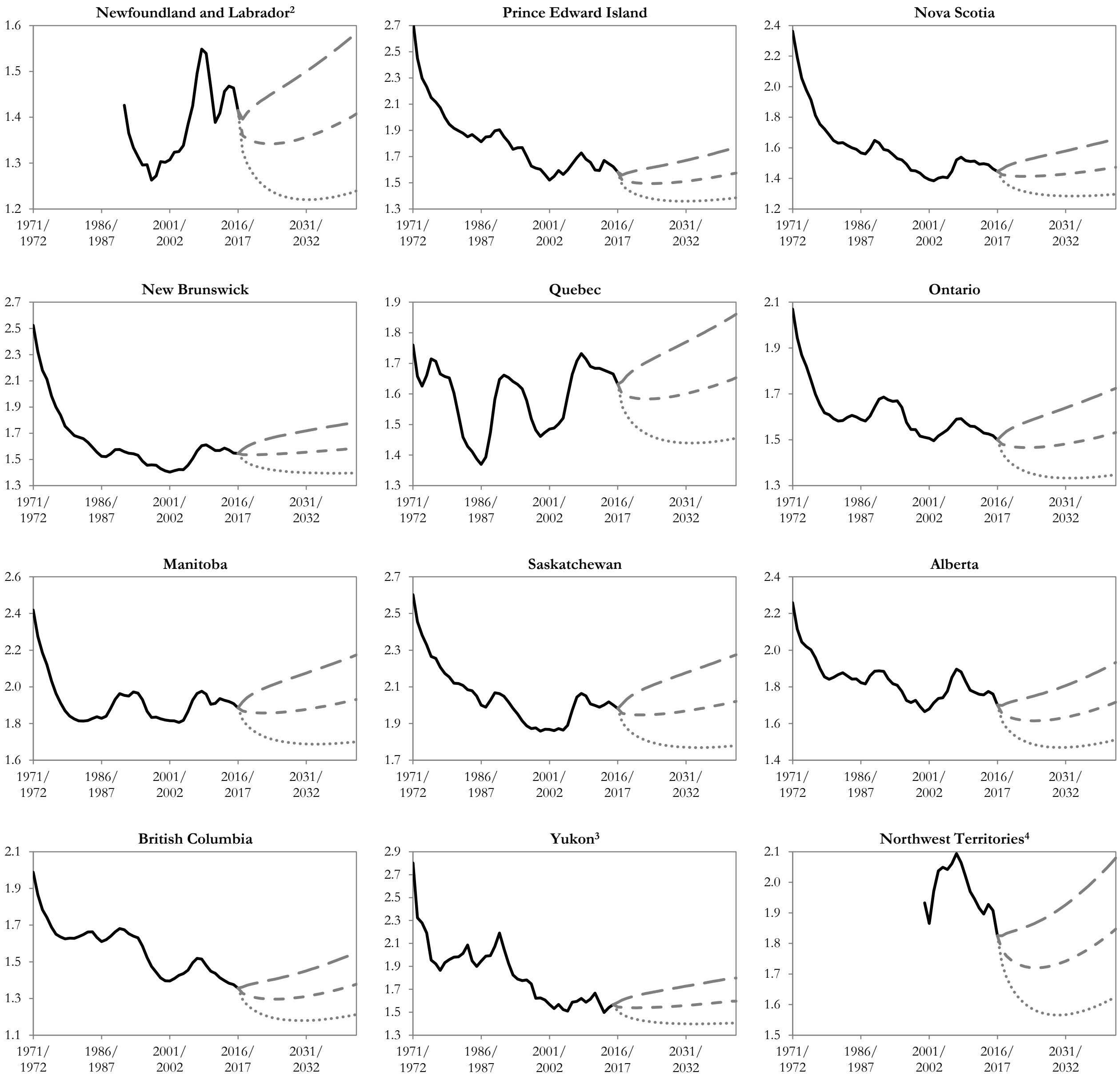
The substantial difference in level comes both from allowing provincial and territorial trends to continue in the initial projection years and from formulating targets in terms of growth rates equivalent to that of Canada's (anticipated) growth rate. Note that despite differences in the overall level of the PTFR, the way it evolves in each province and territory over the course of the projection is similar. This is the result of the logarithmic interpolation scheme used to combine short- and long- term assumptions; the low, medium, and high assumptions are all logarithmic or inverse logarithmic curves, with the low and high assumptions creating a 'fan' around the medium.

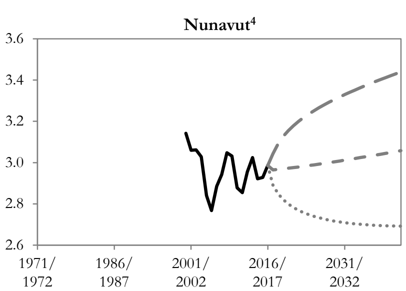
This form of interpolation approximates the typical manner in which uncertainty in projections propagates over time. That is, there is greater uncertainty in earlier projection years (resulting in a rapid widening of the bound created by the high and low assumptions), which tends to fade gradually over time due to the cumulative effect of year-to-year changes in direction.[22]

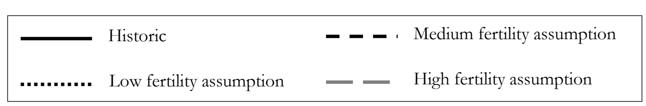
Figure 3.10 provides an example of how the projected age-specific fertility rates evolve differently over the course of the projection and uniquely for each fertility assumption. Between 2017/2018 and 2030/2031(approximately), the projected age structure changes in accordance with recently observed changes in the historical age-specific fertility rates (i.e., postponement or shifting of the predominant ages of childbearing to older ages). From 2030/2031 onwards, the age-structure remains relatively stable, and the curves simply shift vertically depending on the target PTFR in each year. A similar pattern is observed in all of the provinces and territories.

22. For example, years of increases followed by consecutive years of decreases, or vice versa, which results in smaller cumulative variability over the span of the entire projection.

Figure 3.9 Period total fertility rate, provinces and territories, historic (1971/1972 to 2016/2017) and projected (2017/2018 to 2042/2043) according to the low, medium and high fertility assumptions[1]







1. The 2017 data are considered preliminary.
2. Historical series for the Newfoundland and Labrador begin at 1991/1992.
3. Data on births that occurred in Yukon or to residents of Yukon in other provinces or territories are not available for 2017. Therefore, the period total fertility rate for Yukon for 2016/2017 is projected.
4. Historical series for the Northwest Territories and Nunavut begin at 2000/2001.

Note: The Y-axis is the number of children per woman.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 1971 to 2017, Survey 3231 and Demography Division.

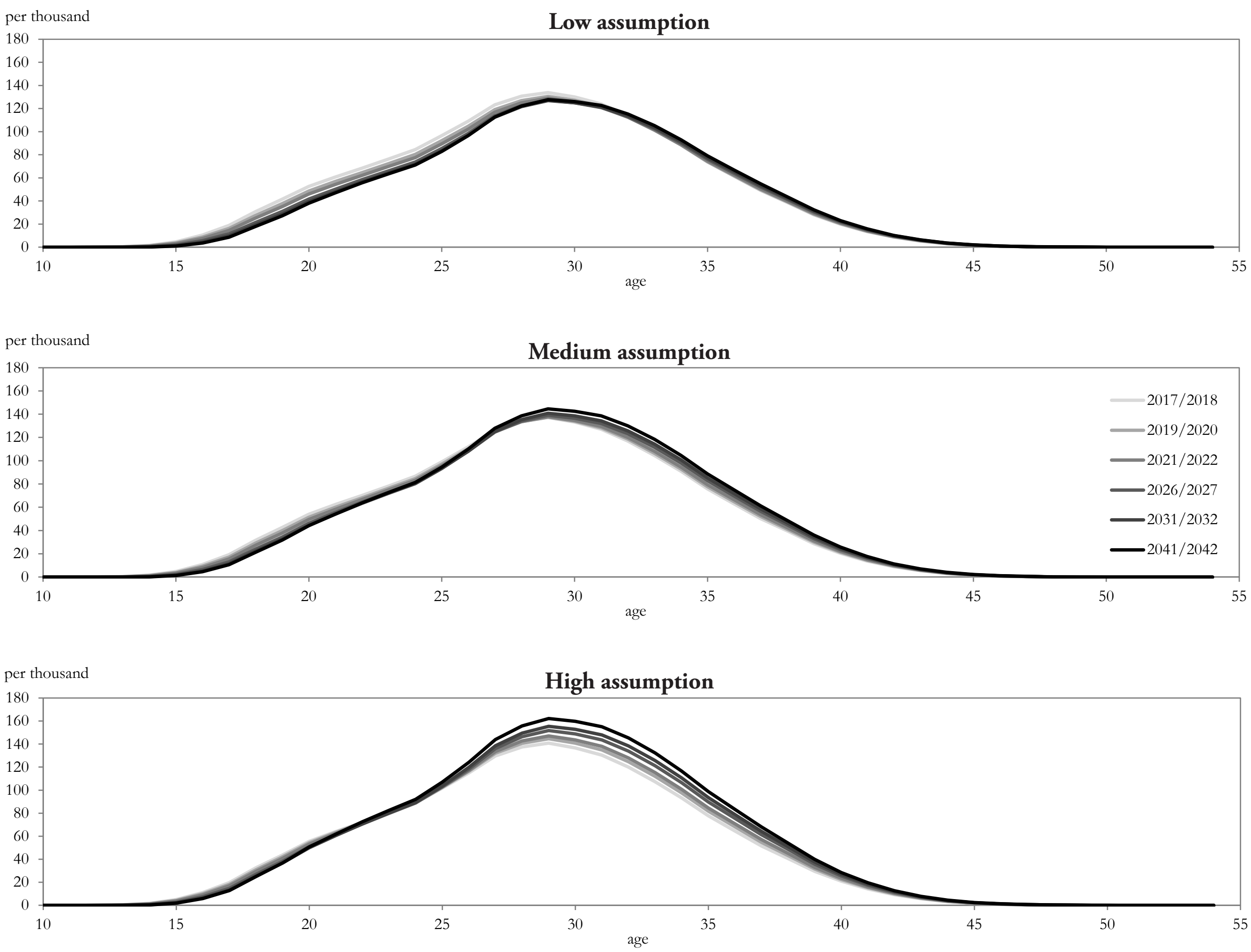
Table 3.2 Period total fertility rate, Canada, provinces and territories, historic (2017)[1] and projected (2043) according to the low, medium and high fertility assumptions

		Region													
		N.L.	P.E.I.	N.S.	N.B.	Que.	Ont.	Man.	Sask.	Alta.	B.C.	Y.T.[2]	N.W.T.	Nvt.	Can.[3]
		number of children per woman													
Historic (2017)		1.36	1.53	1.43	1.54	1.60	1.48	1.87	1.96	1.66	1.34	1.55	1.79	2.96	1.54
Projected (assumptions) (2043)	Low	1.24	1.39	1.30	1.40	1.46	1.35	1.70	1.78	1.51	1.21	1.41	1.63	2.69	1.40
	Medium	1.41	1.57	1.47	1.59	1.65	1.53	1.93	2.02	1.72	1.38	1.60	1.85	3.06	1.59
	High	1.58	1.77	1.66	1.78	1.86	1.72	2.17	2.27	1.93	1.55	1.80	2.08	3.44	1.79

1. The 2017 data are considered preliminary.
2. Data on births that occurred in Yukon or to residents of Yukon in other provinces or territories are not available for 2017. Therefore, the period total fertility rate for Yukon for 2017 is actually 2016.
3. The calculation for Canada in 2017 excludes Yukon.

Sources: Statistics Canada, Canadian Vital Statistics, Births Database, 2016 and 2017, Survey 3231 and Demography Division.

Figure 3.10 Age-specific fertility rates, Saskatchewan, low, medium and high fertility assumptions, selected projection years



Source: Statistics Canada, Demography Division.

References

Basten, S., T. Sobotka and K. Zeman. 2013. "Future fertility in low fertility countries", *Vienna Institute of Demography Working Papers*, no. 5/2013, Austrian Academy of Sciences.

Beaujot, R. and J. Wang. 2010. "Low fertility in Canada: The Nordic model in Quebec and the U.S. model in Alberta", *Canadian Studies in Population*, volume 37, issue 3-4, pages 411 to 443.

Bernardi, L. and A. Klarner. 2014. "Social networks and fertility", *Demographic Research*, volume 30, article 22, pages 641 to 670.

Billari, F.C., H.P. Kohler, G. Andersson and H. Lundstrom. 2007. "Approaching the limit: Long-term trends in late and very late fertility", *Population and Development Review*, volume 33, issue 1, pages 149 to 170.

Billari, F.C. 2018. "Chapter 2: A 'Great Divergence' in Fertility?", in D.L. Poston, Jr. (editor). 2018. *Low Fertility Regimes and Demographic and Societal Change*, Springer International Publishing.

Bohnert, N. and P. Dion. 2015. "Chapter 3: Projection of Fertility", in Bohnert, N., J. Chagnon, S. Coulombe, P. Dion and L. Martel. 2015. *Population Projections for Canada (2013 to 2063), Provinces and Territories (2013 to 2038): Technical Report on Methodology and Assumptions*, Statistics Canada catalogue no. 91-620-X.

Bohnert, N., J. Chagnon and P. Dion. 2015. *Population Projections for Canada (2013 to 2063), Provinces and Territories (2013 to 2038)*, Statistics Canada catalogue no. 91-520-X.

Brauner-Otto, S.R. 2016. "Canadian Fertility Trends and Policies: A Story of Regional Variation", in Rindfuss, R.R. and M.K. Choe (editors). 2016. *Low Fertility, Institutions and their Policies*, Springer International Publishing, pages 99 to 130.

Brehm, U. and H. Englehardt. 2015. "On the age-specific correlation between fertility and female employment: Heterogeneity over space and time in OECD countries", *Demographic Research*, volume 32, article 23, pages 691 to 722.

Bui, Q. and C. Cain Miller. 2018. "The Age That Women Have Babies: How a Gap Divides America", *The New York Times*, August 4 2018.

Duvander, A.Z., T. Lappegard and G. Andersson. 2010. "Family policy and fertility: fathers' and mothers' use of parental leave and continued childbearing in Norway and Sweden", *Journal of European Social Policy*, volume 20, issue 1, pages 45 to 57.

Duvander, A.Z and G. Andersson. 2006. "Gender Equality and Fertility in Sweden", *Marriage and Family Review*, volume 39, issue 1-2, pages 121 to 142.

Frejka, T. 2017. "The fertility transition revisited: A cohort perspective", *Comparative Population Studies*, volume 42, pages 89 to 116.

Habbema, J.D.F., M.J.C. Eijkemans, G. Nargund, G. Beets, H. Leridon and E.R. Te Velde. 2009. "The effect of in vitro fertilization on birth rates in western countries", *Human Reproduction*, volume 24, issue 6, pages 1,414 to 1,419.

Hallman, S., H. Lathe, L. Martel and F.P. Ménard. 2017. "Young adults living with their parents in Canada in 2016", *Census in Brief*, Statistics Canada catalogue no. 98-200-X2016008.

Huinink, J. and M. Kohli. 2014. "A life-course approach to fertility", *Demographic Research*, volume 30, article 45, pages 1,293 to 1,326.

Kaneda, T. and J. Bremner. 2014. "Understanding Population Projections: Assumptions Behind the Numbers", *Population Reference Bureau*, June 2014.

Keelin, T.W. 2016. "The Metalog Distributions", *Decision Analysis*, volume 13, issue 4.

Keelin, T.W. 2018. "The Metalog Distributions – Excel workbook", http://www.metalogdistributions.com/excelworkbooks.html.

Kocourkova, J., B. Burcin and T. Kucera. 2014. "Demographic relevancy of increased use of assisted reproduction in European countries", *Reproductive Health*, volume 11, issue 37.

Kolk, M. 2019. "Weak support for a U-shaped pattern between societal gender equality and fertility when comparing societies across time", *Demographic Research*, volume 40, article 2, pages 27 to 48.

Lanzieri, G. 2013. "Towards a 'baby recession' in Europe? Differential fertility trends during the economic crisis", *Eurostat Statistics in Focus*, 13/2013.

Livingston, G. 2015. "For most highly educated women, motherhood doesn't start until the 30s", *PEW Research Fact Tank*, http://www.pewresearch.org/fact-tank/2015/01/15/for-most-highly-educated-women-motherhood-doesnt-start-until-the-30s/.

Lutz, W., V. Skirbekk and M.R. Testa. 2006. "The low-fertility trap hypothesis: Forces that may lead to further postponement and fewer births in Europe", *Vienna Yearbook of Population Research*, volume 4, pages 167 to 192.

Matysiak, A., T. Sobotka and D. Vignoli. 2018. "The Great Recession and Fertility in Europe: a Sub-national Analysis", *Vienna Institute of Demography Working Papers*, 02/2018, Austrian Academy of Sciences.

McDonald, P. 2013. "Societal foundations for explaining low fertility: Gender equity", *Demographic Research*, volume 28, article 34, pages 981 to 994.

Moyser, M. and A. Milan. 2018. "Fertility rates and labour force participation among women in Quebec and Ontario", *Insights on Canadian Society*, Statistics Canada catalogue no. 75-006-X.

Ní Bhrolcháin, M. and É. Beaujouan. 2012. "Fertility postponement is largely due to rising educational enrolment", *Population Studies*, volume 66, issue 3, pages 311 to 327.

Provencher, C., A. Milan, S. Hallman and C. D'Aoust. 2018. "Fertility: Overview, 2012 to 2016", *Report on the Demographic Situation in Canada*, Statistics Canada catalogue no. 91-209-X.

Rindfuss, R.R., M.K. Choe and S.R. Brauner-Otto. 2016. "The emergence of two distinct fertility regimes in economically advanced countries", *Population Research Policy Review*, volume 35, pages 287 to 304.

Sobotka, T. 2017. "Post-transitional fertility: Childbearing postponement and the shift to low and unstable fertility levels", *Vienna Institute of Demography Working Papers*, no. 01/2017.

Sobotka, T., V. Skirbekk and D. Philipov. 2010. "Economic recession and fertility in the developed world: A literature review", *Research Note: Vienna Institute of Demography*, Austrian Academy of Sciences, European Commission, February 2010.

Te Velde, E.R., D. Habbema, H. Leridon and M. Eijkemans. 2012. "The effect of postponement of first motherhood on permanent involuntary childlessness and total fertility rate in six European countries since the 1970s", *Human Reproduction*, volume 27, issue 4, pages 1,179 to 1,183.

Zeman, K., É. Beaujouan, Z. Brzozowska et T. Sobotka. 2018. "Cohort fertility decline in low fertility countries: Decomposition using parity progression ratios", *Demographic Research*, volume 38, article 25, pages 651 to 690.

Chapter 4: Projection of Mortality

by Yu Zhang, Nora Galbraith and Patrice Dion

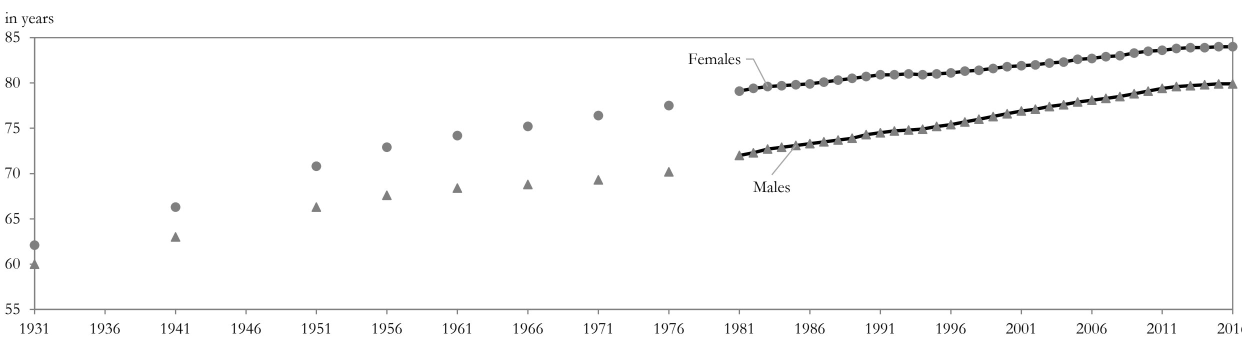
Introduction

Life expectancy at birth is one of the most commonly-used indicators of societal well-being (Mayhew and Smith 2015a; Hiam et al. 2018; Ho and Hendi 2018). The future outlook of this indicator therefore speaks volumes about the general degree of societal optimism for the coming years at the time the projections were made.

Among the components of population growth, mortality is perhaps the most pertinent for the planning of social welfare programs and public expenditures, particularly public pension and healthcare programs. As evidence of this, following a period of substantial slowdown (and one year of reversal) in the trend of life expectancy improvement in the United Kingdom, the Institute and Faculty of Actuaries recently revised its projection of life expectancy downward,[23] potentially reducing the pension liabilities estimate for the United Kingdom by billions of pounds.[24]

Unlike immigration and fertility—which tend to fluctuate up and down from year to year—life expectancy at birth in Canada has been increasing nearly unabated for both sexes since 1931 (Figure 4.1). From a broader international perspective, annual fluctuations in life expectancy resulting from specific events such as war, epidemic and economic recession have lessened in recent decades (Cardona and Bishai 2018). This near-steady progress in life expectancy would seemingly make the projection of mortality straightforward. However, as noted by Keilman (2018) and Mayhew and Smith (2015), among others, in the past, demographers have tended to underestimate future gains in life expectancy. This tendency is rooted in some cases, in the belief that there is a maximum 'ceiling' to the human lifespan (Olshansky et al. 1990) —an assertion that has been, to date, disputed by best-performance life expectancy patterns (Oeppen and Vaupel 2002). Conservatism in mortality projection assumptions also relates to the fact that the pace of life expectancy improvements have slowed considerably since the "golden age of public health"[25] during the mid-20th century (Cardona and Bishai 2018). It is also difficult to envision major technological advancements or changes in health systems which could have a fundamental impact on life expectancy (Kontis 2017), and by some accounts, any such developments are likely to have diminishing returns at best in terms of improving future life expectancy (Cardona and Bishai 2018).

Figure 4.1 Life expectancy at birth, males and females, Canada, 1931 to 2016



Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data are considered preliminary. The calculation for Canada for 2017 excludes Yukon.

Sources: From 1931 to 1976: Official life tables from Statistics Canada. From 1980 onward: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537.

23. March 1 2018. "Clear trend in lower rates of mortality improvements", Institute and Faculty of Actuaries. https://www.actuaries.org.uk/news-and-insights/media-centre/media-releases-and-statements/clear-trend-lower-rates-mortality-improvements.
24. Seekings, C. 2018. "An 'unprecedented' rise in UK deaths sees improving life expectancy stall", *The Actuary*, March 28, http://www.theactuary.com/news/2017/03/an-unprecedented-rise-in-uk-deaths-will-see-life-expectancy-fall/. The article quotes Willis Towers Watson senior consultant Stephen Caine as follows: "For some (pension) schemes about to embark on new funding negotiations, adopting CMI_2016 could cut life expectancy, and represent a reduction in liabilities of up to 2%".
25. As per page 6 of Cardona and Bishai (2018): The mid-20th century, or "golden age of public health", brought about hugely significant advances in income, education, sanitation and medicine across the world, and breakthroughs such as near-universal access to penicillin and other antibiotics.

In addition to this general uncertainty about how much further human life expectancy can rise, a recent disruption in international mortality trends has further complicated the process of developing mortality assumptions for both the short and long term future. In 2015, many countries experienced a substantial decrease in their life expectancies at birth compared to the previous year, the first incident of such widespread and substantial mortality increase in decades (Jasilionis 2018). This incident, paired with a general slowing of life expectancy improvements since 2011 in most countries, is likely to further encourage conservative tendencies regarding the future outlook of mortality improvements in many countries.

In the following section, recent trends in Canadian and international mortality are reviewed with an emphasis on emerging debates and questions regarding future life expectancy trends. For a detailed analysis of the evolution of Canadian mortality by age, sex, region and cause of death from 1921 to 2011, readers are invited to consult Bourbeau and Ouellette (2016). For more recent developments, Shumanty (2018) describes mortality trends in Canada from 2014 to 2016.

Analysis of trends

The international slowdown or reversal in life expectancy trends in 2015

Among 36 OECD countries, the majority experienced either a decrease or no change in their life expectancies at birth for females and males between 2014 and 2015 (Table 4.1). While small decreases in year-to-year life expectancy at birth have been periodically observed in some of these countries in recent decades, the changes observed between 2014 and 2015 were exceptional in terms of how widespread and substantial they were (Ho and Hendi 2018).

In most countries, the 2015 decline in life expectancy was predominantly due to respiratory-disease-related deaths at older ages, linked directly and indirectly to a particularly severe influenza season that year (Jasilionis 2018)—a phenomenon Raleigh (2018) predicts may occur again in 2018 following a long winter flu season. The declines from 2014 to 2015 were generally followed by a gain or stabilization in life expectancy from 2015 to 2016 with the exception of males in the United States and Iceland.

Canada's relatively positive trend in recent years compared to other countries may reflect to a large extent differences in measurement: Statistics Canada's official life tables are released annually but calculated using 3 years of data as opposed to a single year, making it less likely that a single atypical year of mortality trends will impact the life expectancy estimate.

Table 4.1 Change in life expectancy at birth (percent), selected countries, 2013/2014, 2014/2015 and 2015/2016

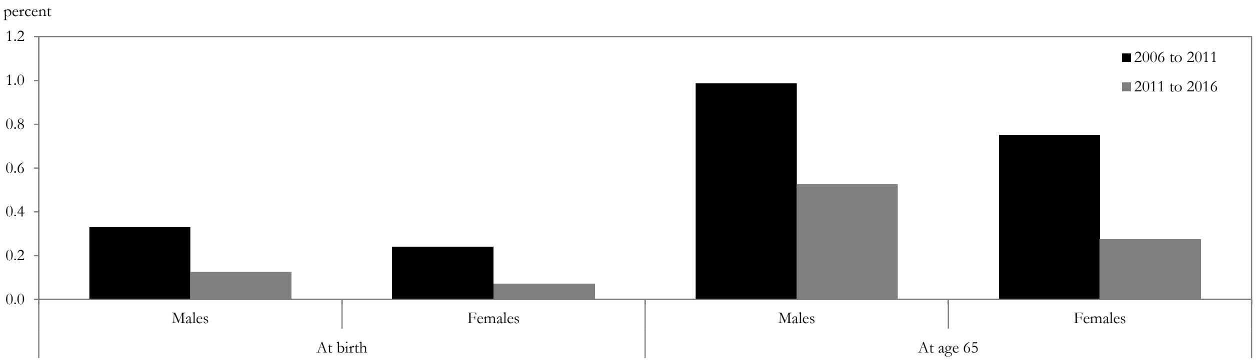
Country	Males			Females		
	2013/2014	2014/2015	2015/2016	2013/2014	2014/2015	2015/2016
	percent					
Australia	0.25	0.12	0.00	0.12	0.12	0.12
Austria	0.64	-0.38	0.63	0.24	-0.36	0.48
Belgium	0.90	-0.13	0.38	0.84	-0.60	0.72
Canada	**0.13**	**0.13**	**0.13**	**0.12**	**0.00**	**0.12**
Chile	0.26	0.39	0.00	0.12	0.24	0.00
Czech Republic	0.80	-0.13	0.53	0.86	-0.49	0.61
Denmark	0.51	0.13	0.25	0.49	-0.12	0.12
Estonia	-0.55	1.10	0.14	0.24	0.37	0.00
Finland	0.51	0.38	-0.13	0.00	0.36	0.00
France	0.63	-0.38	0.00	0.47	-0.58	0.00
Germany	0.77	-0.51	0.38	0.72	-0.60	0.48
Greece	0.13	-0.38	0.51	0.12	-0.48	0.36
Hungary	0.14	0.00	0.41	0.38	-0.50	0.89
Iceland	0.99	-0.12	-0.99	0.96	-0.83	0.36
Ireland	0.51	0.38	0.38	0.48	-0.12	0.24
Israel	0.00	-0.25	0.75	0.24	0.00	0.12
Italy	0.50	-0.50	0.87	0.47	-0.82	0.82
Japan	0.37	0.37	0.25	0.23	0.23	0.11
Korea	0.64	0.51	0.38	0.47	0.24	0.23
Latvia	-0.29	0.87	0.14	0.63	0.13	0.13
Lithuania	1.02	0.00	0.43	0.63	-0.50	0.50
Luxembourg	-0.50	0.76	0.12	1.55	-0.59	0.83
Mexico	0.56	0.28	0.41	0.13	0.26	0.13
Netherlands	0.63	-0.12	0.13	0.36	-0.36	0.00
New Zealand	0.25	0.25	0.13	0.12	0.12	0.00
Norway	0.38	0.50	0.25	0.48	0.00	0.00
Poland	0.96	-0.27	0.54	0.62	-0.12	0.49
Portugal	0.52	0.13	0.00	0.48	-0.12	0.00
Slovak Republic	0.55	-0.27	0.96	0.50	-0.37	0.62
Slovenia	1.30	-0.51	0.51	0.60	-0.24	0.48
Spain	0.25	-0.37	0.50	0.12	-0.58	0.70
Sweden	0.25	0.00	0.25	0.48	-0.12	0.00
Switzerland	0.50	-0.37	1.11	0.47	-0.35	0.59
Turkey	0.00	0.00	0.00	0.00	0.00	0.00
United Kingdom	0.38	-0.38	0.25	0.36	-0.48	0.24
United States	0.13	-0.26	-0.26	0.12	-0.25	0.00

Note: Canada's life expectancy indicators in this table refer to the last year in a three-year reference period. For example, Canada's "2015" life expectancy value in this table refers to the period 2013/2015. Elsewhere in this chapter, Canada's life expectancy periods are indicated by the central year in a 3-year reference period (that is, "2015" refers to the reference period 2014/2016).

Source: Author's calculation using data from OECD, https://stats.oecd.org/index.aspx?queryid=24879.

What is apparent is that Canada has experienced a slowdown in life expectancy gains since 2010. This slowdown has occurred for both sexes and whether examined in terms of life expectancy at birth or at age 65 (Figure 4.2). Similar slowdowns in life expectancy improvements, paired with occasional mortality surges concentrated in the older population, have been observed in many countries since 2011 (Office for National Statistics 2018; Hiam et al. 2018; Raleigh 2018). This 'parallelism' in life expectancy trends across many high-income countries has been occurring for decades, suggesting that there is no single lifestyle or public health factor driving these patterns (Leon 2011).

Figure 4.2 Average annual change (percent) in life expectancy at birth and age 65, by sex, Canada, 2006 to 2010 versus 2011 to 2016



Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data are considered preliminary. The calculation for Canada for 2017 excludes Yukon.

Source: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537.

The near-universal 'shock' to mortality trends experienced among high-income countries in 2015 has raised new questions and debates about the future direction of life expectancy in these countries. In the view of Jasilionis (2018), the fact that the advanced health care systems of high income countries were unable to adequately tackle the unanticipated influenza epidemic in 2015 should be carefully considered by projection makers, as it suggests that substantial and perhaps more long-term health crises could occur in the near future. Indeed, Green (2018, page 38) wonders if the world is beginning to transition "from an era of consistently improving population health to a new age characterised by an instability in population health largely dictated by social and political determinants of health". Yet projection-makers must also attempt to resist "availability bias"—the tendency to give the most weight in their assumption-building process to the most recently-observed trends, ignoring the long-term trend of continual gains in life expectancy (Keilman 2018). The following sections explore some of these debates.

Do the recent slowdowns in life expectancy improvement mean we are approaching the limit of the human lifespan?

While not a new debate, the turnaround in mortality experienced internationally in 2015 has reignited the debate as to the existence of a maximum 'ceiling' to human lifespan and whether humanity is quickly approaching it. Dong et al. (2016) suggest the answer to both questions is 'yes', given that the age at death of the world's oldest person has not increased since the 1990s—in their view, likely a result of fixed genetic programs for development and reproduction present in humans. Back in 1990, Olshansky et al. asserted that life expectancy at birth should not exceed 85 years in the absence of major medical breakthroughs which altered the fundamental rate of aging. Yet, despite the absence of such breakthroughs in the decade since, female life expectancy at birth in 2016 equalled or exceeded 85 years in France, Italy, Japan, Korea, Spain and Switzerland.[26]

In contrast, many researchers argue that humanity is not approaching a ceiling to life expectancy (Tuljapurkar et al. 2000; Oeppen and Vaupel 2002, 2019; Lenart and Vaupel 2017, Barbi et al. 2018). Following a period of slowdown in its life expectancy improvements, Japan—a world leader in life expectancy—has recently experienced a resurgence in the pace of its life expectancy improvement, seemingly dispelling theories that the country was approaching a limit to human lifespan (Office for National Statistics 2018). This also suggests that countries who have experienced slowdowns in improvement or even reversals in their life expectancy trend can recuperate and continue to make sizeable gains in the future.

26. See OECD. Stat, https://stats.oecd.org/index.aspx?queryid=24879.

Others argue that life expectancy should continue to increase for several decades—particularly in countries with high quality health care systems (Kontis et al. 2017)—but at a much slower pace than what was observed over the 20th century. While new technology progress and health breakthroughs related to advanced-aged conditions are nearly impossible to predict, health care systems have shifted away from a preventative approach in the mid-20th century to a more reactive, treatment-oriented approach, making further gains in life expectancy more difficult to achieve (Cardona and Bishai 2018; Jasilionis 2018).

Could life expectancy decrease in the future for a more sustained period?

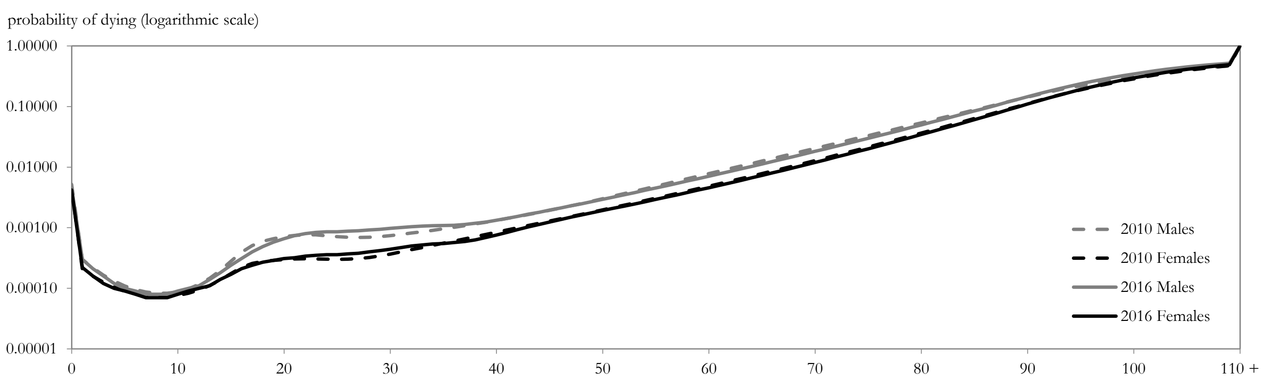
The 'shock' of 2015's life expectancy decrease in many countries has raised questions of whether life expectancy could decrease again in the future for a more sustained period. In particular, rising obesity rates and, more recently, deaths associated with drug use and overdose, might lead to decreasing life expectancies in Canada and other countries.

It is difficult to estimate the direct effects of obesity on mortality, and its impact is likely to be more important for healthy (or disability-free) life expectancy as opposed to actual life expectancy (Bourbeau and Ouellette 2016). That said, Preston et al. (2014), in an examination of the United States, conclude that any negative effects on life expectancy resulting from increasing obesity rates will be more than compensated for by simultaneous reductions in smoking. This suggests that in Canada, where obesity rates are considerably lower than in the United States,[27] obesity is unlikely to have a substantial impact on the volution of life expectancy. Yet obesity does appear to have some underlying connection with life expectancy: among OECD countries, several of those having among the lowest six rates of adult obesity in 2016 (Japan, Italy, Switzerland, Sweden, and Norway) were also among the top six countries in terms of life expectancy at birth in the same year.[28]

The role of drug use and overdose in excess mortality has become an issue of concern in the United States in particular, who has experienced a growing gap in life expectancy with other high income countries in recent years (Ho and Hendi 2018). Indeed, drug poisoning mortality, mainly related to opioid use, resulted in reduced life expectancy for the non-Hispanic white population in the United States between 2000 and 2014 (Kochanek et al. 2016; Dowell et al. 2017; Hedegaard et al. 2017; Ho and Hendi 2018).

Similar concerns have been raised about the impact of opioid-related deaths on life expectancy in Canada recently (Public Health Agency of Canada 2018). As seen in Figure 4.3, the probability of death among young adults aged 25 to 34 was slightly higher in 2015 than in 2010. Ho and Hendi (2018) find that higher relative levels of drug overdose explained in part the change in Canadian male life expectancy between 2014 and 2015. Opioid-related deaths have also been linked to the decrease in life expectancy in some provinces since 2014 (Ye et al. 2018; Statistics Canada 2019a) and to stagnation of life expectancy at birth between 2016 and 2017 (Statistics Canada 2019a).

Figure 4.3 Probabilities of dying by age and sex, Canada, 2010 and 2016



Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data are considered preliminary. The calculation for Canada for 2017 excludes Yukon.

Source: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537.

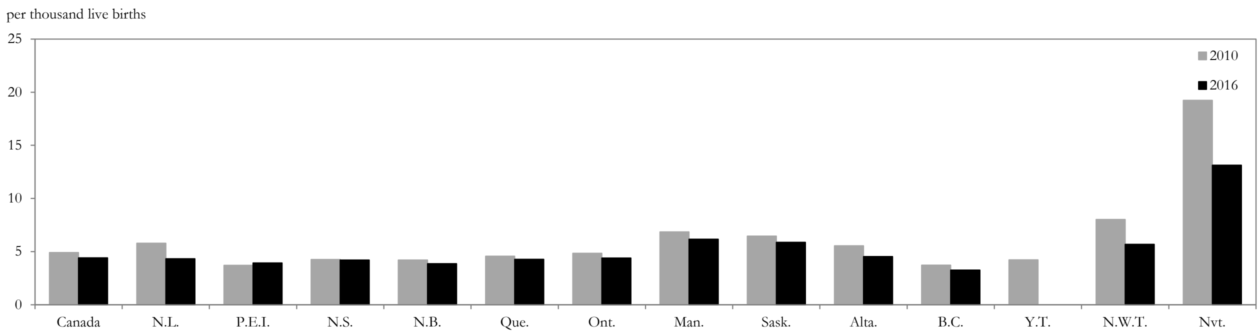
27. According to the OECD, 28% of adults in Canada were obese in 2016, compared to 40% in the United States. Source: OECD Obesity Update 2017, http://www.oecd.org/health/obesity-update.htm.
28. For more information on obesity, go to http://www.oecd.org/health/obesity-update.htm and for statistics, go to https://stats.oecd.org/index.aspx?queryid=24879, in the OECD website.

Jasilionis (2018) and Ho and Hendi (2018) note that growing societal inequality can lead to decreases in life expectancy due to the rise of so-called "deaths of despair" (suicides, accidents and drug overdose). Being the only OECD country without universal health care coverage and high and rising health inequalities, the United States is often given as an example of a country that could experience declining life expectancy in the future due to rising social inequality (Kontis 2017).

Concerns about the impact of growing societal inequality on life expectancy have also been raised in the United Kingdom recently (Bennett et al. 2015; Hiam et al. 2018; Raleigh 2018). Hiam et al. (2018) find that inequalities in life expectancy between local U.K. authorities have widened since 2010, and point to the austerity measures introduced during the period as a possible explanatory factor. Austerity measures have been found to have an overall negative impact on population health in Europe (Green 2018). However, as noted by Raleigh (2018), the slowdown in life expectancy improvements has occurred in numerous countries who did not put similar austerity measures into place, whereas the slowdowns in countries such as Greece, Spain and Portugal – whom implemented more severe austerity measures – were less than that of the United Kingdom over the same period.

In Canada, the inequality gap in life expectancy by socioeconomic status is smaller than that of most other high income countries, but there remains a large gap between the life expectancy of First Nations, Inuit and Métis Peoples and the total population (Public Health Agency of Canada 2018). This health inequality becomes apparent when examining differences in the infant mortality rate and life expectancy at birth of Nunavut (where the vast majority of the population is Inuit) and Canada's other provinces and territories (Figures 4.4 and 4.5). In recent years, the relative ranking, as well as the gap between the lowest and highest life expectancy among the provinces and territories, have been quite stable.

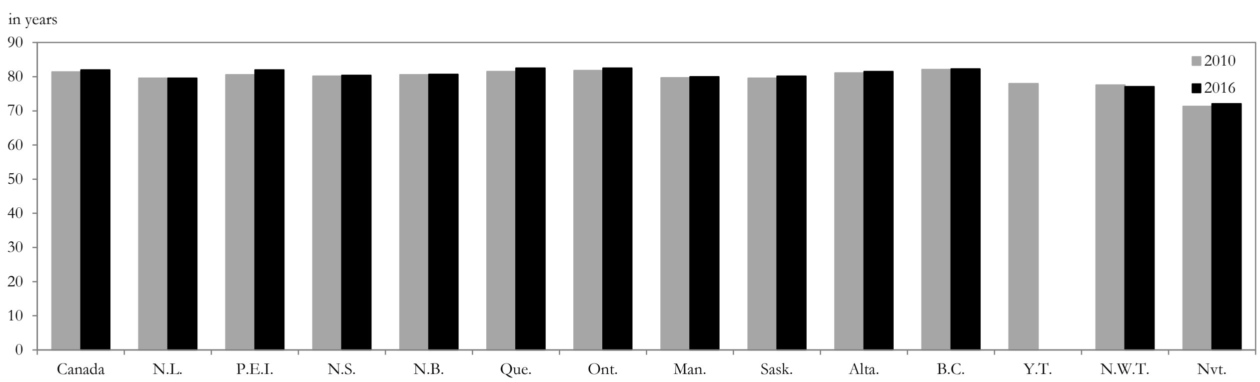
Figure 4.4 Infant mortality rate, both sexes, Canada, provinces and territories, 2010 and 2016



Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. At the time of release, death data for 2017 were not available for Yukon; therefore the infant mortality rate for Yukon for 2016 (2015/2017) could not be calculated. The 2017 data are considered preliminary.

Source: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537.

Figure 4.5 Life expectancy at birth, both sexes, Canada, provinces and territories, 2010 and 2016



Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. At the time of release, death data for 2017 were not available for Yukon; therefore life expectancy for Yukon for 2016 (2015/2017) could not be calculated. The 2017 data are considered preliminary.

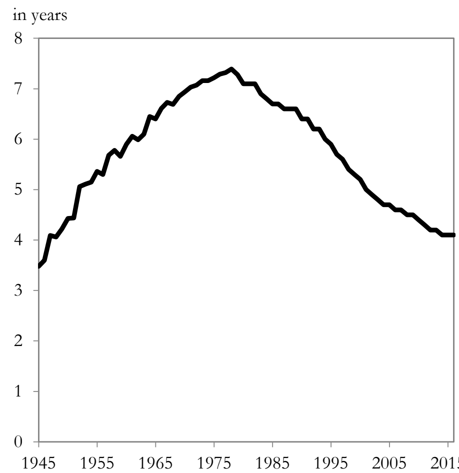
Source: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537.

How much further could the gap in female and male life expectancy close in the future?

Beyond differences in mortality by region and socioeconomic characteristics, the gap in life expectancy between the sexes has been a longstanding pattern in Canada and other countries. Following its peak in 1978 (7.4 years), the Canadian female advantage in life expectancy at birth over males decreased fairly steadily in subsequent years—though it has held constant at 4.1 years since 2014 (Figure 4.6). This decrease in the gender life expectancy gap has been attributed mainly to the fact that female lifestyle and behaviours have become more similar to those of men (Bourbeau and Ouellette 2016), a pattern observed in many countries (Mayhew and Smith 2015).

The female longevity advantage has been found to be rooted in several phenomenon, including biological, behavioural and environmental differences between men and women (Ortiz-Ospina and Beltekien 2018). However, some researchers argue that current gender differences in life expectancy from external causes and conditions such as cardiovascular disease could be minimized in the future, meaning that the female life expectancy advantage could close considerably (Bennett et al. 2015; Kontis et al. 2017). Critics of these assertions insist that the biological longevity advantage of females could not be altered to such a degree (Peters et al. 2015). To support the idea of the female biological life expectancy advantage, the mortality-morbidity paradox of "men die, women get sick"—in other words, women have lower mortality rates than men throughout their life, but women experience higher rates of physical illness, hospital stays and doctor visits than men—is often raised (Verbrugge and Wingward 1987; Kulminski et al. 2008). Conversely, this paradox may reflect societal gendered norms and not simply biological differences in robustness (Singh-Manoux et al. 2008; Ortiz-Ospina and Beltekian 2018).

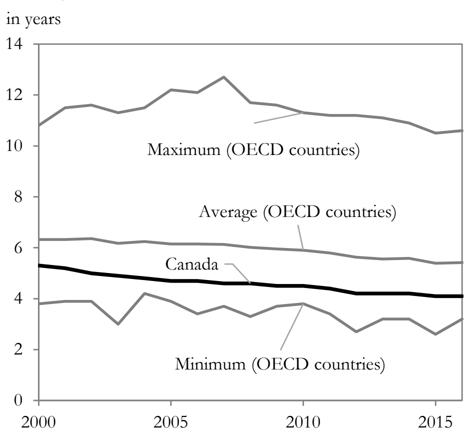
Figure 4.6 Difference (in years) between female and male life expectancy at birth, Canada, 1945 to 2016



Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data are considered preliminary. The calculation for Canada for 2017 excludes Yukon.

Sources: From 1945 to 1980: Annual life tables from the Canadian Human Mortality Database. From 1981 to 2016: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537.

Figure 4.7 Difference (in years) between female and male life expectancy at birth, OECD countries (minimum, maximum and average difference) and Canada, 2000 to 2016



Notes: For Canada, Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data for Canada are considered preliminary. The calculation for Canada for 2017 excludes Yukon.

Sources: OECD Health Stat database. https://stats-1.oecd.org/index.aspx?DatasetCode=HEALTH_STAT. For Canada: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537.

The importance of non-biological factors in the gender gap in life expectancy becomes clear when the gap is compared across countries (Figure 4.7). Among all OECD countries, female life expectancy at birth has consistently been higher than that of males since 2000. However, here is large variation in the magnitude of the gender gap: in 2015, the gap ranged from a difference as small as 2.6 years (Iceland) to as large as 10.5 years (Lithuania). Both Canada and the OECD average life expectancy gap by sex has slowly but steadily diminished since 2000, with Canada's gap being 4.1 years in 2015, less than the OECD average of 5.4 years that year. In their recent probabilistic projections which take into account uncertainty related to the choice of forecasting model,[29] Kontis et al. (2017) estimate that the female life expectancy advantage in Canada will close to approximately 3.1 years by 2030.

29. Under a Bayesian approach, the authors used an ensemble of models, of which contributed (weighted) to the final projection according to how well each predicated withheld data for each country and sex.

Results of the *2018 Survey of Experts on Future Demographic Trends*

In total, 10 Canadian demography experts provided their views on the future evolution of mortality in Canada.[30] Experts were first asked to describe the arguments, trends, theories or possibilities they considered when formulating their views about the probable distribution of the life expectancy at birth of males and females in Canada in 2043 (25 years from the time of the survey). Many experts noted the very long-term stable trend of continued increases in life expectancy at birth in Canada, and some suggested that for this reason, the use of time series models might be better suited over expert opinion for the projection of mortality specifically. The most frequently-mentioned opinion expressed by the experts was that life expectancy was expected to continue to increase but at a slower pace in the coming decades, as has been the trend in recent decades.

In terms of factors which could push life expectancy to increase at a faster pace in the coming years, technological medical advancements or breakthroughs were frequently mentioned, along with a shift in the medical focus to preventive care, healthier lifestyles (including reduction in smoking behaviour) and safer working conditions.

In contrast to the positive trends above, experts described numerous factors which could have a negative impact on life expectancy in the future, including: the opioid crisis, rising obesity rates, climate change, unforeseen catastrophes, the recent legalization of cannabis, and the legalization of medically-assisted death.

Regarding differences in life expectancy between the sexes, the experts appeared to unanimously envision continued convergence in the life expectancy of males and females in the future.

Following their qualitative arguments, experts were asked to communicate their views about the likely evolution of the life expectancy at birth of males and females in Canada in 2043 quantitatively; that is, by building a probability distribution that exemplified their opinion, and level of uncertainty, regarding what values life expectancy at birth could take in 25 years. More specifically, each expert was asked to provide the following parameters (for males and females, separately):

a. Lower and upper bounds of a range covering nearly all plausible values of life expectancy at birth in Canada in 2043;
b. Their level of confidence (expressed in percent, with a minimum of 90% imposed) that the range specified in Step (a) will contain the true value of life expectancy at birth in 2043;
c. The median value of the plausible range provided in Step (a), such that they expect an equal (50-50) chance that the true value of life expectancy at birth lies above or below the median;
d. Probabilities that life expectancy at birth in 2043 will fall below and above the mid-points between:
    - the lower bound of the plausible range provided in Step (a) and the median provided in Step (c); and
    - the median provided in Step (c) and the upper bound of the plausible range provided in Step (a).[31]

Using these parameters, a visual representation of the resulting probability distribution was displayed to the experts using Keelin's (2016; 2018) metalog algorithm, and the expert was then encouraged to modify their inputs until they arrived at a satisfactory representation of their beliefs. The individual probability distributions of the 10 experts regarding their views about the probable life expectancy at birth of males and females in Canada in 2043 are displayed in Figure 4.8 (grey lines).

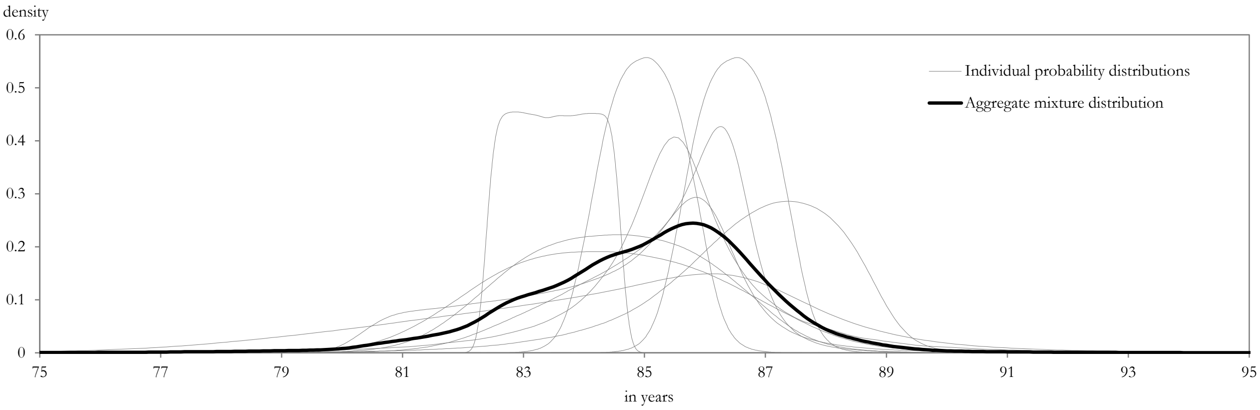
The individual probability distributions of the 10 experts were aggregated via a mixture distribution,[32] the results of which are shown in the black line of Figure 4.8. For females, this aggregation resulted in a bimodal probability distribution (one peak around 87.2 years and the other at 87.9 years), with a median life expectancy at birth of 87.5 years, and the 10th and 90th percentiles of the distribution represented by 85.4 years and 89.9 years, respectively.

For males, the aggregate probability distribution was left skewed, with a median of 85.3 years, and the 10th and 90th percentiles of the distribution represented by 82.6 years and 87.1 years, respectively.

Taken together, the median estimates for each sex would imply a gap of 2.2 years in the life expectancy at birth of females and males—nearly half its current level (4.1 years in 2016).

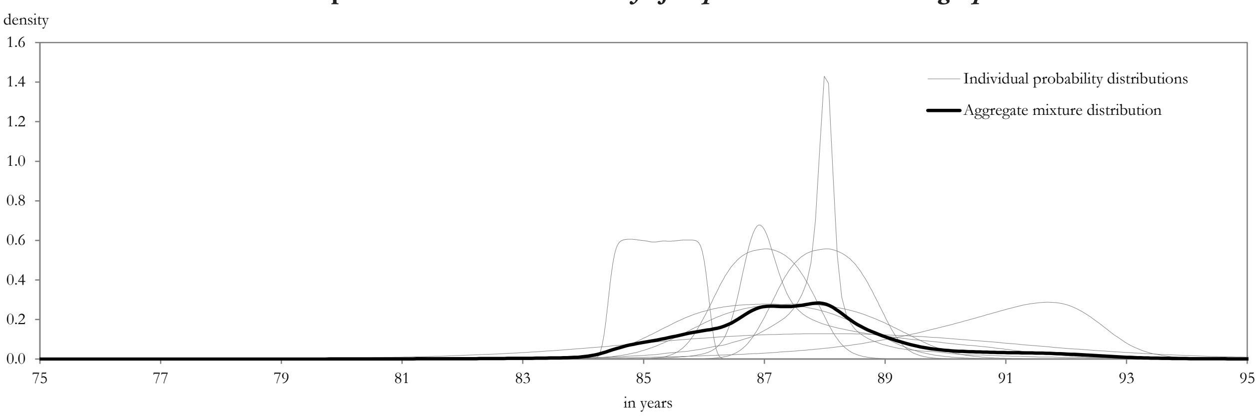
30. For more information on the survey protocol, see Chapter 2: The *2018 Survey of Experts on Future Demographic Trends*.
31. For each of the intervals in Step (d), the expert was asked to imagine that the entire interval sums to 50%.
32. For more information on the aggregation procedure, see Chapter 2: The *2018 Survey of Experts on Future Demographic Trends*.

Figure 4.8a Life expectancy at birth, males, Canada, 2043: Individual probability distributions and aggregate mixture distribution of the respondents of the *2018 Survey of Experts on Future Demographic Trends*



Source: Statistics Canada, Demography Division.

Figure 4.8b Life expectancy at birth, females, Canada, 2043: Individual probability distributions and aggregate mixture distribution of the respondents of the *2018 Survey of Experts on Future Demographic Trends*



Source: Statistics Canada, Demography Division.

Methodology

Overview

As a key part of the population projection, mortality is projected through an extrapolation process. The model was fitted using averaged life table data from 1981 to 2016.[33] As in the previous edition, the Li-Lee (2005) adaptation of the Lee-Carter (1992) method for coherent projections was used, but extended it to integrate three components: total population, population by sex, and population by sex and province/territory. These changes were made to obtain coherent results among both the sexes and the provinces/territories.

Inputs for the model are age specific death rates by province and territory, derived from the life tables recently published by Statistics Canada (2019a). Annual death rates from these life tables were computed using three-year averages, and are smoothed using splines. At old ages, death rates are extrapolated using the Kannisto method (Statistics Canada 2019b). Those methods increase the robustness of the mortality trends while also addressing the issues encountered for regions with smaller death or population counts. For the three territories and Prince Edward Island, where there was only abridged life tables available, the age specific death rates were produced using the national age structure as a standard. For Yukon, missing data for year 2017 were imputed based on the trend of change in mortality from 2014 to 2016.

33. Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, '2016' refers to the period 2015 to 2017.

Coherent Projection Methods

When projecting the mortality rates independently for groups (i.e., sex, region) of the population, the projected trends for each group tends to diverge indefinitely over time. However, it is likely that the forces influencing mortality (such as technology evolution, pollution, etc.) are affecting all groups in a similar way. This is supported by the fact that there has not been strong evidence of mortality divergence among different sexes and regions in the past. For this reason, coherent mortality projection methods were used to limit the degree of divergence among the regions and between the sexes.

The Li-Lee method provides a means to forecast coherently across groups while retaining the simplicity and robustness of the Lee-Carter method (Lee and Miller 2001; Booth 2006). In our extended model, an extra component has been added to allow coherent projection not only between the sexes, but also among each different combination of sex and region.

Estimation of parameters

In the new method, the log of age-specific mortality rates is calculated as:

$$\ln\left(m_{x,t,s,i}\right) = \mu_{x,s,i} + B_x * K_t + b_{x,s} * k_{t,s} + \beta_{x,s,i} * \kappa_{t,s,i} + \in_{x,t,s,i}$$

where *x, t, s, i*, represents the age, time, sex, and region factor, respectively. While $m_{x,t,s,i}$ is the group specific mortality rate, $\mu_{x,s,i}$ is representing the average of $\ln\left(m_{x,t,s,i}\right)$ over all the years, $B_x * K_t$ represents the common factor applied to all sexes and regions, $b_{x,s} * k_{t,s}$ is the sex specific factor applied to all regions, $\beta_{x,s,i} * \kappa_{t,s,i}$ represents the sex-region specific factor for each sex and region combination, and $\in_{x,t,s,i}$ is the random variance term. Note that the log transformation prevents getting negative mortality values.

To quantify the changes in death rate, each modelling component was decomposed into an age pattern, $B_{x(,s,i)}$, and a time pattern, $K_{t(,s,i)}$, using singular value decomposition (SVD). This dimensionality reduction technique was used to obtain the first-order vectors $B_{x(,s,i)}$ and $K_{t(,s,i)}$ with the constraints that would ensure the uniqueness of the solution: the sum of all age-specific coefficients must equal to one, and the sum of all time-specific coefficients must equal to zero.

The national level factor, $B_x * K_t$, was first obtained by decomposing a data matrix in which each element is the difference of the log of the observed age-specific mortality rates, $\ln\left(m_{x,t}\right)$, and the average of these (log) rates over the period, μ_x, using SVD. This is the common factor to each combination of sex and region. A sex-specific factor, $b_{x,s} * k_{t,s}$, was subsequently computed through decomposition of the residuals of the model containing the national factor only, calculated by $\ln\left(m_{x,s,t}\right) - \mu_{x,s} - B_x * K_t$. The resulting matrix contains only these variations that have not yet been captured by the overall national factor. Similarly, a sex- and region- specific factor, $\beta_{x,s,i} * \kappa_{t,s,i}$, was obtained by decomposition of the residuals matrix after subtracting the estimated effects in the model for both the overall national factor and the sex-specific factor.

At each level, national, sex-specific, and sex-region specific, the resulting time varying factor $K_{t(s,i)}$ were adjusted through an iteration process so that, for each year, the modelled life expectancy match those observed. The gaps are mainly due to the model fitting the logs of death rates rather than the death rates themselves. It is those adjusted time factor that are used for estimation in the subsequent step.

Forecast of the time factors

To forecast future mortality rates, the $K_{t(,s,i)}$ were extrapolated using a time series model. At the national level, the time pattern is a predictable highly linear series. A Random Walk with Drift (RWD) was used to predict future K_t values. It is calculated as:

$$K_t = K_{t-1} + d + e_t * \sigma, \quad e_t \sim N\left(0,1\right)$$

where d represents the deterministic drift term reflecting the time trend, e_t is the random walk term, and σ is a stochastic component representing the standard deviation for the random changes of K_t. Thus, the projection of the age-specific mortality rates at the overall Canada level is calculated as:

$$m_{x,t} = e^{\mu_x + B_x * K_t}$$

Sex-specific factors $K_{t,s}$, and factors for each combination of sex and region, $\kappa_{t,s,i}$, were forecast using first order auto-regressive time series (AR1) models:

$$k_{t,s} = c0_s + c1_s * k_{t-1,s} + e_{t,s} * \sigma_{t,s}, \qquad e_{t,s} \sim N(0,1)$$

and

$$\kappa_{t,s,i} = c0_{s,i} + c1_{s,i} * k_{t-1,s,i} + e_{t,s,i} * \sigma_{t,s,i}, \qquad e_{t,s,i} \sim N(0,1)$$

In the equation, $c0$ and $c1$ are model-specific means and slope coefficients specific to each group, and σ_t is the standard deviation. The model allows the sex and sex-region effects to eventually converge to a fixed mean (Li and Lee 2005). So,while the trend projected by the common factor continually evolves over the course of the projection, the specific factors eventually reach a constant level. As a result, those group-specific factors, creating distinct patterns for the mortality trend in each group, would become weaker and weaker over time, yielding a coherent projection among sexes and regions (over time, the projection for each combination of sex and region tends to reflect a common path). Thus, despite the high uncertainty surrounding future mortality levels, the coherent projection method provides a way to project a plausible portrait of anticipated differences in mortality between the sexes and between the provinces and territories in the long-term future.

Adjustments to the age patterns

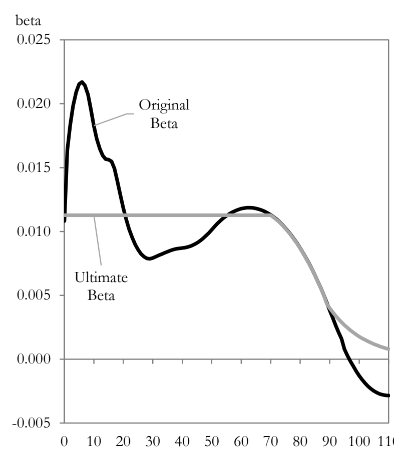
Adjustments at old ages

As a possible artifact of the life table modelling procedure for old ages, the B_x resulting from the model often yield negative values for ages 90 and over. This could change the shape of the mortality curve and cause old age mortality in the later years of the projection to be higher than those from earlier years in the projection. For this reason, an alternative series of B_x was computed using an exponential approximation of the original B_x (starting at age 80 and over), thus ensuring that all values are positive and converging towards zero as age increases. The starting age for applying this modified B_x to replace the original one was determined based on the distance between the original and the modified value to minimize the gap created. By preventing negative values in B_x, the modified age pattern avoids any cross-over for old age mortalities over the course of the projection.

Rotation of age patterns

Age-specific rates of mortality decline have been evolving over the last several decades, accelerating at older ages and slowing down at younger ages. However, it is challenging to forecast those changes -consisting of second-order differences- without strong empirical basis. In this context, Li et al. (2013) suggested as a simple prior for the future age schedule of mortality is that it should remain U-shaped. They support this assumption noting that this shape has been persistent over time, holding even in the face of large reductions in infectious diseases, and that it must be influenced by enduring evolutionary forces supporting reproductive fitness. These forces would explain, for example, why survival is relatively high at ages of sexual maturity and at ages where adults can contribute to the reproductive success of adult children. Thus, Li et al. (2013) suggested a "rotational" model of B_x that gradually reaches a smoother shape over time. After performing the rotation, the new ultimate B_x become flatter and contain less and less information on age heterogeneity, as uncertainty increases. Finally, the K_t values were iterated to ensure that the newly projected life expectancy remains the same as those before the rotation. Figure 4.9 contrasts, at Canada level, the ultimate age pattern of change, adjusted for old ages and then rotated based on methodologies from Li et al. (2013), with the original age pattern estimated from SVD.

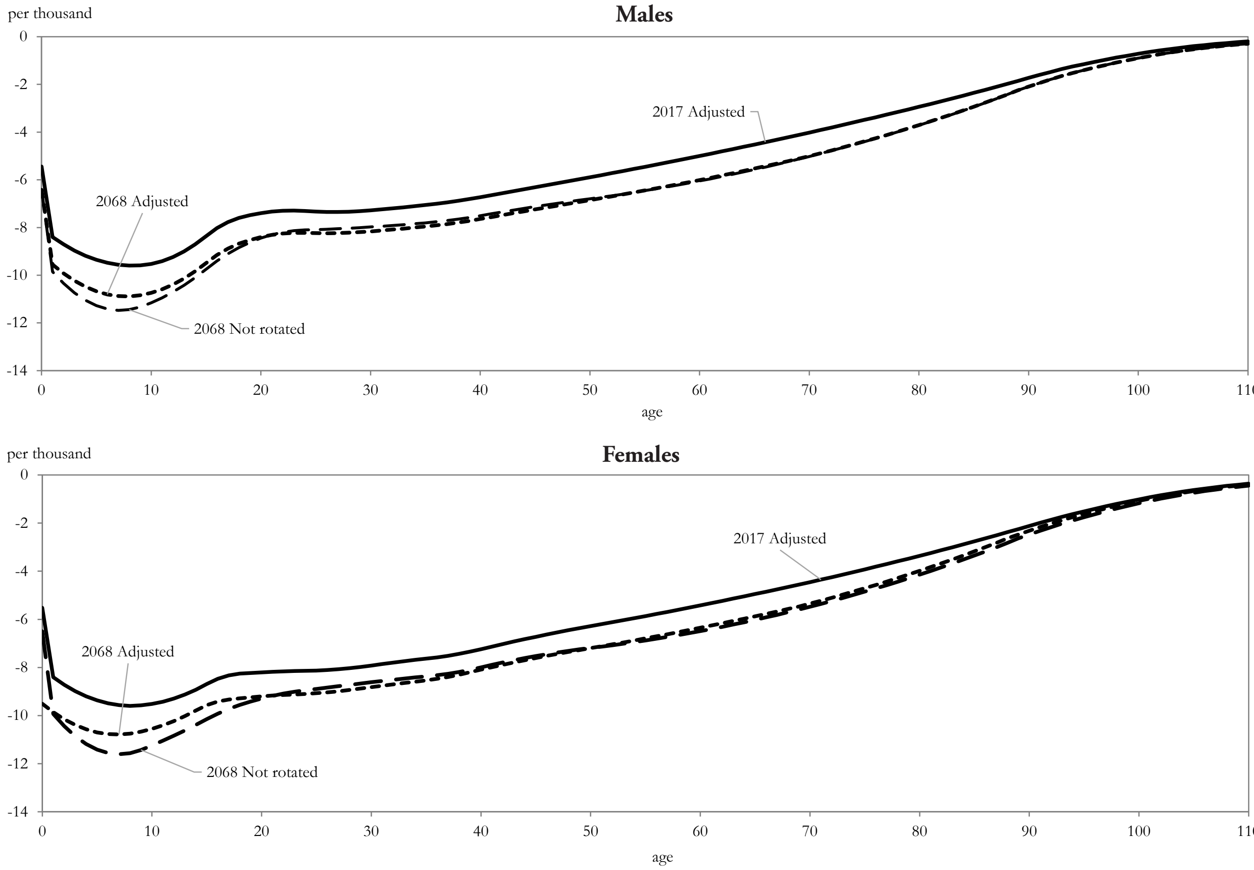
Figure 4.9 Ultimate and original age pattern of changes, Canada



Source: Statistics Canada, Demography Division.

Figure 4.10 shows the age-specific death rates for years 2017, 2043, and 2068. The dashed lines represent the projected mortality curves using the original age pattern, adjusted for old ages, and the solid lines present the curves projected with the rotational age patterns. As the forecast time horizon increases, there tends to be more and more uncertainty and variations in the projected curves. However, the rotation model smooths out those variations and better preserves the checkmark shape of the mortality rates.

Figure 4.10 Age-specific death rates, males and females, Canada, selected projected years



Source: Statistics Canada, Demography Division.

Dealing with uncertainty

An important aspect of the Lee-Carter approach is that it is a probabilistic approach, from which some measurements of uncertainty can be obtained based on statistical fitting. Indeed, alternative assumptions can be constructed using the prediction interval of K_t, obtained from the RWD forecast. However, because it contains only a limited number of parameters and excludes information from other sources, the model tends to underestimate uncertainty (D'Amato et al. 2011; Liu and Braun 2010; Koissi et al. 2006). For this reason, the assumption building process was complemented by integrating results of the *2018 Survey of Experts on Future Demographic Trends*. This was done in six steps:

1. Project life expectancy (LE) for a low and high assumption using the original Lee-Carter approach.
2. Compute low and high LE targets in 2043 for each sex at the national level using an 80% confidence band from the results of the survey.
3. Derive low and high LE targets for each province and territory based on those obtained at the national level in 2043. This was done by applying the ratio of a region's projected LE to Canada's projected LE in 2043, as both calculated in Step 1, to the new Canadian LE target computed from the survey in Step 2.
4. Interpolate the target LE from 2017 to 2042 so it gradually and smoothly reaches the newly adjusted target in 2043. The target LEs for 2043 onward were calculated by keeping the distance between the new and the original LE, from Step 1, constant and equal to those created in 2043.
5. Iterate the K_t values obtained in Step 1 so that the projection yields the LE targets computed in Step 3. Note that this stage, the original K_t vector has been transformed into 26 distinct vectors, one for each combination of sex and region.
6. Run the projections using the new iterated K_t values.

Unlike a direct forecast of life expectancy values, the Lee-Carter approach is sensitive to the distinct traits that regions may have such as their age structures and the way their mortality rates evolved in the past. For instance, regions with relatively high mortality rates at younger ages have more room for improvements at those ages and as a result, show more variation in forecasted life expectancy than other regions do. On the other hand, adjusting the results using values from the expert survey provides a wider and more reasonable level of uncertainty that is not based solely on historical data. It also offers a consistent way of handling uncertainty from one projection component to the next, since data from the survey were also used for other components of the projection such as fertility, immigration, non-permanent resident and emigration. The chosen approach combines the strength of the original Lee-Carter approach with those from using expert opinion.

Mortality assumptions

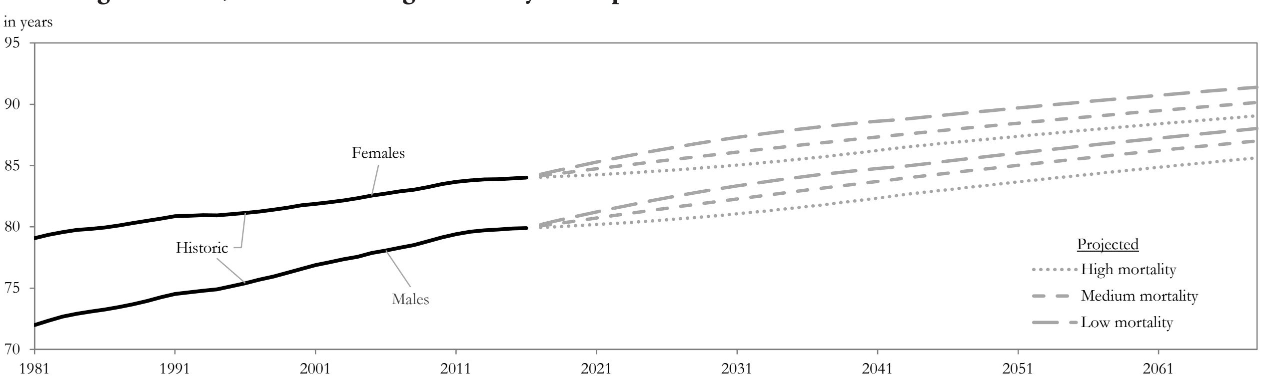
In all three mortality assumptions, life expectancy at birth for all provinces and territories and for both sexes is projected to increase, though at different rates, while the gap in life expectancy between males and females would continue to decrease. Figure 4.11 shows both observed and projected life expectancy at birth at Canada level, for males and females separately, from year 1981 to 2068.

In Canada, life expectancy at birth for males is projected to increase from 79.9 years in 2016 to 83.9 years in 2043 and 87.0 years in 2068 under the medium mortality assumption. Under the high mortality assumption, male life expectancy is projected to reach 82.6 years in 2043 and 85.6 years in 2068. In contrast, male life expectancy would reach 84.9 years in 2043 and 88.0 years in 2068 under low mortality assumption.

Female life expectancy is projected to increase from 84.0 years in 2016 to 87.5 years in 2043 and 90.1 years in 2068 under the medium mortality assumption. Under the high mortality assumption, female life expectancy would reach 86.4 in 2043 and 89.0 years in 2068, in comparison to 88.7 and 91.3 years, respectively, in the low mortality assumption. Projected life expectancies at birth by sex and province/territory for selected years according to the low, medium and high mortality assumptions are shown in tables 4.2, 4.3 and 4.4.

Globally, the projected life expectancies show distinct paths by sex and between the provinces and territories in the short-term but the divergences tend to fade over time, as a result of the coherent projection model. As a result, the projected gap in life expectancy between males and females diminish over time, but male life expectancy never surpasses female life expectancy. The same coherence is observed between the provinces and territories, meaning historical differences between the jurisdictions are maintained.[34]

Figure 4.11 Life expectancy at birth, by sex, Canada, historic (1981 to 2016) and projected (2017 to 2068) according to the low, medium and high mortality assumptions



Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data for Canada are considered preliminary. The calculation for Canada for 2017 excludes Yukon.

Source: Statistics Canada, Demography Division.

34. This holds true in the long-term, as confirmed in a projection of the mortality rates for a period of 350 years, for validation purposes. Over such a long period, the projected life expectancies of the various subgroups would cross had they been projected independently - for example, life expectancies of males would surpass life expectancies of females; this, however, does not occur in the coherent projection.

Table 4.2 Life expectancy at birth, by sex, Canada, provinces and territories, historic (1981 to 2016) and projected according to the medium mortality assumption (2017/2018 to 2067/2068), for selected years or periods

Sex / Region	1981	1986	1991	1996	2001	2006	2011	2016	2017/ 2018	2022/ 2023	2027/ 2028	2032/ 2033	2037/ 2038	2042/ 2043	2047/ 2048	2052/ 2053	2057/ 2058	2062/ 2063	2067/ 2068
	in years																		
Males																			
Canada	72.0	73.3	74.5	75.4	76.9	78.1	79.4	79.9	80.2	81.0	81.7	82.5	83.2	83.9	84.6	85.2	85.8	86.4	87.0
N.L.	71.9	72.9	73.7	74.4	75.3	75.7	77.3	77.5	77.8	78.8	79.7	80.6	81.4	82.2	83.0	83.7	84.4	85.0	85.7
P.E.I.	72.9	73.7	74.6	75.6	76.6	77.6	78.8	80.0	80.2	81.0	81.9	82.6	83.4	84.1	84.7	85.4	86.0	86.6	87.1
N.S.	71.0	72.4	73.7	74.8	76.2	76.9	78.1	78.2	78.5	79.5	80.4	81.3	82.1	82.9	83.6	84.3	85.0	85.6	86.2
N.B.	71.1	72.6	74.2	74.8	76.2	77.4	78.4	78.6	78.9	79.9	80.8	81.6	82.5	83.2	83.9	84.6	85.3	85.9	86.5
Que.	71.2	72.2	73.7	74.6	76.3	78.0	79.5	80.6	80.9	81.6	82.4	83.1	83.8	84.4	85.1	85.7	86.3	86.8	87.4
Ont.	72.4	73.7	74.9	75.8	77.3	78.5	79.8	80.4	80.6	81.4	82.2	82.9	83.7	84.4	85.0	85.7	86.3	86.8	87.4
Man.	72.3	73.3	74.6	75.2	75.6	76.7	77.8	77.9	78.2	79.2	80.1	81.0	81.8	82.6	83.4	84.1	84.8	85.5	86.1
Sask.	72.5	73.8	75.3	75.4	76.2	76.9	77.5	77.9	78.2	79.2	80.1	81.0	81.9	82.7	83.5	84.2	85.0	85.6	86.3
Alta.	72.2	73.7	75.0	75.9	77.1	77.9	79.1	79.2	79.5	80.4	81.3	82.1	82.9	83.7	84.4	85.1	85.7	86.4	86.9
B.C.	72.8	74.4	75.2	76.1	78.0	78.7	80.3	80.1	80.5	81.6	82.5	83.2	83.9	84.6	85.2	85.8	86.4	87.0	87.5
Y.T.	67.2	68.2	69.3	70.5	71.6	72.9	74.1	75.5	75.8	76.8	77.9	78.8	79.8	80.7	81.5	82.3	83.1	83.9	84.6
N.W.T.	..	..	..	..	73.0	73.7	74.5	75.2	75.5	76.6	77.7	78.6	79.6	80.5	81.4	82.2	83.0	83.7	84.4
Nvt.	..	..	..	..	67.0	68.2	69.6	71.0	71.4	72.6	73.8	74.9	75.9	76.9	77.9	78.8	79.7	80.6	81.4
Females																			
Canada	79.1	79.9	80.9	81.1	81.9	82.7	83.7	84.0	84.2	85.0	85.6	86.3	86.9	87.5	88.1	88.6	89.1	89.6	90.1
N.L.	78.8	79.2	79.5	80.2	80.6	80.7	82.1	81.7	82.0	82.9	83.7	84.5	85.3	86.0	86.7	87.3	87.9	88.4	89.0
P.E.I.	80.5	80.9	81.4	81.8	82.3	82.8	83.3	83.8	84.1	84.8	85.5	86.2	86.9	87.5	88.1	88.6	89.2	89.7	90.2
N.S.	78.5	79.4	80.2	80.5	81.1	81.9	82.5	82.6	82.8	83.7	84.5	85.3	86.0	86.7	87.3	87.9	88.5	89.0	89.5
N.B.	79.1	80.1	80.8	81.2	81.8	82.3	83.2	82.9	83.2	84.0	84.8	85.6	86.2	86.9	87.5	88.1	88.7	89.2	89.7
Que.	78.8	79.6	80.8	81.0	81.9	82.8	83.6	84.2	84.4	85.1	85.7	86.3	86.9	87.4	88.0	88.5	89.0	89.4	89.9
Ont.	79.1	80.0	80.9	81.2	82.0	83.0	84.0	84.4	84.6	85.1	85.8	86.4	87.0	87.6	88.2	88.8	89.3	89.8	90.2
Man.	78.9	79.9	80.7	80.5	81.1	81.6	82.1	82.1	82.4	83.3	84.1	84.9	85.6	86.3	87.0	87.6	88.2	88.8	89.3
Sask.	79.9	80.6	81.6	81.4	81.5	81.8	82.3	82.7	82.9	83.8	84.6	85.3	86.0	86.7	87.3	87.9	88.5	89.1	89.6
Alta.	79.2	80.2	81.1	81.3	81.9	82.7	83.6	83.8	84.0	84.9	85.6	86.3	87.0	87.6	88.2	88.8	89.3	89.8	90.3
B.C.	79.7	80.7	81.4	81.8	82.6	83.2	84.3	84.6	84.8	85.5	86.2	86.9	87.5	88.0	88.6	89.1	89.6	90.1	90.5
Y.T.	73.5	74.6	75.7	76.9	78.1	79.4	80.7	82.0	82.2	82.7	83.4	84.1	84.7	85.4	86.0	86.6	87.2	87.7	88.2
N.W.T.	..	..	..	..	78.2	78.5	78.9	79.3	79.6	80.5	81.4	82.3	83.1	83.9	84.7	85.4	86.0	86.7	87.3
Nvt.	..	..	..	..	70.7	71.6	72.5	73.5	73.9	75.0	76.1	77.1	78.1	79.1	80.0	80.9	81.7	82.6	83.3

.. Not available for a specific reference period.

Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data are considered preliminary. The calculation for Canada for 2016 (2015/2017) excludes Yukon. The numbers for Yukon in 2016 are projected.

Sources: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537 and Demography Division.

Table 4.3 Life expectancy at birth, by sex, Canada, provinces and territories, historic (1981 to 2016) and projected according to the high mortality assumption (2017/2018 to 2067/2068), for selected years or periods

Sex / Region	1981	1986	1991	1996	2001	2006	2011	2016	2017/ 2018	2022/ 2023	2027/ 2028	2032/ 2033	2037/ 2038	2042/ 2043	2047/ 2048	2052/ 2053	2057/ 2058	2062/ 2063	2067/ 2068
	in years																		
Males																			
Canada	72.0	73.3	74.5	75.4	76.9	78.1	79.4	79.9	80.0	80.3	80.7	81.2	81.9	82.6	83.2	83.8	84.4	85.0	85.6
N.L.	71.9	72.9	73.7	74.4	75.3	75.7	77.3	77.5	77.6	77.9	78.3	78.9	79.5	80.2	80.9	81.6	82.3	83.0	83.6
P.E.I.	72.9	73.7	74.6	75.6	76.6	77.6	78.8	80.0	80.0	80.2	80.5	80.9	81.4	82.1	82.7	83.3	83.9	84.5	85.1
N.S.	71.0	72.4	73.7	74.8	76.2	76.9	78.1	78.2	78.3	78.6	79.0	79.5	80.1	80.8	81.6	82.3	82.9	83.5	84.2
N.B.	71.1	72.6	74.2	74.8	76.2	77.4	78.4	78.6	78.6	79.0	79.4	79.9	80.5	81.2	81.9	82.6	83.2	83.9	84.5
Que.	71.2	72.2	73.7	74.6	76.3	78.0	79.5	80.6	80.7	80.8	81.1	81.4	81.9	82.4	83.0	83.6	84.2	84.8	85.3
Ont.	72.4	73.7	74.9	75.8	77.3	78.5	79.8	80.4	80.4	80.6	80.9	81.3	81.8	82.3	83.0	83.6	84.2	84.8	85.3
Man.	72.3	73.3	74.6	75.2	75.6	76.7	77.8	77.9	78.0	78.3	78.7	79.3	79.9	80.6	81.4	82.1	82.8	83.4	84.1
Sask.	72.5	73.8	75.3	75.4	76.2	76.9	77.5	77.9	78.0	78.3	78.8	79.3	79.9	80.7	81.5	82.2	82.9	83.6	84.2
Alta.	72.2	73.7	75.0	75.9	77.1	77.9	79.1	79.2	79.3	79.5	79.9	80.4	81.0	81.6	82.3	83.0	83.7	84.3	84.9
B.C.	72.8	74.4	75.2	76.1	78.0	78.7	80.3	80.1	80.2	80.4	80.8	81.3	81.9	82.6	83.2	83.8	84.4	84.9	85.5
Y.T.	67.2	68.2	69.3	70.5	71.6	72.9	74.1	75.5	75.6	76.0	76.5	77.1	77.8	78.6	79.5	80.3	81.1	81.8	82.5
N.W.T.	..	..	..	..	73.0	73.7	74.5	75.2	75.3	75.7	76.3	76.9	77.6	78.5	79.3	80.1	80.9	81.6	82.4
Nvt.	..	..	..	..	67.0	68.2	69.6	71.0	71.1	71.7	72.3	73.1	74.0	74.9	75.9	76.8	77.7	78.5	79.3
Females																			
Canada	79.1	79.9	80.9	81.1	81.9	82.7	83.7	84.0	84.1	84.3	84.7	85.2	85.8	86.4	87.0	87.5	88.1	88.5	89.0
N.L.	78.8	79.2	79.5	80.2	80.6	80.7	82.1	81.7	81.7	82.1	82.5	83.0	83.6	84.4	85.0	85.6	86.2	86.8	87.3
P.E.I.	80.5	80.9	81.4	81.8	82.3	82.8	83.3	83.8	83.9	84.1	84.4	84.8	85.2	85.8	86.4	87.0	87.5	88.0	88.5
N.S.	78.5	79.4	80.2	80.5	81.1	81.9	82.5	82.6	82.6	82.9	83.3	83.8	84.4	85.0	85.7	86.3	86.8	87.3	87.9
N.B.	79.1	80.1	80.8	81.2	81.8	82.3	83.2	82.9	83.0	83.3	83.6	84.1	84.6	85.3	85.9	86.5	87.0	87.5	88.0
Que.	78.8	79.6	80.8	81.0	81.9	82.8	83.6	84.2	84.2	84.4	84.6	84.9	85.3	85.8	86.3	86.8	87.3	87.8	88.3
Ont.	79.1	80.0	80.9	81.2	82.0	83.0	84.0	84.4	84.4	84.5	84.8	85.1	85.5	86.0	86.6	87.1	87.6	88.1	88.6
Man.	78.9	79.9	80.7	80.5	81.1	81.6	82.1	82.1	82.2	82.5	82.9	83.4	84.0	84.7	85.3	85.9	86.5	87.1	87.6
Sask.	79.9	80.6	81.6	81.4	81.5	81.8	82.3	82.7	82.7	83.0	83.4	83.8	84.4	85.0	85.7	86.3	86.8	87.4	87.9
Alta.	79.2	80.2	81.1	81.3	81.9	82.7	83.6	83.8	83.8	84.0	84.4	84.8	85.3	86.0	86.6	87.1	87.6	88.1	88.6
B.C.	79.7	80.7	81.4	81.8	82.6	83.2	84.3	84.6	84.6	84.8	85.0	85.4	85.8	86.4	86.9	87.5	88.0	88.4	88.9
Y.T.	73.5	74.6	75.7	76.9	78.1	79.4	80.7	82.0	82.0	82.2	82.4	82.8	83.2	83.8	84.4	84.9	85.5	86.0	86.6
N.W.T.	..	..	..	..	78.2	78.5	78.9	79.3	79.4	79.8	80.2	80.8	81.5	82.2	83.0	83.7	84.4	85.0	85.6
Nvt.	..	..	..	..	70.7	71.6	72.5	73.5	73.7	74.2	74.9	75.6	76.5	77.4	78.3	79.2	80.0	80.8	81.6

.. Not available for a specific reference period.

Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data are considered preliminary. The calculation for Canada for 2016 (2015/2017) excludes Yukon. The numbers for Yukon in 2016 are projected.

Sources: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537 and Demography Division.

Table 4.4 Life expectancy at birth, by sex, Canada, provinces and territories, historic (1981 to 2016) and projected according to the low mortality assumption (2017/2018 to 2067/2068), for selected years or periods

Sex / Region	1981	1986	1991	1996	2001	2006	2011	2016	2017/2018	2022/2023	2027/2028	2032/2033	2037/2038	2042/2043	2047/2048	2052/2053	2057/2058	2062/2063	2067/2068
	in years																		
Males																			
Canada	72.0	73.3	74.5	75.4	76.9	78.1	79.4	79.9	80.3	81.6	82.7	83.6	84.3	84.9	85.6	86.2	86.8	87.4	88.0
N.L.	71.9	72.9	73.7	74.4	75.3	75.7	77.3	77.5	78.0	79.4	80.6	81.6	82.5	83.2	84.0	84.7	85.4	86.1	86.7
P.E.I.	72.9	73.7	74.6	75.6	76.6	77.6	78.8	80.0	80.4	81.7	82.8	83.7	84.5	85.1	85.7	86.4	87.0	87.6	88.1
N.S.	71.0	72.4	73.7	74.8	76.2	76.9	78.1	78.2	78.7	80.1	81.3	82.3	83.2	83.9	84.6	85.3	86.0	86.6	87.3
N.B.	71.1	72.6	74.2	74.8	76.2	77.4	78.4	78.6	79.0	80.4	81.6	82.7	83.5	84.2	85.0	85.7	86.3	87.0	87.6
Que.	71.2	72.2	73.7	74.6	76.3	78.0	79.5	80.6	81.0	82.3	83.3	84.2	84.9	85.4	86.1	86.7	87.3	87.8	88.4
Ont.	72.4	73.7	74.9	75.8	77.3	78.5	79.8	80.4	80.8	82.1	83.1	84.1	84.8	85.4	86.0	86.7	87.3	87.9	88.4
Man.	72.3	73.3	74.6	75.2	75.6	76.7	77.8	77.9	78.4	79.8	81.0	82.1	82.9	83.7	84.4	85.2	85.9	86.6	87.2
Sask.	72.5	73.8	75.3	75.4	76.2	76.9	77.5	77.9	78.4	79.8	81.1	82.1	83.0	83.8	84.5	85.3	86.0	86.7	87.3
Alta.	72.2	73.7	75.0	75.9	77.1	77.9	79.1	79.2	79.6	81.0	82.2	83.2	84.0	84.7	85.4	86.1	86.8	87.4	88.0
B.C.	72.8	74.4	75.2	76.1	78.0	78.7	80.3	80.1	80.5	81.9	83.1	84.1	84.9	85.6	86.2	86.8	87.4	88.0	88.5
Y.T.	67.2	68.2	69.3	70.5	71.6	72.9	74.1	75.5	76.0	77.5	78.8	79.9	80.9	81.7	82.6	83.4	84.2	85.0	85.7
N.W.T.	..	..	..	..	73.0	73.7	74.5	75.2	75.7	77.2	78.6	79.7	80.7	81.5	82.4	83.2	84.0	84.8	85.5
Nvt.	..	..	..	..	67.0	68.2	69.6	71.0	71.5	73.2	74.6	76.0	77.1	78.0	79.0	79.9	80.8	81.7	82.5
Females																			
Canada	79.1	79.9	80.9	81.1	81.9	82.7	83.7	84.0	84.4	85.6	86.7	87.5	88.2	88.7	89.3	89.9	90.4	90.9	91.3
N.L.	78.8	79.2	79.5	80.2	80.6	80.7	82.1	81.7	82.1	83.5	84.7	85.7	86.6	87.2	87.9	88.5	89.1	89.7	90.2
P.E.I.	80.5	80.9	81.4	81.8	82.3	82.8	83.3	83.8	84.2	85.5	86.6	87.5	88.2	88.7	89.3	89.9	90.4	90.9	91.4
N.S.	78.5	79.4	80.2	80.5	81.1	81.9	82.5	82.6	83.0	84.3	85.5	86.5	87.3	87.9	88.6	89.2	89.7	90.3	90.8
N.B.	79.1	80.1	80.8	81.2	81.8	82.3	83.2	82.9	83.4	84.7	85.8	86.8	87.5	88.2	88.8	89.4	89.9	90.5	91.0
Que.	78.8	79.6	80.8	81.0	81.9	82.8	83.6	84.2	84.6	85.8	86.7	87.5	88.2	88.6	89.2	89.7	90.2	90.7	91.1
Ont.	79.1	80.0	80.9	81.2	82.0	83.0	84.0	84.4	84.8	86.0	87.0	87.8	88.4	88.9	89.4	90.0	90.5	91.0	91.5
Man.	78.9	79.9	80.7	80.5	81.1	81.6	82.1	82.1	82.6	83.9	85.1	86.1	86.9	87.6	88.2	88.9	89.5	90.1	90.6
Sask.	79.9	80.6	81.6	81.4	81.5	81.8	82.3	82.7	83.1	84.4	85.6	86.5	87.3	87.9	88.6	89.2	89.8	90.3	90.9
Alta.	79.2	80.2	81.1	81.3	81.9	82.7	83.6	83.8	84.2	85.5	86.6	87.5	88.3	88.9	89.5	90.0	90.6	91.1	91.5
B.C.	79.7	80.7	81.4	81.8	82.6	83.2	84.3	84.6	85.0	86.2	87.2	88.1	88.8	89.3	89.8	90.4	90.9	91.3	91.8
Y.T.	73.5	74.6	75.7	76.9	78.1	79.4	80.7	82.0	82.4	83.6	84.6	85.5	86.1	86.6	87.2	87.8	88.4	89.0	89.5
N.W.T.	..	..	..	..	78.2	78.5	78.9	79.3	79.8	81.2	82.5	83.5	84.4	85.2	85.9	86.7	87.3	88.0	88.6
Nvt.	..	..	..	..	70.7	71.6	72.5	73.5	74.1	75.7	77.1	78.4	79.5	80.4	81.4	82.2	83.1	83.9	84.7

.. Not available for a specific reference period.

Notes: Statistics Canada produces life tables for a three-year reference period. For ease of reading, each stated year refers to the middle of the three-year period. For example, "2016" refers to the period 2015 to 2017. The 2017 data are considered preliminary. The calculation for Canada for 2016 (2015/2017) excludes Yukon. The numbers for Yukon in 2016 are projected.

Sources: Statistics Canada. 2019. *Life Tables, Canada, Provinces and Territories*, catalogue no. 84-537 and Demography Division.

References

Barbi, E., F. Lagona, M. Marsili, J.W. Vaupel and K.W. Wachter. 2018. "The plateau of human mortality: Demography of longevity pioneers", *Science*, volume 360, pages 1,459 to 1,461.

Bennett, J.E., G. Li, K. Foreman, N. Best, V. Kontis, C. Pearson, P. Hambly and M. Ezzati. 2015. "The future of life expectancy and life expectancy inequalities in England and Wales: Bayesian spatiotemporal forecasting", *The Lancet*, volume 386, pages 163 to 170.

Booth, H. 2006. "Demographic forecasting: 1980 to 2005 in review", *Working Papers in Demography*, no. 100, The Australian National University, Canberra.

Bourbeau, R. and N. Ouellette. 2016. "Trends, patterns and differentials in Canadian mortality over nearly a century (1921-2011)", *Canadian Studies in Population*, volume 43, issue 1-2, pages 48 to 77.

Cardona, C. and D. Bishai. 2018. "The slowing pace of life expectancy gains since 1950", *BMC Public Health*, volume 18, issue 151.

D'Amato, V., G. Piscopo and M. Russolillio. 2011. "The mortality of the Italian population: Smoothing techniques on the Lee-Carter model", *The Annals of Applied Statistics*, volume 5, issue 2A, pages 705 to 724.

Dong, X., B. Milholland and J. Vijg. 2016. "Evidence for a limit to human lifespan", *Nature*, volume 538, pages 257 to 259.

Dowell, D., E. Arias, K. Kochanek, R. Anderson, G.P. Guy Jr., J.L. Losby and G. Baldwin. 2017. "Contribution of Opioid-Involved Poisoning to the Change in Life Expectancy in the United States, 2000-2015", *Journal of the American Medical Association*, volume 318, issue 11, pages 1,065 to 1,067.

Green, M.A. 2018. "Austerity and the new age of population health?", *Scandinavian Journal of Public Health*, volume 46, pages 38 to 41.

Hedegaard, H., M. Warner and A.M. Minino. 2017. "Drug overdose deaths in the United States, 1999-2016", *NCHS Data Brief*, no. 294, December 2017.

Hiam, L., D. Harrison, M. McKee and D. Dorling. 2018. "Why is life expectancy in England and Wales 'stalling'?", *Journal of Epidemiology and Community Health*, Epub: doi: 10.1136/jech-2017-210401.

Ho, J.Y. and A.S. Hendi. 2018. "Recent trends in life expectancy across high income countries: retrospective observational study", *British Medical Journal*, volume 35, issue K2562.

Jasilionis, D. 2018. "Reversals in life expectancy in high income countries?", *British Medical Journal*, volume 362, issue K3399.

Keelin, T.W. 2016. "The Metalog Distributions", *Decision Analysis*, volume 13, issue 4.

Keelin, T.W. 2018. "The Metalog Distributions – Excel workbook", http://www.metalogdistributions.com/excelworkbooks.html.

Keilman, N. 2018. "Increasing (but insufficient?) optimism about future life expectancy", N-IUSSP, October 15 2018, http://www.niussp.org/article/increasing-but-insufficient-optimism-about-future-life/.

Kochanek, K.D., E.A. Arias and B.A. Bastian. 2016. "The effect of changes in selected age-specific causes of death on non-Hispanic white life expectancy between 2000 and 2014", *NCHS Data Brief*, no. 250, National Center for Health Statistics, June 2016.

Koissi, M.C., A.F. Shapiro and G. Hognas. 2006. "Evaluating and extending Lee-Carter model for mortality forecasting: Bootstrap confidence intervals", *Insurance Mathematics and Economics*, volume 38, pages 1 to 20.

Kontis, V., J.E. Bennett, C.D. Mathers, G. Li, K. Foreman and M. Ezzati. 2017. "Future life expectancy in 35 industrialized countries: projections with a Bayesian model ensemble", *The Lancet*, volume 389, pages 1,323 to 1,335.

Kulminiski, A.M., I.V. Culminskaya, S.V. Ukrainsteva, K.G. Arbeev, K.C. Land and A.I. Yashin. 2008. "Sex-specific health deterioration and mortality: the morbidity-mortality paradox over age and time", *Experimental Gerontology*, volume 43, issue 12, pages 1,052 to 1,057.

Lee, R.D. and L. Carter. 1992. "Modeling and forecasting the time series of U.S. mortality", *Journal of the American Statistical Association*, volume 87, pages 659 to 671.

Lee, R. and T. Miller. 2001. "Evaluating the performance of the Lee-Carter method for forecasting mortality", *Demography*, volume 38, pages 537 to 549.

Leon, D.A. 2011. "Editorial: Trends in European life expectancy: A salutary view", *International Journal of Epidemiology*, volume 40, pages 271 to 277.

Lenart, A. and J.W. Vaupel. 2017. "Questionable evidence for a limit to the human lifespan", *Nature*, volume 546, E13-E14.

Li, N. and R. Lee. 2005. "Coherent mortality forecasts for a group of populations: An extension of the Lee-Carter method", *Demography*, volume 42, pages 575 to 594.

Liu, X. and W.J. Braun. 2010. "Investigating mortality uncertainty using the block bootstrap", *Journal of Probability and Statistics*, volume 2010, pages 1 to 15.

Mayhew, L. and D. Smith, 2015. "On the decomposition of life expectancy and limits to life", *Population Studies*, volume 69, issue 1, pages 73 to 89.

Oeppen, J. and J.W. Vaupel. 2002. "Broken limits to life expectancy", *Science*, volume 296, issue 70, pages 1,029 to 1,031.

Oeppen, J. and J.W. Vaupel. 2019. "The linear rise in the number of our days", *Old and New Perspectives on Mortality Forecasting*, Springer Open Access Books, pages 159 to 166.

Office for National Statistics. 2018. "Changing trends in mortality: an international comparison: 2000 to 2016", August 7 2018.

Olshansky, S.J., B.A. Carnes and C. Cassel. 1990. “In search of Methuselah: estimating the upper limits to human longevity”, *Science*, volume 250, pages 634 to 640.

Ortiz-Ospina, E. and D. Beltekian. 2018. “Why do women live longer than men?”, *Our World in Data: Blog*, https://ourworldindata.org/why-do-women-live-longer-than-men.

Peters, F., C. Bohk-Ewald and R. Rau. 2015. “Correspondence: Future inequalities in life expectancy in England and Wales”, *The Lancet*, volume 386, page 2,391.

Preston, S.H., A. Stokes, N.K. Mehta and B. Cao. 2014. “Projecting the effect of changes in smoking and obesity on future life expectancy in the United States”, *Demography*, volume 51, issue 1, pages 27 to 49.

Public Health Agency of Canada. 2018. *The Chief Public Health Officer’s Report on the State of Public Health in Canada 2018: Preventing Problematic Substance Use in Youth*.

Raleigh, V.S. 2018. “Stalling life expectancy in the UK”, *British Medical Journal*, volume 362, issue K4050.

Shumanty, R. 2018. “Mortality: overview, 2014 to 2016”, *Report on the Demographic Situation in Canada*, Statistics Canada catalogue no. 91-209-X.

Singh-Manoux, A., A. Guéguen, J. Ferrie, M. Shipley, P. Martikainen, S. Bonenfant, M. Goldberg and M. Marmot. 2008. “Gender differences in the association between morbidity and mortality among middle-aged men and women”, *American Journal of Public Health*, volume 98, issue 12, pages 2,251 to 2,257.

Statistics Canada. 2019a. “Changes in life expectancy by selected causes of death, 2017”, *The Daily*, May 30 2019, https://www150.statcan.gc.ca/n1/daily-quotidien/190530/dq190530d-eng.htm.

Statistics Canada. 2019b. *Methods for constructing life tables for Canada, provinces and territories*, Statistics Canada catalogue no. 84-538-X.

Tuljapurkar, S., N. Li and C. Boe. 2000. “A universal pattern of mortality decline in the G7 countries”, *Nature*, volume 405, pages 789 to 792.

Vaupel, J., K. Manton and E. Stallard. 1979. “The impact of heterogeneity in individual frailty on the dynamics of mortality”, *Demography*, volume 16, pages 439 to 454.

Verbrugge, L.M. and D.L. Wingward. 1987. “Sex differentials in health and mortality”, *Women and Health Review*, volume 12, issue 2, pages 103 to 145.

Ye, X., J. Sutherland, B. Henry, M. Tyndall and P.R.W. Kendall. 2018. “Impact of drug overdose-related deaths on life expectancy at birth in British Columbia”, *At-a-Glance*, Health Promotion and Chronic Disease Prevention in Canada, volume 38, issue 6, pages 248 to 251.

Chapter 5: Projection of Immigration

by Nora Galbraith

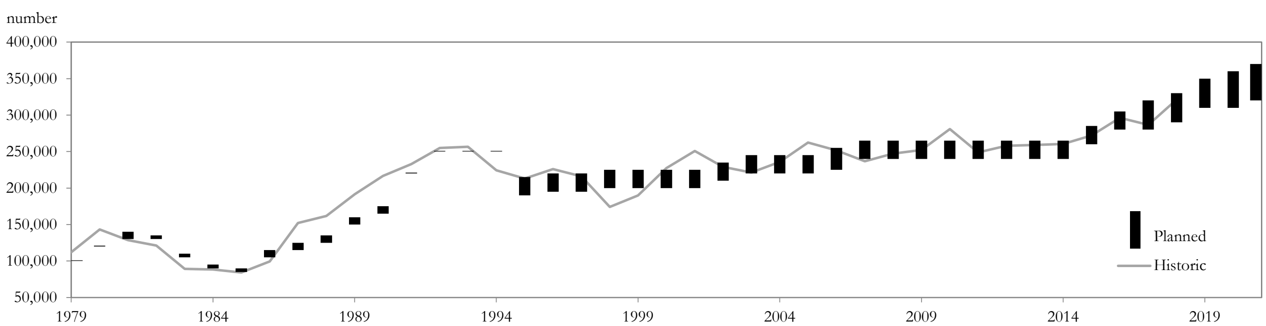
Introduction

Creating long-term assumptions about immigration is a particularly difficult task. Unlike other projection components such as fertility and mortality, immigration levels are largely determined by the government of the day. As a result, these levels are subject to change markedly from year to year depending on a variety of factors which influence the political decision-making process. Adding to this challenge is the fact that Canada has made more changes to its immigration policy in recent decades than any other nation aside from France (De Haas et al. 2015). As stated in the technical report accompanying the previous edition of the projections:

> "Migration processes are very complex, involving the interactions of economic, cultural, historical and political factors between countries (Bijak 2006). Moreover, no theory of migration provides a satisfactory means of projecting future flows, rather, different theories attempt to explain different aspects of the process (Massey et al. 1994). These theories are not easily applied in practice; this is in part due to the absence of suitable data about the contributing factors as well as the fact that those factors would also need to be projected, rendering the procedure undesirably complex."[35]

Following a period of relative stability in annual admission targets and the immigration rate, in 2017, the federal government announced it would be significantly increasing the level of planned immigration to Canada for the following three years (IRCC 2017d). In 2018, these targets were extended even higher for the years 2019 to 2021 (Figure 5.1) (IRCC 2018a).

Figure 5.1 Number of immigrants, planned (1979 to 2021) and historic (1979 to 2018), Canada

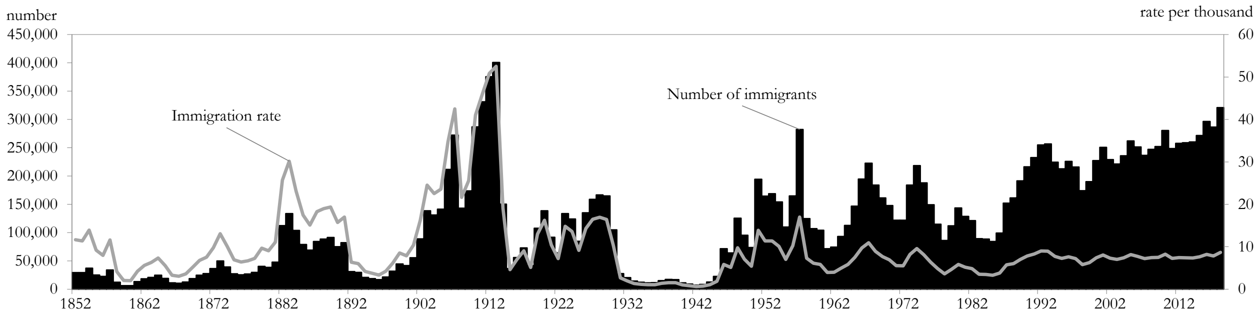


Source: Immigration, Refugees and Citizenship Canada.

Situated historically, these planned immigration targets represent a marked increase in the annual number, and associated rate, compared to the last 30 years. However, much higher immigration rates were experienced at different points in the 20th century. As recently as the mid-1950s, immigration rates were well over 1% of the population (Figure 5.2).

35. Chapter 5 of Bohnert et al. (2015).

Figure 5.2 Number of immigrants and immigration rate, Canada, 1852 to 2018



Sources: From 1852 to 1979: Employment and Immigration Canada. 1982. *1980 Immigration Statistics*, Immigration and Demographic Policy Group, catalogue no. MP22-1/1980. From 1980 to 2018, Immigration, Refugees and Citizenship Canada and Statistics Canada, Demography Division, Demographic Estimates Program.

In designing our immigration projection assumptions, we must consider the plausibility of outcomes under both a short-term and a long-term perspective, and attempt to build a range of immigration assumptions that reflect an appropriate level of uncertainty. To build these assumptions, in addition to analyzing recent trends in the level and distribution of immigration by age, sex, region and category of immigration, we conducted a literature review which included:

- Publications and statements from Immigration, Refugees and Citizenship Canada (IRCC);
- Public opinion polls, media coverage and media narratives regarding immigration;
- International reports on immigration (e.g., OECD, United Nations);
- Peer-reviewed journal articles on the impacts and dynamics of immigration and theories of immigration;
- Relevant publications from "think tanks" and other key policy influencers;
- The views of the respondents to the *2018 Survey of Experts on Future Demographic Trends* regarding future immigration levels in Canada.

In the remainder of this chapter, arguments in support of an increase versus a stabilization or slight decrease in immigration levels in the future are first explored, followed by a summary of the views of respondents to the *2018 Survey of Experts on Future Demographic Trends*. Lastly, the immigration assumptions and associated methodology are described.

Arguments in support of an increase in immigration levels in the future

The current federal government have indicated a desire to increase immigration levels even further beyond the current short-term plans.

In the news release accompanying the announcement of immigration targets for 2018 to 2020, IRCC states "This measured, gradual increase will trend towards one percent of the population by 2020, spurring innovation and representing a major investment in Canada's prosperity, now and into the future" (IRCC 2017d). Immigration, Refugees and Citizenship Minister Ahmed Hussen, in presenting the new immigration targets, called it a historic and responsible plan and "the most ambitious" in recent history (IRCC 2017d; Harris 2017). Previously, 2016 Immigration, Refugees and Citizenship Minister John McCallum stated that he hoped to "substantially increase" immigration (Corcoran 2016), though he cautioned that the recent recommendations of the Advisory Council on Economic Growth for 450,000 annual immigrants by 2021 (more on this later) might be too fast-paced of an increase: "We have an aging population, we have labour shortages, but there are also constraints" (Blatchford 2016).

Furthermore, IRCC's news releases accompanying the most recent immigration plan emphasized repeatedly the fact that immigration levels would be "nearing 1 percent of Canada's population in 2021" (IRCC 2018b). These developments suggest that an immigration target of 1% of the Canadian population should be considered as a very plausible possibility, at least in the short-to-medium term future.

Key consultants of the current federal government have recommended substantially higher immigration levels in the future.

In 2016, the Advisory Council on Economic Growth was established by the Minister of Finance to "develop advice on concrete policy actions to help create the conditions for strong and sustained long-term economic growth" and to "help inform the Government's future actions and policies".[36] The Advisory Council recently released a report that recommended increasing immigration levels to 450,000 by 2021 in order to counter demographic challenges and grow the economy (Advisory Council on Economic Growth 2016). The Advisory Council support their recommendations using a report from the Conference Board of Canada[37] which concludes that higher immigration levels—specifically those that would result in a population of 100 million Canadians by 2100—will increase the growth of Canada's labour force over the long term thus generating higher economic growth as compared to lower immigration projection scenarios (Adès et al. 2016; Alini 2017).

Recent consultations by IRCC have revealed that many key stakeholders working in industries, service and organizations related to immigration are, perhaps not surprisingly, in favour of higher immigration (IRCC 2017c).

There is growing momentum among many Canadian public figures and media to embrace a pro-population growth stance, to be achieved through higher immigration.

The pro-higher-immigration stance of the Advisory Council on Economic Growth and many stakeholders follows a growing momentum in recent years by some national media to highlight editorials and other discussions in support of growing the population to 100 million in 2100 through substantially higher immigration levels (Kirby 2017). Common among these narratives is the view that higher immigration and the resulting larger population is a chance for "national rebirth" (Corcoran 2016); a way to shed the country's colonial past and its close ties to the United States to become a more impactful world leader. For example, in 2012, the Globe and Mail published a series of editorials in this vein called "The Immigrant Answer". Included was a piece by Doug Saunders (2012) which recommended a minimum of 400,000 immigrants per year to achieve the goal of 100 million people living in Canada by 2100. He argues that there isn't a large enough population in Canada to support a minimal level of quality or scope in its various institutions and that cultural development requires a much larger population.[38]

Saunders' ideas were echoed by Irvin Studin (2017), President of The Institute for 21st Century Questions,[39] an organization which recommends increasing immigration levels in Canada for geostrategic and defence reasons. He also argues that in contrast to concerns raised about the environmental impacts of overpopulation, a larger population will lead to far better environmental outcomes for Canada since there will be greater capacity to develop technologies to protect the environment. Corcoran (2016), in a Financial Post editorial, also argued in favour of the Advisory Council on Economic Growth's recommendation for 100 million people by 2100.

Critics of this "populationist" movement (a term used by Paquet (2017)) note that its proponents do not discuss the potential difficulties—economic, ecological and sociological, capacity-wise—of such a substantial increase in immigration, among other possible consequences.[40] Numerous critiques of Saunders' proposal have come from the Canadian demography community (see for example Beaujot and Patterson 2018, Darroch 2018, Miller 2018, Marois 2018, Rees 2018). While they welcome the fact that Mr. Saunders has opened up public discussion of Canada's population history and future

36. Advisory Council on Economic Growth (http://www.budget.gc.ca/aceg-ccce/home-accueil-en.html).
37. The Conference Board of Canada's National Immigration Centre states that one of its goals is to "raise public awareness of the nature and importance of immigration to Canada's economy, society and culture" (El-Assal and Fields 2017).
38. Saunders uses the example of the United States as a justification for the 100 million target in 2100; it was when the U.S. population hit 100 million, in the 1920s, that in his view it became a world leader. He applies a sense of urgency to his arguments: he argues that Canada needs to substantially increase its immigration levels now, as by 2050, world population growth will have peaked, making it more difficult to attract large numbers of skilled immigrants.
39. The Institute for 21st Century Questions (www.i21cq.com).
40. Critics such as The Fraser Institute (2017) and Grubel (2016a, 2016b) dispute the cultural institutional depravity argument and state that the justification for 100 million is vague and almost entirely ideological. Anglin (2016) questions the Century Initiative's (2017) use of population size as a means of identifying "world leaders", noting that the countries that regularly rank highest on standard of living, equality, happiness are of relatively small populations, such as Sweden, Iceland and Denmark. Questions about how the current large backlogs in the immigration system will be resolved remain unanswered (Levitz 2017). Critics also raise concerns about possible negative impacts (particularly distributional) on standard of living and per capita income growth, as well as the potential added fiscal burden on Canadian taxpayers: with a higher population, the demand for professionals, such as doctors, and affordable housing will also increase, two phenomenon already experiencing challenges to meet demand in many parts of the country (Grubel 2016a, 2016b).

population, they argue that this dialogue about what the future Canadian population should be needs to include voices from a wider range of disciplines and interests, including economists, ecologists, urban planners, health and social scientists, among others. In addition to ecological concerns, these scholars raise concerns about the impacts of such large increases in immigration on various aspects of Canadian life, including the marginalization of rural communities and possible cultural conflicts arising from increased ethnic fragmentation and the associated decrease in the weight of the Quebec and French-speaking populations in Canada (Marois 2018, Darroch 2018).

While it is unknown how much further the idea of population growth through higher immigration will continue to build in momentum, recent trends in this regard suggest that a higher immigration scenario than in recent years must be considered in the realm of possibility.

Public support for immigration is relatively strong in Canada.

Public opinion is an imperative factor in immigration policy (Jones 2016). In Canada, public support for immigration, particularly economic immigrants, is relatively strong in comparison with the United States and Europe (Bloemraad 2012). Bauder (2014) notes that in public debate on the topic, there is an "overarching paradigm" that immigration is a necessary part of Canada's identity—a sentiment echoed by recent public consultations by IRCC on immigration levels (IRCC 2016). It is generally not questioned by the Canadian public that immigration results in economic benefits, despite the lack of concrete evidence of this fact (Bauder 2014; Bloemraad 2012)). Immigration has become a "normative part of Canadian life" (Jones 2016), especially in the nation's urban areas, which Bloemraad (2012) views as "remarkable" in how easily they have transitioned to become highly multicultural in a short period of time.

Relatively strong public support for immigration in Canada may also be linked in part to the country's fairly unique characteristics. With its large landmass, low population density and natural resources, Sachs (2016) sees Canada as an ideal setting for absorbing high immigration levels. Furthermore, Canada's single border with a developed country, as well as its points system that aims to select immigrants with skills that are in demand for the economy, may explain in part why public support for immigration in Canada continues to be fairly strong, deemed "Canadian exceptionalism" by Bloemraad (2012). Given this, it is possible that public approval for immigration will remain strong even if immigration levels increase substantially. Indeed, to date, there has been no strong public opposition to the proposed increases to immigration levels made by IRCC in recent years.

Pressure to admit a greater number of refugees could increase in the future.

Canada has been identified as a world leader and pioneer in terms of resettlement of refugees (OECD 2016a). As the number of refugees worldwide increases[41]—and may continue to increase further in the future due to demographic disparities and climate change, among other factors (Sachs 2016; McGrath 2017; Missirian and Schlenker 2017) —there could be greater pressures directed toward Canada to increase its humanitarian immigration in the future. In fact, the United Nations High Commissioner for Refugees recently asked the Canadian government to consider a special program to bring in more refugees (Ponomare 2017), in a context where many other countries, such as the United States, have scaled back their refugee programs in recent years (Levitz 2017).

Peak population aging could intensify the perceived need for higher immigration.

Between now and 2031, Canada is expected to experience peak aging of the population. The aging phenomenon could create new pressures and associated justifications to increase immigration in an effort to counter demographic and economic challenges.

Canada is expected to maintain its status as a desirable country for immigrants in the future.

While global competition for immigrants has grown, Canada is considered to be well placed in this competition and remains a very attractive country to immigrants (OECD 2016b). As evidence of this, Canada's international ranking in terms of number of immigrants received was essentially unchanged between 2000 (tied for 4th most) and 2015 (tied for 5th most) (United Nations 2016).

41. The number of refugees worldwide has recently reached the highest level since World War II (United Nations 2015).

Arguments in support of a stabilization or slight decrease in immigration levels in the future

Integration and system capacity issues could prevent further increases to immigration levels.

Despite the current federal government's stated intention to increase immigration levels, there could be capacity issues on several fronts which could impede the achievement of these goals. In IRCC's 2017/2018 Departmental Plan, the increasing use of partners and third parties to support program implementation is identified as a key risk that could affect the ability to reach immigration targets (IRCC 2017b). Results of IRCC's recent consultations with stakeholders and the general public revealed some concerns regarding the integration of immigrants. For instance, some stakeholders noted that should immigration levels increase, the settlement sector would need time and resources to increase its capacity for associated programming (IRCC 2016; 2017c). Additionally, some members of the public called for reductions in immigration levels, citing concerns about social and labour market integration and the costs associated with integration supports (IRCC 2017c). Concerns about the linguistic and economic integration issues, the capacity of Canada's labour market to supply adequate employment opportunities to newcomers, the capacity of Canada to properly support and educate newcomers, among others (IRCC 2016).

The sociocultural absorptive capacity for increased immigration may be approaching limits within some of Canada's urban centres in particular. Overall, integration of the immigration population in Canadian society is considered to be higher than in most other OECD countries (OECD 2016b), a characteristic often used to explain in part the continued public support for immigration in the country (OECD 2016b; Jones 2016). However, concerns have been raised recently by various immigrant settlement organization representatives in Toronto and Vancouver, who have pointed to issues related to affordable housing, the high rate of unemployment and precarious, low-paying work among visible minority immigrant women in particular in these cities (Pelley 2017; Todd 2017).

The Advisory Council on Economic Growth (2016) acknowledges that the higher population growth resulting from its recommendation of increased immigration will require increased investments in public services and infrastructure by all levels of government. However they state "The recommended increase of 150,000 permanent economic immigrants is not expected to strain public education, transportation, or healthcare systems over the course of the 5 year ramp up period" (p.6).

These integration concerns, if they become more vocal and numerous, could motivate a stabilization of immigration levels as opposed to an increase in the future.

The economic benefits of immigration, often used to justify planned increases, may be questionable and could be held up to increasing scrutiny if levels continue to increase in the future.

Most advocates of the economic benefits of higher immigration do not support their claims with evidence, nor quantify the additional investments needed for successful integration (Grubel 2016a, 2016b; Griffith September 1 2017; Todd 2017). As Hou and Picot (2016) note, measuring the net benefit of a given immigration level is difficult since the various costs and benefits associated with the diverse goals attached to immigration cannot be compared on the same scale. Attempting to select appropriate immigration levels and admitted categories by trying to predict in advance the needs for the coming year(s) is very difficult (OECD 2016b). This situation is further complicated by the fact that Canada has large regional diversity in labour needs, but there are few regional labour forecasting systems in place (OECD 2016b). Additionally, discussions of the economic impacts of permanent versus non-permanent migration are often done in isolation from one another, further muddying understanding of the issue (Riddell et al. 2016).

Given these challenges, economists largely agree that the economic impact of immigration is a controversial topic and one needing more research (OECD 2013; OECD 2014; Riddell et al. 2016; National Academies of Sciences, Engineering and Medicine (NAS) 2016; Lee 2017), particularly Canada-specific analyses, since Canada has unique immigration characteristics owing to its points system (Riddell et al. 2016). There have been few in-depth analyses of the impacts of immigration levels in Canada, in part because long-term impacts are difficult to measure (Hou and Picot 2014) and findings vary depending on assumptions made and the methodology used (OECD 2013; NAS 2016; Lee 2017).

That said, economists generally agree that according to evidence to date, the net economic impact of immigration is very small, and varies by job sector, quantile of the income distribution and geographic region–details that are masked when statements are made about average impacts at the national level (OECD 2013; NAS 2016; Riddell et al. 2016). Immigration has both negative (added competition for jobs and housing) and positive (larger consumer base and increased businesses) effects (Riddell et al. 2016). An increase in overall gross domestic product resulting from a larger population is arguably only beneficial if it also translates into a rise in quality of life for an average Canadian. However, increasing the size of the economy does not necessarily create a proportional increase in individual wellbeing (Riddell et al. 2016, Beaujot 2017).

Recent findings from the Conference Board of Canada provide further evidence of this notion: in a test of the fiscal and demographic impact of raising immigration to the levels proposed by the Advisory Council on Economic Growth (2016), they found that in fact the "status quo" projection scenario (continuing the immigration rate of around 0.8%) resulted in the highest rise in real GDP per capita. In contrast, increasing immigration to 1.1% per year resulted in greater fiscal challenges since it would lead to higher social expenditures (El-Assal and Fields 2017).[42] According to Riddell et al. (2016), "immigration cannot be relied upon as a source of higher per capita incomes as measured by employment prospects and wages", and as a result, "we should not view immigration as a source of greater prosperity".

In Lee's (2017) opinion, given the difficulty in drawing conclusions about the fiscal effects of immigration, immigration policy should not be designed with economic goals in mind; instead "a rationale for setting the quantitative levels of immigration must be found elsewhere" (Lee 2017, p.173). Riddell et al. (2016) find this notion "liberating", since "it means that we can think about other goals for immigration policy – in terms of yielding a more diverse, dynamic society or offering opportunities to people from other parts of the world – without concern for significant negative effects on Canadian workers". Recent IRCC consultations revealed that even stakeholders generally see immigration as only one part of a larger strategy to meet labour market needs, and that it should be balanced with fostering talent within Canada (IRCC 2017c).

There is currently a gap in economic outcomes between immigrants and the Canadian-born population. The continuation of this phenomenon, or its intensification, could provoke decreased public support for immigration or decrease the attractiveness of Canada to potential immigrants in a more competitive international migrant market in the future.

IRCC's recent public consultations revealed that some members of the general public called for reductions in immigration levels, citing concerns about labour market integration (IRCC 2016; 2017c). There is some evidence that recent cohorts of new immigrants have not improved their income positions relative to the Canadian born (Picot and Hou 2014). Riddell et al. (2016) argue that these trends imply that new immigrants are a net "drag" on the public fiscal balance: due to their lower incomes, they pay less in taxes on average and make slightly above average use of government services and benefits. These negative outcomes, at least in the short-term, could be exacerbated in the context of a sudden substantial increase in immigration levels: Hou and Picot (2016), in their analysis of the influence of immigrant levels on immigrant entry earnings, find that increased immigrant cohort size tended to put downward pressure on immigrant entry earnings, regardless of macroeconomic conditions or place in the earnings distribution.

The 2017 IRCC Annual Report to Parliament states "IRCC is mindful of the gaps between immigrants and the Canadian-born in economic outcomes, as well as the gender gap between female and male immigrants. IRCC will continue to monitor the economic outcomes of immigrants closely, particularly the gender gap, and to enhance the Settlement Program through innovative ways to position and support immigrants to achieve success" (IRCC 2017a, p. 28), though no further details are provided. Progress in this regard seems to have plateaued in recent years: among new immigrants, entry earnings remained fairly constant throughout the 1990s and 2000s (Hou and Picot 2016). The economic outcomes of immigrants also tend to vary more strongly with the economic cycle than that of native-born persons (OECD 2013), making them more vulnerable to economic recessions and depressions.

Motivated in part by the desire to improve the economic and social integration of immigrants, the federal government has in recent years created new programs and program modifications to ease the transition from non-permanent to permanent residence under certain conditions, foremost among them the Canadian Experience Class (CEC), which heavily favours admissions with

42. This projection exercise did not take into account the costs of higher immigration levels, the potential impacts of automation, nor the rise of the non-permanent resident population, which could further reduce the fiscal benefits of higher immigration. The authors note that if the labour market outcomes of new immigrants deteriorate further in the future, the economic benefits to the country could be worse – and this risk is inflated as immigration levels rise, as more resources would be required to ensure that new immigrants find quality jobs – something that has proven challenging even at lower immigration target levels (El-Assal and Fields 2017).

pre-arranged employment offers. The OECD, in a review of Canada's immigration program, notes that a significant proportion of admissions under the CEC program in recently years have been in the category of Food Service Supervisors and Cooks, with few pathways to permanent residency via "intermediate" skill jobs, raising questions about the effectiveness of the system to select and attract those with the highest skills (OECD 2016b). Hou and Picot (2016) observe that if economic principal applicants whose status changes from temporary foreign worker to permanent resident are in increasingly lower-paying, lower-skilled jobs, then entry earnings of immigrants may fall in the future, despite them having Canadian work experience.

The federal government has recently modified its Express Entry program to make it easier for newly-graduated international students to become permanent residents (Zilio and Chiose 2017), following recommendations from the OECD (2016b) and the Advisory Council on Economic Growth (2016). It remains to be seen whether program adjustments such as this will achieve the federal government's goal to allow "immigrants [to] contribute their talents to support our economic growth and innovations, helping to keep our country at the forefront of the global economy" (IRCC 2017d).

The demographic benefits of immigration, often used to justify planned increases, may be questionable and could be held up to increasing scrutiny if levels continue to increase in the future.

While international migration can partly reduce old-age dependency ratios, it cannot reverse the trend of population aging (United Nations 2016). It has been found that immigration to Canada has both rejuvenating and aging effects on the population, resulting in very little net change in terms of population aging (Caron Malenfant et al. 2011; Riddell et al. 2016; Robson and Mahboubi 2018). In a recent article from the C.D. Howe Institute (Robson and Mahboubi 2018), it is argued that, compared to increasing immigration levels, a policy directed at encouraging people to work longer may result in equal if not greater reductions in the fiscal challenges and pressure on living standards associated with the aging of the population through its direct impact on the dependency ratio. The authors conclude "Canada's success in managing the stresses created by low fertility and longer lifespans will depend on much more than immigrants." (Robson and Mahboubi 2018, p. 13).

Furthermore, certain Canadian demographers such as Beaujot (2017) have recently argued that as an alternative to continual population growth through sustained high immigration, stabilization of the population (also known as a stationary population) would in fact permit the achievement of greater quality of life standards, social cohesion and longer-term ecological goals. According to Romaniuk (2017), immigration has been wrongly considered a "palliative solution for all problems, real and imaginary, that beset Western societies" (p. 168). He argues that rather than increasing immigration—which in his view does little to combat population aging, has no proven record of economic benefit and holds potential negative societal and ecological impacts—Western nations should instead focus on implementing policies which reduce the barriers to women achieving replacement-level fertility. In his view, "there is a need to rethink the balance in the allocation of resources between production and reproduction. So far, the former is being privileged at the expense of the latter" (Romaniuk 2017, p. 173).

Generally, the Canadian public is not in favour of increasing immigration levels.

Public opinion of immigration is key to the successful integration of immigrants (Jones 2016), and therefore levels could stabilize in the future if there is evidence of decreasing public support. Sachs (2016) identifies Canada's "pace" of immigration in the recent past as being exemplary of a phased approach which results in continued public support of immigration.

While the public is generally poor at accurately estimating the level of immigration[43] (Butler 2014; Willekens et al. 2016), they are aware that levels are increasing (Ipsos Reid 2017), and when informed about current immigration levels, they become more likely to think levels are too high (IRCC 2016). In a recent public opinion poll, of all response options ("agree", "neither", "disagree" or "don't know"), Canadians were most likely to state that they "agree" that "immigration has placed too much pressure on public services in Canada" (50%), that "immigration is causing Canada to change in ways that I don't like" (40%) and that "there are too many immigrants in Canada" (35%) (Ipsos Reid 2017). Griffith (2017) cautions that while Canada has managed previous immigration increases without major public backlash, it is important to carefully manage the immigration program in order to maintain public support.

43. Findings from IRCC's recent public consultations indicated that very few focus group participants were familiar with the annual immigration levels, and many didn't feel they could judge the immigration figures. They felt that they needed additional context to help understand the current and proposed immigration levels. Commonly, the sentiment was expressed that there was trust in the authorities to select the correct levels (IRCC 2016).

Public support for immigration could decline in the future for various reasons, leading to a decrease in immigration levels.

Recent IRCC (2016; 2017c) consultations with stakeholders and the public at large revealed that many feel Canada's immigrants need to be more widely distributed across the country than they currently are, particularly into rural areas and smaller urban centres. Some Canadian economists agree with this sentiment (Riddell et al. 2016; Griffith 2017). To date, however, most immigrants continue to reside in the three largest urban centres (Toronto, Montreal and Vancouver), where concerns have been raised publicly about the economic prospects of immigrants in these areas and the ability of these cities to successfully integrate and house newcomers in higher numbers in the future (Harris 2017; Pelley 2017; Todd 2017). Despite recent efforts to attract and retain more immigrants in the Atlantic provinces, there has been fairly limited success in this regard to date (for more details, see Appendix A5.2).

Even if greater success could be achieved in attracting immigrants to more rural parts of the country, there may be practical barriers to the settlement of immigrants into rural communities such as the lack of community infrastructure, settlement services and transportation (IRCC 2017c).

Public support for immigration in Canada has been found to be selective, in that Canadians—in contrast to many other countries—vastly prefer permanent (particularly economic category) over temporary migration (Bloemraad 2012; Jones 2016). If the number of non-permanent residents in Canada continues its recent strong increasing trend (Bauder 2014; Lu and Hou 2017) and the public begins to perceive that this number is becoming too high, public support for immigration could deteriorate in response (Bloemraad 2012).

Many Canadians express a strong desire for immigrants to integrate into society (Bloemraad 2012; IRCC 2016; 2017c), and new, larger or unexpected immigration flows can cause unrest and controversy, particularly around the issues of religious accommodation and unauthorized asylum seekers. Canadians are not overly supportive of unauthorized immigration, and a rapid increase in this population could have a negative effect on public opinion about immigration (Bloemraad 2012). There is some evidence of growing support for a "closed door" approach to refugees in public polls (from 6% in 2016 to 25% in 2017), though the majority of respondents (65%) still do not agree with this sentiment (Ipsos Reid 2017). With recent events involving large increases in the number of asylum seekers irregularly entering Canada, there has been an increase in more public, vocal opposition to these migrants (Forrest 2017; Cochrane and Laventure 2017; Tasker 2017; Loewen 2017).

Technological advancements and other developments could substantially alter the labour market in the future, lessening the demand for higher immigration levels.

While Canada faces a rapidly aging population and potential labour shortages in some segments and regions of the labour market, technological advancements (particularly artificial intelligence) could substantially alter the labour market in the future, creating an environment where jobs become scarcer or labour productivity gains can be made without adding workers to the labour force—evolutions that could lessen the desire for continued higher immigration levels (El-Assal and Fields 2017; Romaniuk 2017; Griffith 2017; NAS 2016). Romaniuk (2017) also points to the potential productivity gains for the senior populations of today and the near future as they experience comparatively good health and longevity and therefore could continue working to older ages than seniors of the past.

Results of the *2018 Survey of Experts on Future Demographic Trends*

In total, 16 experts provided their views on the future evolution of immigration in Canada. Experts were first asked to describe the arguments, trends or possibilities they considered when formulating their views about the probable distribution of the immigration rate (number of immigrants per thousand total population) in Canada in 2043.

Some experts thought that the immigration rate would likely stay close to the average observed over the last several decades noting that Canada's large geographic territory and continued public support for immigration should permit a similar 'welcoming capacity' to be maintained in the future. Additionally, some experts offered arguments which might suggest higher immigration levels in the future. Among these were the powerful sway of pro-immigration lobbyists, the discourse around population aging and labour shortages which views immigration as a solution to these challenges, possible environmental (climate change) or other humanitarian crises leading to an influx of refugee claimants, and growing demographic pressures on the part of non-industrialized countries.

Alternatively, other factors raised by the experts could suggests a decrease in immigration levels in the future. Several experts mentioned the growth of nationalism, protectionism and populism in many parts of the world; such movements could on one hand lead to proportionally more immigrants wanting to settle in Canada (providing Canada continues to resist such political orientations). On the other hand, if anti-immigration sentiments grow in Canada (perhaps in reaction to increased asylum claimants entering the country irregularly), this could lead to decreased admissions targets or a move to increase non-permanent resident admissions over permanent ones. It was also mentioned by several experts that technological advancements such as automatization and artificial intelligence could diminish the perceived need for immigrants to fill anticipated labour shortages.

Multiple experts pointed out the difficulty of trying to envision the long-term future of immigration when it is a highly political decision, reactive to economic fluctuations and therefore subject to considerable uncertainty. The possibility of unique immigration trends in Quebec in the future was also noted by numerous experts.

Following their qualitative arguments, experts were asked to communicate their views about the likely evolution of the immigration rate in Canada in 2043 quantitatively; that is, by building a probability distribution that exemplified their opinion, and level of uncertainty, regarding what values the immigration rate could take in 25 years. More specifically, each expert was asked to provide the following parameters:

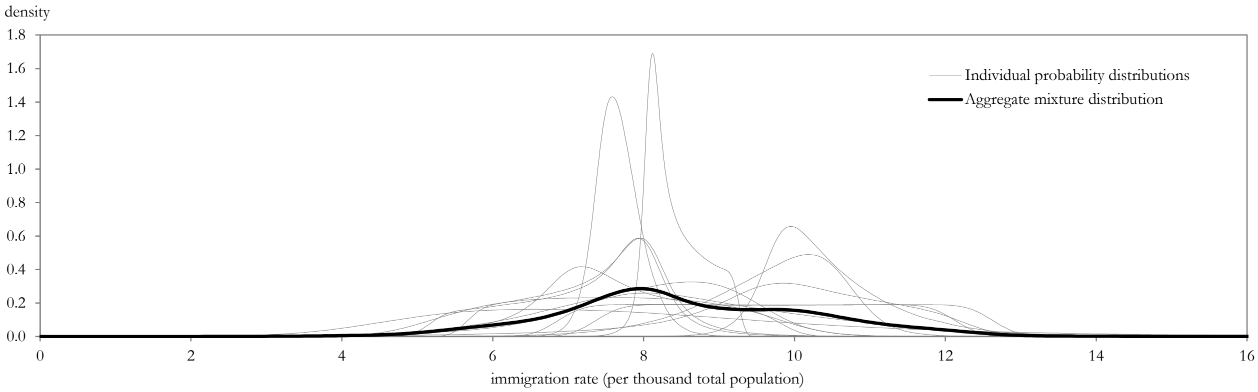
a. Lower and upper bounds of a range covering nearly all plausible values of the immigration rate in Canada in 2043;
b. Their level of confidence (expressed in percent, with a minimum of 90% imposed) that the true value of the immigration rate in 2043 will fall within the range specified in Step (a);
c. The median value of the plausible range provided in Step (a), such that they expect an equal (50-50) chance that the immigration rate lies above or below the median;
d. Probabilities that the immigration rate in 2043 will fall below and above the mid-points between:
    - the lower bound of the plausible range provided in Step (a) and the median provided in Step (c); and
    - the median provided in Step (c) and the upper bound of the plausible range provided in Step (a).[44]

Using these parameters, a visual representation of the resulting probability distribution was displayed, and the expert was then encouraged to modify their inputs until they arrived at a satisfactory visual representation of their beliefs. The individual probability distributions of 14 experts[45] regarding their views about the probable immigration rate in Canada in 2043 are displayed in Figure 5.3 (grey lines).

The individual probability distributions of the 14 experts were aggregated via a mixture distribution,[46] the result of which is shown in the black solid line of Figure 5.3. This aggregation resulted in a bimodal, right-skewed probability distribution, with one peak at 8.0 immigrants per thousand and another at 9.7 immigrants per thousand, and a median of 8.3 immigrants per thousand total population. The 10th and 90th percentiles of the distribution were represented by 6.5 and 10.8 immigrants per thousand population, respectively. Taken together, the expert views seem to envision that an immigration rate close to that recently observed is most likely, but that it is also fairly possible (though not quite as likely) that immigration rates could increase by 2043.

44. For each of the intervals in Step (d), the expert was asked to imagine that the entire interval sums to 50%.
45. Of the 16 experts who completed the section of the survey related to immigration, two provided their quantitative estimates in the form of immigration numbers rather than in the form of immigration rates as was specified in the survey. In follow-up communications, it was established that both experts intentionally provided their estimates in the form of numbers as they felt this was a more appropriate form than immigration rate. This debate is not new, as detailed in Appendix A5.1. While the qualitative arguments of these two experts were taken into consideration when forming the immigration assumptions, it was unfortunately not possible to incorporate their quantitative estimates into the aggregate probability distribution.
46. For more information on the aggregation procedure, see Chapter 2: *2018 Survey of Experts on Future Demographic Trends*.

Figure 5.3 Immigration rate, Canada, 2043: Individual probability distributions and aggregate mixture distribution of the respondents of the *2018 Survey of Experts on Future Demographic Trends*



Source: Statistics Canada, Demography Division.

Immigration assumptions

Canada's total immigration rate

Assumptions about immigration are formulated in terms of immigration rates (that is, the number of immigrants per thousand total Canadian population) at the national level. Appendix A5.1 provides a rationale to utilize rates instead of raw numbers in our assumptions.

The general approach to building the immigration assumptions—that is, combining short- and long-term trajectories—is similar to that described in Chapter 1: General Approach to Assumption Building. Unique to the immigration component, however, is the integration of IRCC's planned immigration admission level targets[47] for the years 2019 to 2021.[48] IRCC's targets were considered to be the best guide for these years, since, as seen earlier in Figure 5.1, the observed number of immigrants in a given year tends to fall within or close to the planned range. While this results in a relatively narrow range of immigration rates in the very early years of the projection across scenarios, this was deemed acceptable since, unlike most other demographic behaviours projected, immigration levels are controlled by the government and planned in advance—thus reducing their uncertainty in the very short term future.

After 2020/2021, short-term trajectories of Canada's immigration rate were obtained by extrapolating trends in the change in total immigration rates observed between 2007/2008 and 2017/2018). Long-term trajectories were derived from the views of the respondents to the *2018 Survey of Experts on Future Demographic Trends*. More specifically, the median (50th percentile) of the aggregate distribution from experts regarding the plausible range of the immigration rate in 2043 was used to obtain a medium immigration target for Canada; the 90th percentile to obtain a high immigration target; and the 10th percentile to obtain a low immigration target.

The short- and long-term trajectories were combined in a manner that allows Canada's immigration rate to follow recent trends in the earlier projection years (i.e., an increasing trend), while in the long term, immigration rates follow the views of the respondents to the expert survey regarding the plausible range of Canada's immigration rate in 2042/2043. After 2042/2043, Canada's immigration rate is held constant for the remainder of the projection.

Under the medium immigration assumption, the annual immigration rate would reach 8.3 per thousand (or 0.83% of the total population) in 2042/2043, holding constant for the remainder of the projection.

47. As stated in Immigration, Refugees and Citizenship Canada. 2018. "2019-2021 Immigration Levels Plan", *2018 Annual Report to Parliament on Immigration*.
48. Specifically, the low, medium and high immigration targets planned by IRCC for the years 2019 to 2021 were converted into rates. To create the total Canadian population denominator in each of the three years, it was assumed that the Canadian population would grow at the same annual rate as that observed between 2017 and 2018 (1.014%). To ensure a smooth trajectory, a linear interpolation was made between the most recent historical year (2017/2018) and 2020/2021 (the final year of IRCC's 3-year plan, when converted from calendar to census years).

In addition to representing the median value in the aggregate probability distribution from the respondents to the *2018 Survey of Experts on Future Demographic Trends* regarding what values the immigration rate in Canada could plausibly be in 2042/2043, the long-term medium immigration assumption of 8.3 per thousand is nearly identical to the most recently-observed immigration rate of 8.2 per thousand in 2017/2018. This assumption represents a balance of the various arguments in favour of future immigration increases with those suggesting immigration could reasonably decrease in the future. While the current federal government clearly intends to increase immigration in the short term, a change in federal leadership, a decrease in public support for immigration or other possible evolutions could result in a stabilization of immigration close to the rates experienced most recently.

Under the high immigration assumption, the annual immigration rate would evolve to reach 10.8 per thousand (or 1.08% of the population) in 2042/2043, holding constant for the remainder of the projection.

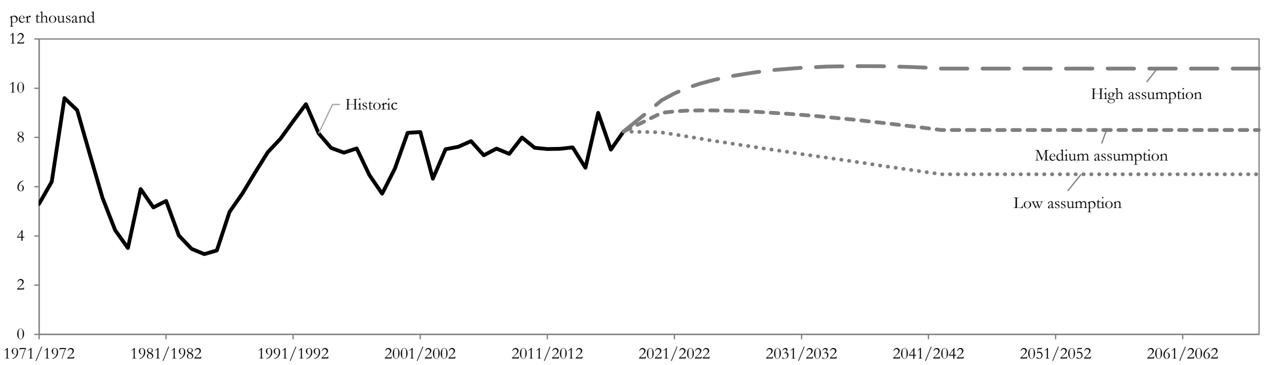
The long-term high immigration target of 10.8 immigrants per thousand represents the 90th percentile of the aggregate probability distribution from the respondents to the *2018 Survey of Experts on Future Demographic Trends* regarding what values the immigration rate in Canada could plausibly be in 2042/2043. The high immigration assumption reflects the growing momentum for a pro-higher-immigration stance, as exemplified by the immigration targets of the current federal government up to 2021 and the recommendations of key advisors of the current federal leadership, certain segments of the national media, and immigration stakeholders.

Under the low immigration assumption, the annual immigration rate would gradually decrease to reach 6.5 per thousand (or 0.65% of the total population) in 2042/2043, holding constant for the remainder of the projection.

The long-term low immigration assumption of 6.5 per thousand represents the 10th percentile of the aggregate probability distribution from the respondents to the *2018 Survey of Experts on Future Demographic Trends* regarding what values the immigration rate in Canada could plausibly be in 2042/2043. Under this assumption, a decrease in public support for immigration, capacity limits of various kinds or major shifts in the nature of the labour market could dampen the recent emphasis on higher immigration rates.

Figure 5.4 summarizes the historical and projected immigration rate per thousand at the Canada level.

Figure 5.4 Immigration rate (per thousand), Canada, historic (1971/1972 to 2017/2018) and projected (2018/2019 to 2067/2068) according to the low, medium and high immigration assumptions



Sources: Immigration, Refugees and Citizenship Canada and Statistics Canada, Demography Division.

Distribution of Canada's immigrants by province/territory, age and sex

There is a single, unique assumption regarding the distribution of Canada's immigrants by province/territory, age and sex. The possibility of developing multiple assumptions regarding the distribution was investigated but ultimately not pursued (see Appendix A5.2 for more details).

Historical data used in the calculation of the distribution of immigrants by age, sex and province/territory were adjusted using data from the Longitudinal Immigration Database (IMDB). Following the same procedure detailed in Chapter 5 of Bohnert et al. (2015), an adjustment factor was calculated for each province and territory, by major age group and sex, based on the degree of discrepancy between the intended destination of an immigrant stated before entering Canada and the province or territory of residence reported by the immigrant in income tax files during the first (reference) year in Canada.

Table 5.1 shows the change in the historical geographic distribution of Canada's immigrants following the implementation of the adjustment factor for each province and territory in 2017/2018. The adjustment results in a decrease in the proportion of Canada's immigrants residing in each of the Atlantic provinces, Quebec, Manitoba, Saskatchewan and Yukon, while the proportion residing in Ontario, Alberta, British Columbia, Northwest Territories and Nunavut are adjusted slightly upward.

Table 5.1 Distribution (percent) of immigrants by province and territory, unadjusted and adjusted, 2017/2018

Region	Unadjusted	Adjusted
	percent	
N.L.	0.4	0.3
P.E.I.	0.7	0.6
N.S.	1.7	1.5
N.B.	1.4	1.2
Que.	15.8	15.0
Ont.	43.7	44.9
Man.	4.7	4.2
Sask.	4.9	4.5
Alta.	12.8	13.3
B.C.	13.8	14.2
Y.T.	0.1	0.1
N.W.T.	0.1	0.1
Nvt.	0.0	0.0
Total	100.0	100.0

Source: IMDB.

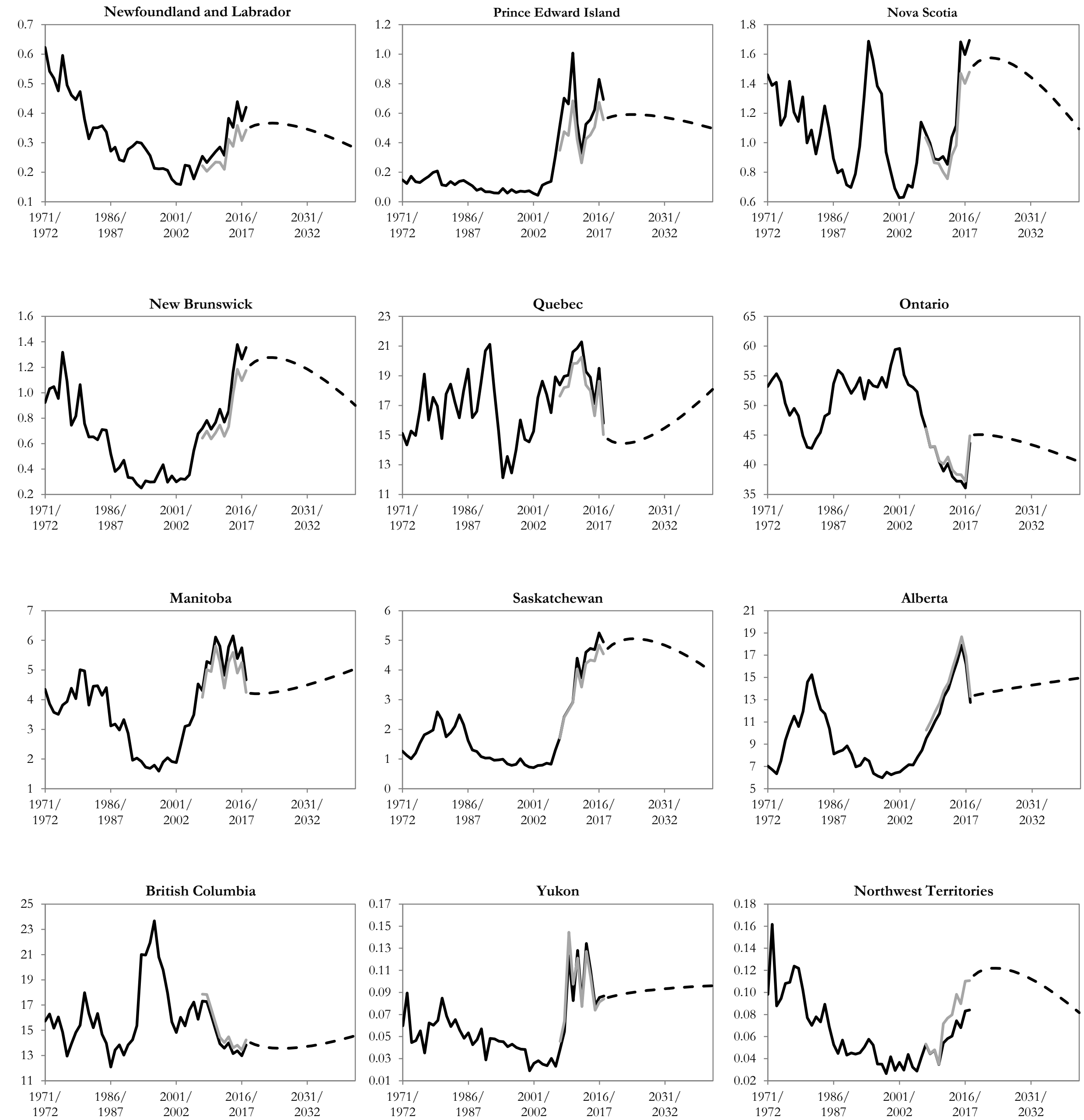
The assumption regarding the evolution of the geographic distribution of immigrants utilizes the same general short-term/long-term trajectory combination approach as described in Chapter 1: General Approach to Assumption Building. For the short-term trajectory, each province/territory's historical proportion of Canada's total immigrants is extrapolated based on the (adjusted) trends observed during the period 2007/2008 to 2017/2018.[49] For the long-term trajectory, target proportions are established for the year 2042/2043 based on the (adjusted) average proportion of immigrants going to each province/territory during the period 2007/2008 to 2017/2018. These short-term and long-term trajectories are combined into a single, unique assumption regarding the evolution of the geographic distribution of Canada's immigrants over the course of the projection.[50]

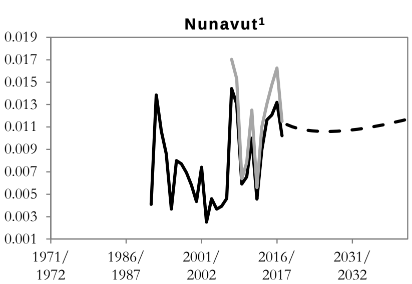
Under this approach, in the early years of the projection, it is assumed that recent trends in the distribution of Canada's immigrants will continue, while in the longer term, the geographic distribution of Canada's immigrants will reflect the patterns over a longer-term historical average. For instance, the share of Canada's immigrants residing in Nova Scotia would be maintained at their relatively elevated levels in the early years of the projection—reflecting a recent uptick in the share in the last few years of observed data. In the later years of the projection however, the share of immigrants going to Nova Scotia would gradually decrease to a level in line with the average proportion observed over the last 10 years. Figure 5.5 displays the assumptions regarding the projected distribution of Canada's immigrants among the provinces and territories over the course of the projection.

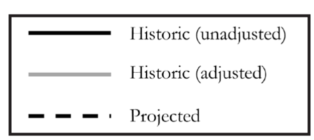
Within each province and territory, it is assumed that the distribution of immigrants by age and sex is equal to the average (adjusted) distribution observed over the period 2007/2008 to 2017/2018.

49. A set of linearly increasing weights is chosen such that the ratio of the weight applied to the most recent year is twice that of the weight applied to the first year in the selected reference period. This allows changes in age-specific rates in more recent years to have a larger influence on expected changes in the near future than changes in earlier years.
50. Since each province and territory's evolution was forecast independently, it was necessary to adjust the projected distributions of the 13 regions so that they summed to 100%. This adjustment was done by proportionally scaling up or down each province/territory's percentage.

Figure 5.5 Distribution (percent) of Canada's total immigrants by province and territory, historic (1971/1972 to 2017/2018) and projected (2018/2019 to 2067/2068)







1. Historical series for Nunavut begins at 1991/1992.

Note: The Y-axis is in percent.

Sources: Immigration, Refugees and Citizenship Canada and Statistics Canada, Demography Division.

Appendix A5.1: Assumptions in the form of numbers instead of rates

There is a strong argument for formulating immigration assumptions in terms of numbers as opposed to rates, as this is how planned immigration levels are presented publicly by IRCC. When we asked about this issue in the *2013 Opinion Survey on Demographic Trends*,[51] the number of arguments offered in support of using rates was nearly equal to those offered in support of using numbers. We ultimately decided to build our assumptions using rates for that edition of the projections, based on the following rationale as stated in the technical report accompanying those projections:

> "Since the population size changes over the course of the projection (the magnitude of which is unknown at the time of elaborating the assumptions), a fixed rate implies a varying number of new admissions but a stable contribution to the growth rate of the provinces and territories (as long as the rate is unchanged.)"[52]

There are also some indications that IRCC intends to formulate immigration level planning in terms of percentages, as opposed to numbers, even if final targets continue to be publicly presented in numbers. In its recent public opinion consultations, IRCC (2016; 2017c) found that the public, when informed about the current number of annual immigrants, became more likely to think that it is too high than when asked generally about their feelings on the current immigration levels. However, when current levels were presented instead as being "just under 1% of the total population", Canadians became more favourable in opinion of the levels.

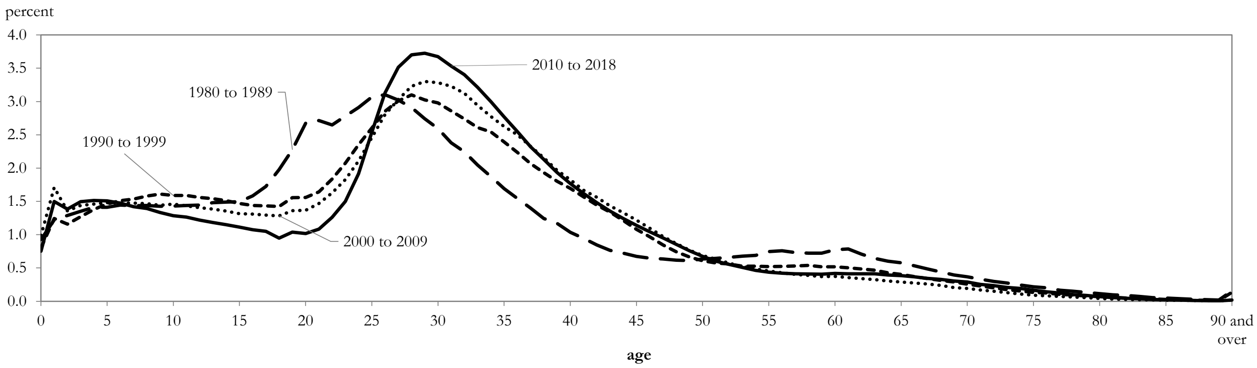
Further, IRCC noted that the concept of immigration levels reaching 1% in the future did not generate any significant 'pushback' or concerns from the Canadian public, and for many, it helped them make sense of the associated number and made it more acceptable in their minds. As mentioned in the main text, IRCC's news releases accompanying the most recent immigration plan emphasized repeatedly the fact that immigration levels would be "nearing 1 percent of the Canada's population in 2021" (IRCC 2018b). This suggests that the government may soon frame immigration plans publicly in terms of rates, as opposed to numbers. For these reasons, we formulate immigration assumptions as rates.

51. See Chapter 2 of Bohnert et al. (2015).
52. See Chapter 5 of Bohnert et al. (2015).

Appendix A5.2: The investigation of alternative assumptions for the distribution of immigrants by province, age and sex

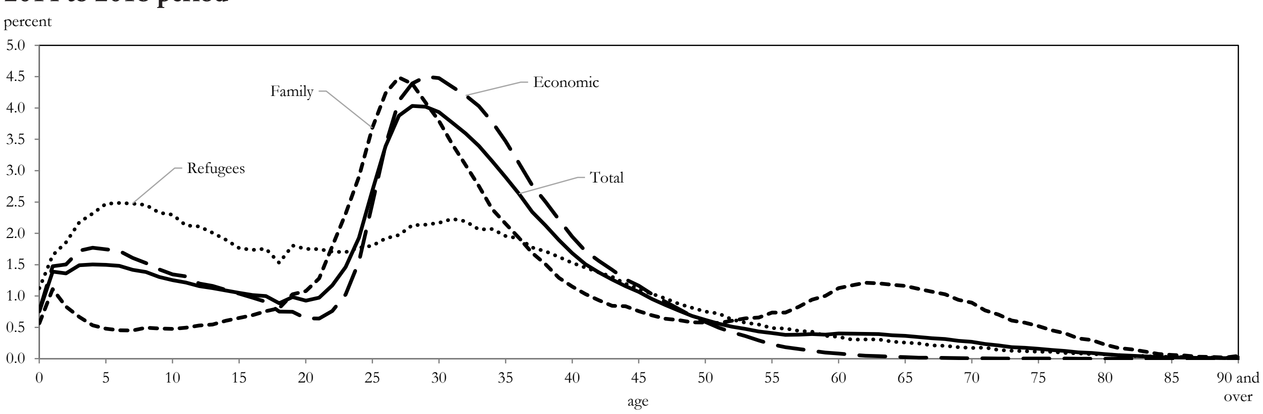
While it could be possible to create several different assumptions about the distribution of immigrants, we did not find any concrete evidence that, for example, the age or sex distribution of immigrants might change markedly from what has been observed in the recent past. As seen in Figure A5.1, the distribution of immigrants by age has become more concentrated in recent decades, with most immigrants falling between ages 25 and 49. This reflects in part the fact that economic immigrants have become more prevalent in recent years; economic immigrants are more concentrated in the core working ages (Figure A5.2). Since 2010, the median age of immigrants has been remarkably stable, averaging 30.5 years.

Figure A5.1 Distribution (percent) of immigrants to Canada, by age, average of selected periods, 1980 to 2018



Source: Immigration, Refugees and Citizenship Canada.

Figure A5.2 Distribution (percent) of immigrants to Canada, by age and category of admission, average of 2014 to 2018 period



Note: An 'other' category, of which the definition has varied over time, is not shown.

Source: Immigration, Refugees and Citizenship Canada.

For the short-term future, the Advisory Council on Economic Growth (2016) recently recommended that along with the increase in overall immigration levels, the relative proportion of economic-category immigration admissions should increase.[53] Recent consultations undertaken by IRCC also revealed that some stakeholders desired as much as 70% of annual admissions to come from the economic stream (IRCC 2017c). Such a proportional increase in economic immigrant admissions could cause the immigrant age distribution to become even more concentrated in the core working ages. However, IRCC did not release specific targets by category of admission in its most recent immigration plan (IRCC 2017a).

53. As stated on page 2 of the 2016 Advisory Council on Economic Growth report "Attracting the Talent Canada Needs Through Immigration", it is recommended to "increase permanent economic immigration by 150K by 2021, translating to 75K additional principal applicants per year and 75K of their family members".

There is also evidence that greater emphasis could be placed on transitioning international students from non-permanent to permanent residents. In 2016, the federal government announced reforms to the Express Entry program to make it easier for international students to become permanent residents in Canada following graduation (Zilio and Chiose 2016).[54] The Advisory Council on Economic Growth (2016) has also recently put forth the key recommendation that Canada "qualify more international students for permanent residency" (p. 2). A proportional increase of more recent university graduates in immigration admissions could also alter the age distribution of immigrants, providing a slight "rejuvenating" effect. Again, however, IRCC provided no concrete targets in terms of admissions in this regard in its most recent immigration plan.

Other factors such as the general aging of the world population, and in turn, the aging of the population of immigrants, are expected to continue in the coming decades (United Nations 2016), and could also impact the distribution of immigrants to Canada in the long-term. Due to the high level of uncertainty associated with the age distribution of immigrants in both the short and long term, it was determined that the most credible assumption would be to hold constant the age and sex distribution of immigrates observed within each province/territory over the last 10 years of historical data.

Furthermore, we did not find any information that would justify an assumption representing a marked change from the geographic distribution of immigrants observed recently. As seen in Figure A5.3, beginning in the early 2000s, there was a substantial shift in the geographic distribution of immigrants to Canada, with levels decreasing in Ontario, Quebec and British Columbia and increasing in other provinces, particularly Alberta, Manitoba and Saskatchewan. In more recent years, the share of immigrants selecting Nova Scotia or New Brunswick as their intended destination have also increased (while still accounting for less than 2% of all immigrants each).

Trends in the geographic distribution of immigrants tend to be tied to economic conditions in the respective regions which are very difficult to predict. Changes to immigration programs targeted at certain provinces and territories, such as the Provincial Nominee Program (PNP), could also warrant a modification to the geographic distribution assumption. Recently, immigrant service providers, stakeholders, economists and the public have called for even greater dispersion of immigrants away from the Toronto metropolitan area in particular and to Canada's less urban regions more generally in order to improve the economic outcomes of immigrants themselves and to better address regional labour and demographic needs (Riddell et al. 2016; Pelley 2017; IRCC 2016; 2017c; Griffith 2017).

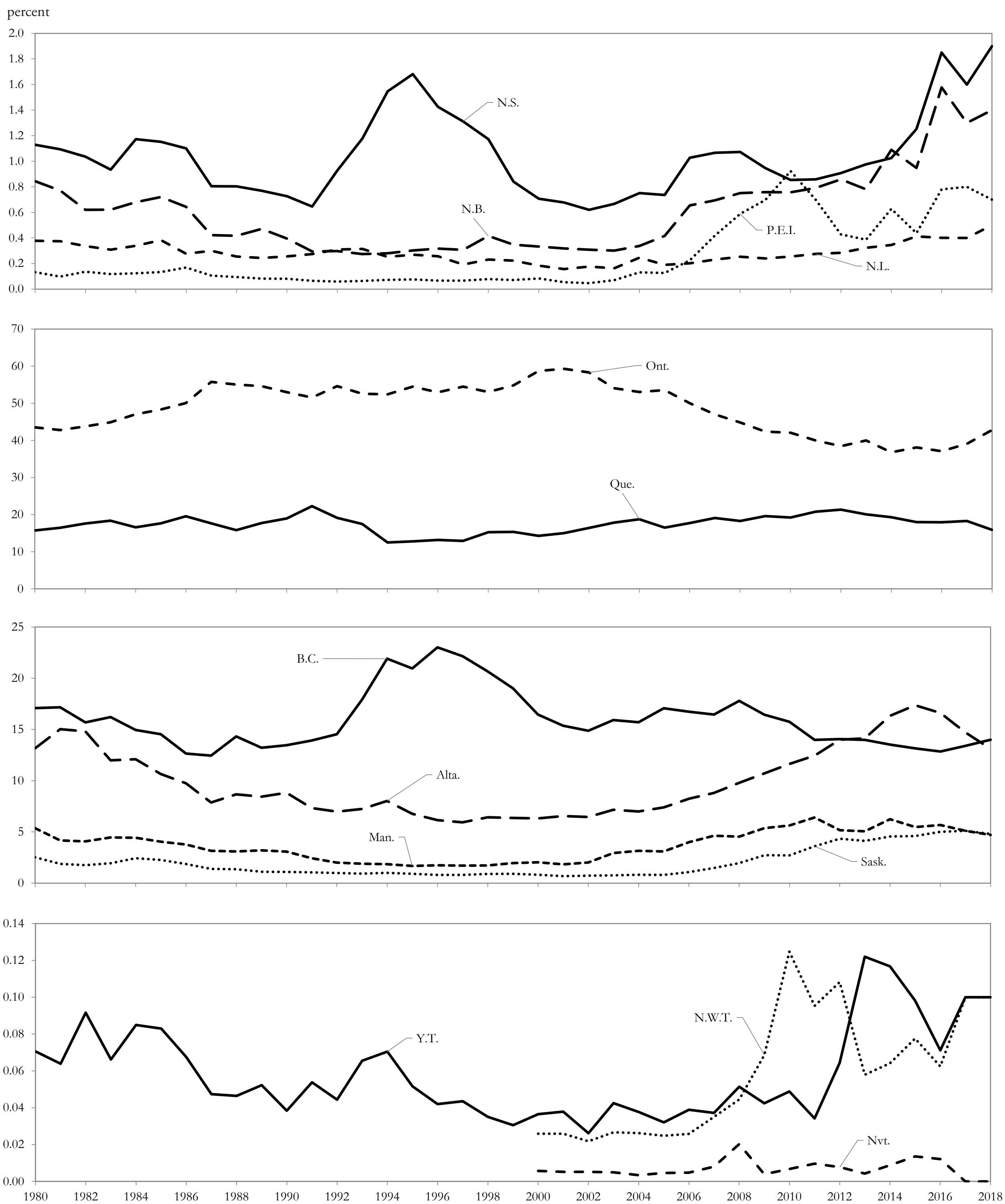
Recently, there have been efforts from both federal and provincial governments to increase immigration (and immigrant retention) to Atlantic Canada in particular:

- In 2017, the Federal Government launched the Atlantic Immigration Pilot Program to "test innovative approaches to permanent immigration to attract and retain skilled immigrants to meet labour market needs in the region." (IRCC 2017b, p. 16). However, no precise targets are attached to the Atlantic Immigration Pilot Program, nor is there an assurance it will continue in the future beyond its pilot state.
- In her November 2017 Speech From the Throne, Lt.-Gov. Antoinette Perry announced a goal of increasing the population of Prince Edward Island to 160,000 by 2022, to be achieved in part through various efforts that aim to maximize retention rates for new immigrants (Bissett 2017; Prince Edward Island Speech From the Throne 2017). The PNP has generally been regarded as an important factor in the decreasing concentration of immigrants within Canada's three most populous provinces (Bonikowska et al. 2015). However, the program has been less successful for Prince Edward Island in particular, where 90% of the province's new permanent residents are PNPs: It was found that between 2008 and 2013, the province retained less than one-third of the immigrants originally destined there (Van Huytsee 2016).
- In November 2017, the Premier of New Brunswick announced a new cabinet portfolio of Labour, Employment and Population Growth which will focus on attracting in-migration to the province through various means (Bundale 2017).

The success of these new approaches to increasing immigration to Atlantic Canada remains to be seen. The President of the Atlantic Canada Opportunities Agency recently remarked "The provincial government is listening to what the private sector has been saying for a couple years. We just can't find the people" (quoted by Bundale 2017). As was the case for the age and sex distribution of immigrants, the lack of clear signals that the geographic distribution will alter considerably in the future led us to develop a single assumption which continue short-term trends in the early years of the projection, gradually evolving to a longer-term historical average in the later years of the projection.

54. In 2016, then-Minister of Immigration, Refugees and Citizenship John McCallum stated "I believe international students are among the most fertile source of new immigrants for Canada…they should be first on our list of people who we court to Canada." (quoted in Zilio and Chiose 2016).

Figure A5.3 Distribution (percent) of immigrants to Canada according to the province or territory of destination, 1980 to 2018



Source: Immigration, Refugees and Citizenship Canada.

References

Adès, J., D. Fields, A. Macdonald and M. Stewart. 2016. "A Long-term View of Canada's Changing Demographics: Are Higher Immigration Levels an Appropriate Response to Canada's Aging Population?", The Conference Board of Canada, Ottawa.

Advisory Council on Economic Growth. 2016. "Attracting the Talent Canada Needs Through Immigration", https://www.budget.gc.ca/aceg-ccce/pdf/immigration-eng.pdf.

Alini, E. 2017. "450,000 immigrants a year? Canada could do it, report suggests", Global News, October 3, https://globalnews.ca/news/3782202/450000-immigration-target-canada/.

Anglin, H. 2016. "A Canada of 100 Million – Are They Insane?", iPolitics Insights, October 27, http://ipolitics.ca/2016/10/27/a-canada-of-100-million-are-they-insane/.

Bauder, H. 2014. "Re-imagining the nation: Lessons from the debates of immigration in a settler society and an ethnic nation", *Comparative Migration Studies*, volume 2, issue 1, pages 9 to 27.

Beaujot, R. 2017. "Canada: The case for stable population with moderately low fertility and modest immigration", *Canadian Studies in Population*, volume 44, issue 3-4, pages 185 to 190.

Beaujot, R. and L. Patterson. 2018. "Maximum Canada: What do Canadians wish to maximize? Review/Forum: Doug Saunders' Maximum Canada", *Canadian Studies in Population*, volume 45, issue 1-2, pages 67 to 78.

Bissett, K. 2017. "'Help newcomers feel at home': P.E.I. plans to boost population through immigration", The Toronto Star, November 14, https://www.thestar.com/news/canada/2017/11/14/help-newcomers-feel-at-home-pei-plans-to-boost-population-through-immigration.html.

Blatchford, A. 2016. "Finance Minister's key advisers want 100M Canadians by 2100", The Toronto Star, October 23, https://www.thestar.com/business/2016/10/23/finance-ministers-key-advisers-want-100m-canadians-by-2100.html.

Bloemraad, I. 2012. "Understanding "Canadian Exceptionalism" in immigration and pluralism policy", Transatlantic Council on Migration: A Project of the Migration Policy Institute, https://www.migrationpolicy.org/pubs/CanadianExceptionalism.pdf.

Bohnert, N., J. Chagnon and P. Dion. 2015. *Population Projections for Canada (2013 to 2063), Province and Territories (2013 to 2038): Technical Report on Methodology and Assumptions*, Statistics Canada catalogue no. 91-620-X.

Bonikowska, A., F. Hou and G. Picot 2015. "Changes in the Regional Distribution of New Immigrants to Canada", *Analytical Studies Branch Research Paper Series*, Statistics Canada catalogue no. 11F0019M – no. 366.

Bundale, B. 2017. "'They can't fill the jobs': New Brunswick adds new cabinet portfolio on population growth", The Toronto Star, September 6, https://www.thestar.com/news/canada/2017/09/06/they-cant-fill-the-jobs-new-brunswick-adds-new-cabinet-portfolio-on-population-growth.html.

Butler, D. 2014. "Canadians in the dark about immigration numbers: survey", Ottawa Citizen, August 27, http://ottawacitizen.com/news/national/canadians-in-the-dark-about-immigration-numbers-survey.

Caron Malenfant, É., P. Dion, A. Lebel and D. Grenier. 2011. "Immigration et structure par âge de la population du Canada: quelles relations?", *Cahiers québécois de démographie*, volume 40, issue 2, pages 239 to 265.

The Century Initiative. 2017. "Press Release: Canada Needs a Population of 100 Million by 2100", October 6, http://www.centuryinitiative.ca/2016/10/06/canada-needs-a-population-of-100-million-by-2100/.

Cochrane, D. and L. Laventure. 2017. "Waves of asylum seekers keep coming at illegal border crossing in Quebec", CBC News, August 2, http://www.cbc.ca/news/politics/asylum-seekers-quebec-roxham-1.4232608.

Corcoran, T. 2016. "100 million Canadians? We could only hope", The Financial Post, October 20, http://business.financialpost.com/opinion/terence-corcoran-100-million-canadians-we-could-only-hope.

Darroch, D. 2018. "Bigger, bolder, better: Historical images and Canadian population history: Review/Forum: Doug Saunders' Maximum Canada", *Canadian Studies in Population*, volume 45, issue 1-2, pages 62 to 66.

De Haas, H., K. Natter and S. Vezzoli. 2015. "Conceptualizing and measuring migration policy change", *Comparative Migration Studies*, volume 3, issue 15.

El-Assal, K. and D. Fields. 2017. "450,000 Immigrants Annually? Integration is Imperative to Growth", The Conference Board of Canada, Ottawa.

Forrest, M. 2017. "More than 32,000 asylum seekers have arrived in Canada so far in 2017", The National Post, September 28, http://nationalpost.com/news/politics/more-than-32000-asylum-seekers-have-arrived-in-canada-so-far-in-2017.

Griffith, A. 2017. "How to debate immigration issues in Canada", *Policy Options*, Institute for Research on Public Policy, September 1.

Grubel, H. 2016a. "Opinion: Doubts cast over push to have 100 million Canadians by 2100", The Vancouver Sun, November 11, http://vancouversun.com/opinion/opinion-100-million-in-2100-and-canadas-influence-on-the-world.

Grubel, H. 2016b. "A population of 100 million comes with a price; Are Canadians willing to pay it?", The Fraser Institute.

Harris, K. 2017. "Strengthen immigrant integration strategy or risk public backlash, experts warn", CBC News, October 29, http://www.cbc.ca/news/politics/canada-immigration-levels-2018-1.4370681.

Hou, F. and G. Picot. 2016. "Changing Immigrant Characteristics and Entry Earnings", *Analytical Studies Branch Research Paper Series*, Statistics Canada catalogue no. 11F0019M, no. 374.

Immigration, Refugees and Citizenship Canada. 2016. "Summary Report: Consultations and Public Opinion Research on the Future of Immigration in Canada", https://www.canada.ca/en/immigration-refugees-citizenship/corporate/transparency/consultations/public-opinion-research-future-immigration-canada.html.

Immigration, Refugees and Citizenship Canada. 2017a. "Annual Report to Parliament 2017", https://www.canada.ca/en/immigration-refugees-citizenship/corporate/publications-manuals/annual-report-parliament-immigration-2017.html.

Immigration, Refugees and Citizenship Canada. 2017b. "Departmental Plan 2017-2018", https://www.canada.ca/en/immigration-refugees-citizenship/corporate/publications-manuals/departmental-plan-2017-2018.html.

Immigration, Refugees and Citizenship Canada. 2017c. "2017 Consultations on Immigration Levels, Settlement and Integration – Final Report", https://www.canada.ca/en/immigration-refugees-citizenship/corporate/transparency/consultations/2017-consultations-immigration-levels-settlement-integration-final-report.html.

Immigration, Refugees and Citizenship Canada. 2017d. "News Release: Growing Canada's Economic Future", https://www.canada.ca/en/immigration-refugees-citizenship/news/2017/11/news_release_growingcanadaseconomicfuture.html.

Immigration, Refugees and Citizenship Canada. 2018a. "Departmental Plan 2018-2019", https://www.canada.ca/en/immigration-refugees-citizenship/corporate/publications-manuals/departmental-plan-2018-2019.html.

Immigration, Refugees and Citizenship Canada. 2018b. "News Release. Businesses and communities across Canada to benefit from increased immigration", October 31, https://www.canada.ca/en/immigration-refugees-citizenship/news/2018/10/businesses-and-communities-across-canada-to-benefit-from-increased-immigration.html.

Ipsos-Reid. 2017. "Global and Canadian Views on Immigration and Refugees", *Public Perspective*.

Jones, T. 2016. "The role of public opinion in US and Canadian immigration policies", *American Review of Canadian Studies*, volume 46, issue 1, pages 1 to 15.

Kirby, J. 2017. "Canada was supposed to have 100 million people by the 1970s", Macleans, June 28, http://www.macleans.ca/news/canada/canada-was-supposed-to-have-100-million-people-by-the-1970s/.

Lee, R. 2017. "National Academies of Sciences, Engineering and Medicine: The Economic and Fiscal Consequences of Immigration: Book Review", *Population and Development Review*, volume 43, issue 1, pages 168 to 173.

Levitz, S. 2017. “Number of newcomers in 2018 not only question for immigration plan”, The National Post, October 30, https://nationalpost.com/pmn/news-pmn/canada-news-pmn/numbers-of-newcomers-in-2018-not-only-question-for-federal-immigration-plan.

Loewen, C. 2017. “Hundreds of counter-protestors swarm far-right La Meute protest in Quebec City”, The National Post, August 20, http://nationalpost.com/news/canada/hundreds-of-counter-protesters-swarm-far-right-la-meute-protest-in-quebec-city.

Lu, Y. and F. Hou. 2017. “Transition from temporary foreign workers to permanent residents, 1990 to 2014”, *Analytical Studies Branch Research Paper Series*, Statistics Canada catalogue no. 11F0019M, no. 389.

Marois, G. 2018. “Does size really matter? Review/Forum: Doug Saunders’ Maximum Canada”, *Canadian Studies in Population*, volume 45, issue 1-2, pages 79 to 83.

McGrath, M. 2017. “Higher temperatures linked to EU asylum figures”, BBC News, December 22, http://www.bbc.com/news/science-environment-42446085.

Miller, E. 2018. “Minimum ecology in Maximum Canada: A review from an ecological economics perspective. Review/Forum: Doug Saunders’ Maximum Canada”, *Canadian Studies in Population*, volume 45, issue 1-2, pages 84 to 88.

Missirian, A. and W. Schlenker. 2017. “Asylum applications respond to temperature fluctuations”, *Science*, volume 358, pages 1,610 to 1,614.

Organization for Economic Co-operation and Development. 2013. “Chapter 3: The fiscal impact of immigration in OECD countries”, *International Migration Outlook 2013*.

Organization for Economic Co-operation and Development. 2014. “Is migration good for the economy?”, *Migration Policy Debates*, May.

Organization for Economic Co-operation and Development. 2016a. “Chapter 4: International migration following environmental and geopolitical shocks: How can OECD countries respond?”, *International Migration Outlook 2016*.

Organization for Economic Co-operation and Development. 2016b. “Recruiting for Success: Challenges for Canada’s Labour Migration System”, International Migration Division.

The National Academies of Sciences, Engineering and Medicine. 2016. *The Economic and Fiscal Consequences of Immigration*, Blau, F.D. and C. Mackie (editors), The National Academies Press.

Paquet, G. 2017. “Stationary population as a Fata Morgana”, *Canadian Studies in Population*, volume 44, issue 3-4, pages 179 to 184.

Pelley, L. 2017. “Toronto could welcome almost 170,000 immigrants over the next 3 years – are we ready?”, CBC News, November 5, http://www.cbc.ca/news/canada/toronto/toronto-immigration-1.4383867.

Picot, G and F. Hou. 2014. “Immigration, Low Income and Income Inequality in Canada: What’s New in the 2000s?”, *Analytical Studies Branch Research Paper Series*, Statistics Canada catalogue no. 11F0019M, no. 364.

Ponomare, S. 2017. “After Syria initiative, UN looks to Canada as a refugee haven”, The Globe and Mail, November 3, https://beta.theglobeandmail.com/news/politics/after-syria-initiative-un-looks-to-canada-as-a-refugee-haven/article36836631/?ref=http://www.theglobeandmail.com.

Prince Edward Island Speech From The Throne. 2017. Opening of the Third Session of the Sixty-fifth General Assembly of Prince Edward Island. November 14.

Rees, W.E. 2018. “The end (of growth) is nigh: Review/Forum: Doug Saunders’ Maximum Canada”, *Canadian Studies in Population*, volume 45, issue 1-2, pages 89 to 92.

Riddell, W.C., C. Worswick and D.A. Green. 2016. “How does increasing immigration affect the economy?”, *Policy Options*, Institute for Research on Public Policy, November 2.

Robson, W.B.P. and P. Mahboubi. 2018. “Inflated Expectations: More Immigrants Can’t Solve Canada’s Aging Problem on Their Own”, C.D. Howe Institute, E-Brief: Demographics and Immigration, March 13.

Romaniuk, A. 2017. "Stationary population, immigration, social cohesion, and national identity: What are the links and the policy implications? With special attention to Canada, a demographer's point of view", *Canadian Studies in Population*, volume 44, issue 3-4, pages 165 to 178.

Sachs, J.D. 2016. "Toward an International Migration Regime", *American Economic Review: Papers & Proceedings*, volume 106, issue 5, pages 451 to 455.

Saunders, D. 2012. "What would a Canada of 100 million feel like? More comfortable, better served, better defended", The Globe and Mail, May 17, https://www.theglobeandmail.com/news/national/time-to-lead/what-would-a-canada-of-100-million-feel-like-more-comfortable-better-served-better-defended/article4186906/.

Studin, I. 2017. "Review: Doug Saunders' Maximum Canada argues the more the merrier", The Globe and Mail, October 6, https://www.theglobeandmail.com/arts/books-and-media/book-reviews/review-doug-saunderss-maximum-canada-argues-the-more-the-merrier/article36510614/.

Tasker, J.P. 2017. "Far-right, anti-fascist protestors temporarily shut down Quebec border crossing", CBC News, September 30, http://www.cbc.ca/news/politics/far-right-antifa-clash-across-canada-1.4315053.

Todd, D. 2017. "High migration can suppress wages", Vancouver Sun, November 20, http://vancouversun.com/opinion/columnists/douglas-todd-high-migration-might-suppress-wages-in-some-places-and-in-some-jobs.

United Nations. 2016. *International Migration Report 2015: Highlights*, Department of Economic and Social Affairs, Population Division (ST/ESA/SER.A/375).

Van Huytsee, M. 2016. "Interprovincial mobility: Retention rates and net inflow rates", Policy Research Division, Immigration, Refugees and Citizenship Canada, R33-2016.

Willekens, F., D. Massey, J. Raymer and C. Beauchemin. 2016. "International migration under the microscope", *Science*, volume 352, issue 6288, pages 897 to 899.

Zilio, M and S. Chiose. 2016. "Ottawa looks to ease international students' path to permanent residency", The Globe and Mail, March 14, https://www.theglobeandmail.com/news/politics/ottawa-looks-to-ease-international-students-path-to-permanent-residency/article29242266/.

Chapter 6: Projection of Emigration

by Elham Sirag and Patrice Dion

Introduction

Despite having a relatively minor impact on population growth, emigration – consisting of permanent emigrants, returning emigrants, and temporary emigrants – is one of the most difficult components of demographic change to measure accurately.[55] This is due largely to issues with data availability; Canadians who have left the country, whether on a permanent or temporary basis, are not required to give notice of their departure. In addition, the conceptual ambiguity associated with distinguishing between types of emigrants (i.e. permanent and temporary) makes obtaining precise estimates of each of the three sub-components of emigration a challenging task (Bérard-Chagnon 2018).

As a result of these conceptual issues, the original *2018 Survey of Experts on Future Demographic Trends* did not include content on emigration. Rather, a modified version of the survey with questions pertaining to emigration was circulated among select experts within Statistics Canada's Demography Division with significant exposure to the limitations of the data to assist in the derivation of long-term emigration assumptions. Final assumptions were derived by combining survey results with short-term assumptions based on historical trends, as outlined in Chapter 1: General Approach to Assumption Building.

Results of the *2018 Survey of Experts on Future Demographic Trends*

A total of nine experts responded to the emigration portion of the modified survey. Respondents were first asked to briefly describe the main factors, i.e., trends, theories, and plausible new developments that would likely influence the evolution of the *gross migraproduction rate* (GMPR) in Canada in 2043.[56] The GMPR, an alternative measure of emigration to the crude emigration rate,[57] is defined as the sum of age-specific (from ages 0 to 110 and over) emigration rates. It can be interpreted as the number of emigrations an individual could expect to make over the course of his or her lifespan, were the current age-specific rates to apply, and assuming he or she survives to the oldest age group. Experts were asked to formulate their responses in terms of the GMPR because, unlike the crude emigration rate, it has the advantage of being impervious to changes in the age structure of the population.

On average, experts envisioned a slight increase in the GMPR from its current level over the course of the next 25 years. The primary argument provided by experts is the growing number of immigrants received in recent years, with the rationale being that immigrants are more likely to emigrate (e.g. to return to their home countries) than persons born in Canada. Other arguments offered in support of increased emigration include the changing profile of recent immigrants to Canada (from less skilled to moderately/highly skilled), the economic development of countries that provide immigrants to Canada, and the increase in educational attainment of Canadians (potentially leading to phenomena such as a "brain drain").

A few experts argued the possibility of either no change or a slight decrease in emigration. This is attributed primarily to the economic and political stability experienced in Canada relative to the home countries of various immigrants.

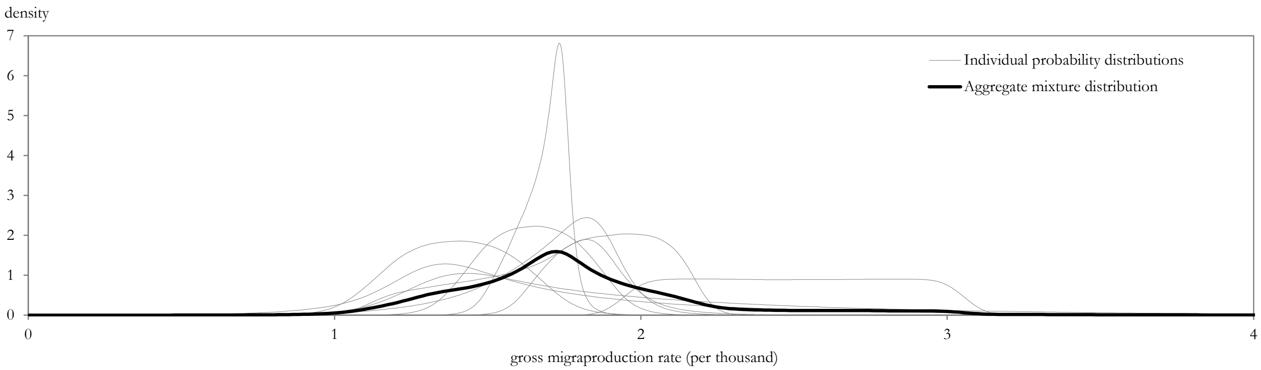
Following their qualitative arguments, experts were asked to communicate their views about the likely evolution of the GMPR in Canada in 2043 quantitatively; that is, by building a probability distribution that exemplified their opinion, and level of uncertainty, regarding what values the GMPR could take in 25 years. More specifically, each expert was asked to provide the following parameters:

a. Lower and upper bounds of a range covering nearly all plausible values of the GMPR in Canada in 2043;
b. Their level of confidence (expressed in percent, with a minimum of 90% imposed) that the range specified in Step (a) will contain the true value of the GMPR;
c. The median value of the plausible range provided in Step (a), such that they expect an equal (50-50) chance that the GMPR lies above or below the median;
d. Probabilities that the GMPR 2043 will fall below and above the mid-points between:
    - the lower bound of the plausible range provided in Step (a) and the median provided in Step (c); and
    - the median provided in Step (c) and the upper bound of the plausible range provided in Step (a).

55. See *Population and Family Estimation Methods at Statistics Canada*, Statistics Canada catalogue no. 91-528-X, for a description of the methodology used to obtain estimates of emigration, including the associated challenges.
56. Experts were asked only about permanent emigration on the survey.
57. The crude emigration rate is defined as the proportion of emigrants in the total population (per thousand).

In the survey, a visual representation of the probability distribution resulting from these parameters was displayed, allowing the experts to evaluate their responses. Experts were then encouraged to modify their inputs until they arrived at a satisfactory visual representation of their beliefs. The individual probability distributions of nine experts regarding their views about the probable GMPR in Canada in 2043, as well as the resulting aggregate probability distribution, are shown in Figure 6.1.

Figure 6.1 Gross migraproduction rate, Canada, 2043: Individual probability distributions and aggregate mixture distribution of the respondents of the *2018 Survey of Experts on Future Demographic Trends*



Source: Statistics Canada, Demography Division.

Emigration assumptions

Permanent emigration

Permanent emigrants, referred to simply as emigrants, are defined as Canadian citizens or immigrants who have left Canada to establish permanent residence in another country. As noted, long-term assumptions for emigration are formulated in terms of the GMPR. Historically, the GMPR has been relatively stable, notably in recent years, fluctuating between 1.45 and 1.68 per thousand between 2006/2007 and 2016/2017.

The approach used to derive assumptions is described in Chapter 1: General Approach to Assumption Building. The method combines short-term assumptions based on the extrapolation of recent trends in the GMPR, based on a reference period of 2006/2007 to 2016/2017, with long-term assumptions derived from survey responses. In particular, long-term low, medium, and high assumptions were obtained using the 10th, 50th (median), and 90th percentiles, respectively, of the aggregate probability distribution of the GMPR.

Under the low emigration assumption, the GMPR would reach a level of 1.34 per thousand in 2042/2043, after which it is held constant for the remainder of the projection. Similarly, under the medium assumption, the GMPR would gradually increase to attain a level of 1.74 per thousand in 2042/2043, again holding constant throughout the remainder of the projection. Finally, under the high assumption, the GMPR would further increase to attain a level of 2.33 per thousand in 2042/2043, holding constant thereafter.

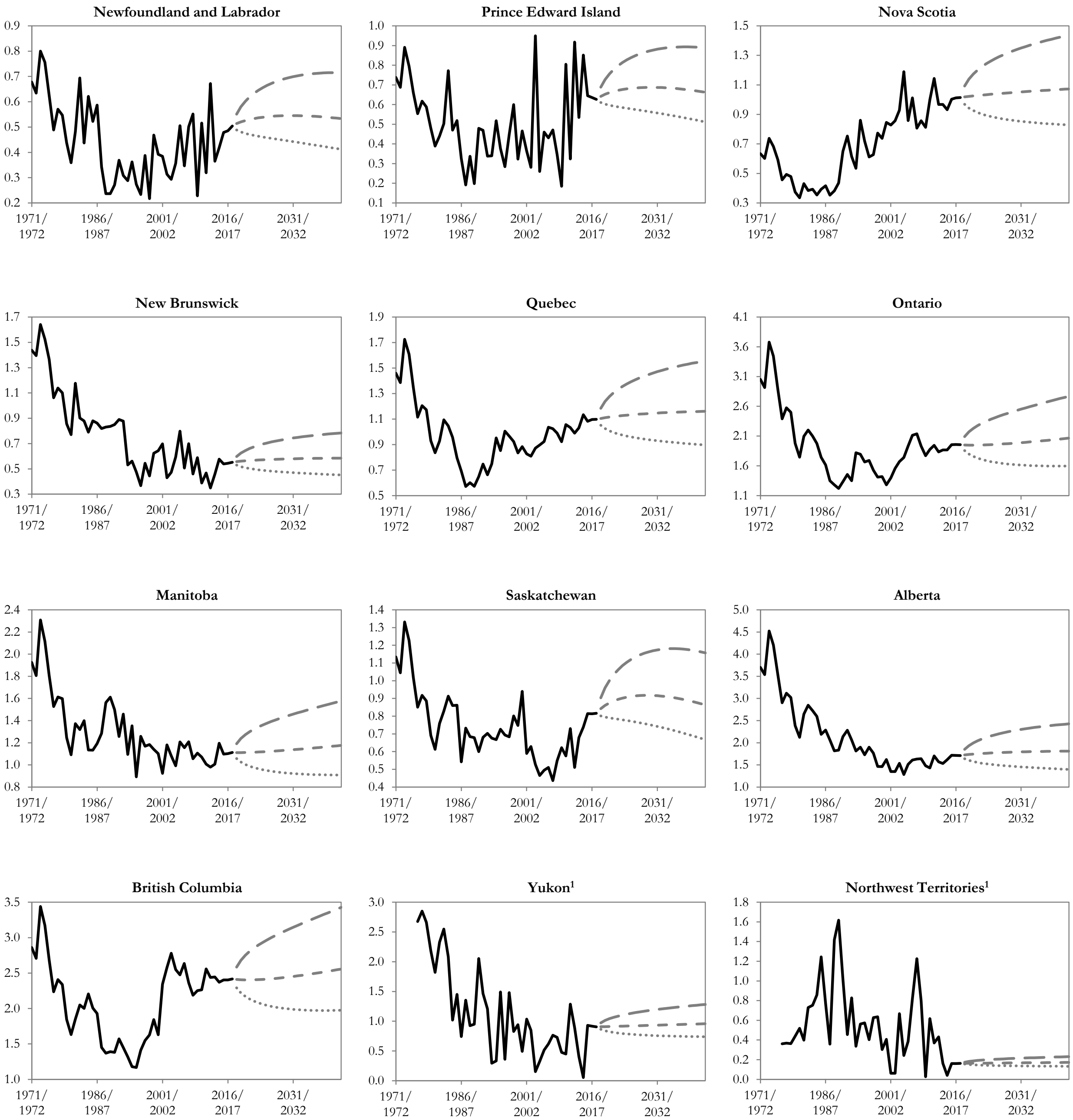
Figure 6.2 displays the historic GMPRs (1971/1972 to 2017/2018) along with the projected GMPRs (2018/2019 to 2042/2043) according to the low, medium, and high assumptions for each of the provinces and territories.

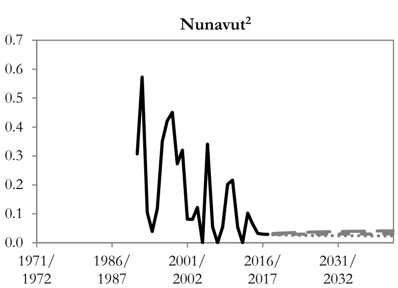
Returning emigration

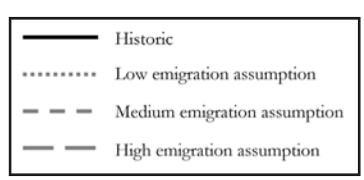
Returning emigrants are defined as Canadian citizens or immigrants who have returned to Canada to re-establish a permanent residence after having previously emigrated. Much like permanent emigration, the crude rate of returning emigrants has also remained stable, decreasing slightly from 1.22 per thousand in 2006/2007 to 1.13 per thousand in 2016/2017.

Returning emigration being an even more difficult component to estimate than permanent emigration, assumptions for this component were derived indirectly, rather than from expert elicitation. More specifically, an average of the ratio of returning emigrants to permanent emigrants was computed for the years 2007/2008 to 2016/2017, and then applied to the long-term low, medium, and high targets for permanent emigration obtained from the survey to derive long-term low, medium, and high assumptions for returning emigration. Short-term assumptions were obtained in the same manner

Figure 6.2 Gross migraproduction rate, provinces and territories, historic (1971/1972 to 2017/2018) and projected (2018/2019 to 2042/2043) according to the low, medium and high emigration assumptions







1. Historical series for Yukon and the Northwest Territories begin in 1976/1977.
2. Historical series for Nunavut begins in 1991/1992.

Note: The Y-axis is per thousand.

Source: Statistics Canada, Demography Division.

as for permanent emigration, based on the extrapolation of trends in the age-specific returning emigration rates throughout the period 2006/2007 to 2016/2017. The short-term and long-term assumptions were then combined using the method described in Chapter 1: General Approach to Assumption Building.

An implication of this approach is that the ratio of the rate of returning emigration to that of permanent emigration is assumed to be close to constant throughout the duration of the projection. Given that it has remained relatively stable historically – fluctuating between approximately 51% and 60% throughout the ten-year reference period – it was deemed a plausible assumption.

The low, medium, and high assumptions for permanent emigration described in the previous section are formulated in terms of the GMPR. Consequently, targets for the returning rate of emigration must also be formulated in terms of a gross migraproduction rate for returning emigrants (i.e. by using the sum of the age-specific rates of returning emigration). The average of the ratio of the GMPR of returning emigrants to the GMPR of permanent emigrants between 2007/2008 and 2016/2017 was 56.6%. The resulting low, medium, and high assumptions for the gross migraproduction rate of returning emigrants are 0.76, 0.98, and 1.32 per thousand in 2042/2043, respectively. The rates are held constant for the remainder of the projection.

Temporary emigration

Temporary emigrants are Canadian citizens or immigrants who are living abroad temporarily and no longer have a usual place of residence in Canada. A single assumption was derived for the rate of temporary emigration, based on an average of the observed rates between 1991/1992 and 2015/2016 for each province and territory. At the Canada level, this rate was 0.75 temporary emigrants per thousand.

A summary of the assumptions for each sub-component of emigration by province and territory can be found in Table 6.1.

Table 6.1 Assumptions for each component of emigration, Canada, provinces and territories, 2042/2043

Assumption / Region	Low assumption			Medium assumption			High assumption		
	Emigration	Returning emigration	Temporary emigration	Emigration	Returning emigration	Temporary emigration	Emigration	Returning emigration	Temporary emigration
	per thousand								
Canada	1.3	0.8	0.8	1.7	1.0	0.8	2.3	1.3	0.8
Newfoundland and Labrador	0.4	0.1	0.3	0.5	0.2	0.3	0.7	0.2	0.3
Prince Edward Island	0.5	0.2	0.3	0.7	0.2	0.3	0.9	0.3	0.3
Nova Scotia	0.8	0.5	0.4	1.1	0.6	0.4	1.4	0.9	0.4
New Brunswick	0.5	0.3	0.3	0.6	0.3	0.3	0.8	0.5	0.3
Quebec	0.9	0.5	0.5	1.2	0.6	0.5	1.6	0.9	0.5
Ontario	1.6	1.0	0.9	2.1	1.2	0.9	2.8	1.7	0.9
Manitoba	0.9	0.6	0.5	1.2	0.8	0.5	1.6	1.1	0.5
Saskatchewan	0.7	0.4	0.4	0.9	0.5	0.4	1.2	0.6	0.4
Alberta	1.4	0.8	0.8	1.8	1.1	0.8	2.4	1.4	0.8
British Columbia	2.0	1.0	1.2	2.6	1.3	1.2	3.4	1.7	1.2
Yukon	0.7	0.0	0.7	1.0	0.1	0.7	1.3	0.1	0.7
Northwest Territories	0.1	0.0	0.6	0.2	0.1	0.6	0.2	0.1	0.6
Nunavut	0.0	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.5

Source: Statistics Canada, Demography Division.

Acknowledgements

We would like to thank the following members of Statistics Canada's Demographic Estimates Program: Julien Bérard-Chagnon, David Binet, Patrick Charbonneau, Hubert Denis, Anna Mao and Mélanie Meunier. These individuals volunteered their time and expertise to complete a modified version of the *2018 Survey of Experts on Future Demographic Trends*, the results of which were used in the formulation of the emigration assumptions.

References

Bérard-Chagnon, J. 2018. "Measuring emigration in Canada: Review of available data sources and methods", *Demographic Documents*, Statistics Canada catalogue no. 91F0015M, no. 14.

Chapter 7: Projection of Non-Permanent Residents

by Nora Galbraith, Elham Sirag and Jonathan Chagnon

Introduction

Non-permanent residents (NPRs), or temporary residents,[58] are persons who have been legally granted the right to live in Canada on a temporary basis under the authority of a temporary resident permit, along with members of their family living with them. They include individuals holding visitor permits, work permits, student permits, special temporary residents' permits, as well as refugee status claimants (Statistics Canada 2016).

Worldwide, the number of temporary residents have generally increased in recent years, a result of many factors including the growth of international students and temporary workers, globalization and the creation of new economic communities such as the European Union (Florida 2005; Castles and Miller 2009; Lu and Hou 2017).

As with permanent immigration, anticipating future trends in NPR levels is difficult, since admissions are driven mainly by economic needs, geopolitical developments and political decisions which can be unpredictable in both the short and long-term. Furthermore, unlike permanent immigration, the federal government does not publicly release planned annual admission targets for NPRs, nor does it discuss in a more general manner broad goals for NPR in its official Departmental Plans (IRCC 2018).

Note to users

Assumptions regarding non-permanents residents were formulated based on analyses of recent trends in the annual number (stock) of NPR as produced by Statistics Canada's Demographic Estimates Program (DEP). However, there are limitations associated with these data. First, due to the methodology used, it is possible that these estimates differ from those released by Immigration, Refugees and Citizenship Canada (IRCC). As a result, it is possible that these estimates overestimate the number of NPR in the country.

This overestimation can be explained in two ways. First, it is possible that a permit (study or work) grants residency permission to more than one person. Besides the principal applicant, dependant persons can also be attached to a permit (generally, the spouse/partner or child(ren)). Given the fact that these dependant persons can also obtain study or work permits later on their own, there can be duplications of individuals that the DEP cannot currently recognize and eliminate.

Moreover, it is not possible for the DEP to define precisely when NPR leave the country. In cases when NPR do not obtain permanent residency or are the subject of a removal decision, the DEP makes the assumption that those NPR stay in Canada until the latest validity date of the permits that were granted to them. In the case of refugee status claimants, the DEP adds two years to the latest validity date of their permits or to their last presence in the IRCC files.

Information from the 2016 Reverse Record Check (RRC) indicates that the number of NPR in the country, as calculated by the DEP, was overestimated by 10% to 15% as of 2016 Census Day. With the increasing number of NPR in Canada's population, this potential error is no longer negligible and must be underlined with more emphasis.

For these reasons, Statistics Canada's DEP does not currently publish estimates of the number of NPRs, but instead, it publishes the net changes in the population of NPRs, measured on a quarterly or annual basis.[59]

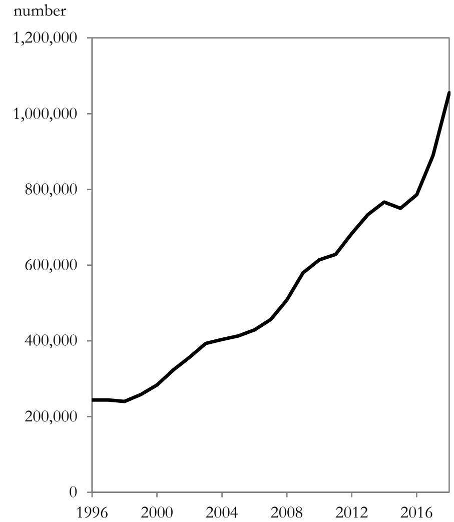
Despite their limitations, these historical estimates of the number of NPR are useful for projecting the future evolution of the NPR population, which will affect the size of the total population.[60] Principally, it is more conceivable to envision the future number of NPR in the longer-term future—which implies also considering the cumulative effects (both direction and size) of year-to-year changes throughout the interim period—than to attempt to imagine the annual flow of NPR in a distant future year in isolation. This consideration was particularly important given our assumption-building method (detailed later in the chapter), whereby we asked experts to envision the size of the NPR population in 25 years (2043).

58. Immigration, Refugees and Citizenship Canada uses the term "temporary resident" rather than non-permanent resident.
59. The historical estimates of the total annual number of NPR were provided as a custom table to the Population Projections team at Statistics Canada by the DEP. These estimates are accessible on demand. For more information, please contact statcan.demography-demographie.statcan@canada.ca.
60. Statistics Canada includes NPR in the population count in its censuses. As a result, NPR are also included in the formulation of DEP's population.

Trends in the number of non-permanent residents

Between 1996 and 2016, the total number of NPR in Canada rose gradually and fairly steadily, from 243,800 to 785,680 (Figure 7.1). More recently, the total number of NPR has increased substantially, to 889,280 in 2017 and to 1,055,010 in 2018—the latter value representing the highest number on record. This large influx may have related in part to the establishment in 2017 by Immigration, Refugees and Citizenship Canada (IRCC) of the Global Skills Strategy, a program offering among other features a two-week expedited processing of select work permits (IRCC 2018).[61]

Figure 7.1 Total number of non-permanent residents, Canada, 1996 to 2018



Source: Statistics Canada, Demography Division.

The federal government has also recently placed greater emphasis on creating incentives for international students to come to Canada, primarily via reforms to the Express Entry program which facilitate the transition of international students to permanent residents in Canada following graduation (Zilio and Chiose 2016). These developments follow the recommendations of the Minister of Finance-appointed Advisory Council on Economic Growth (2016), who recently put forth the key recommendation that Canada "qualify more international students for permanent residency" (p. 2).[62]

Public opinion can influence the levels of international migration to Canada (Jones 2016). Unlike many other countries, the Canadian public at large tends to favour permanent immigration over temporary migrants (Bloemraad 2012; Jones 2016). If the number of non-permanent residents in Canada continues its recent strong increasing trend (Bauder et al. 2014; Lu and Hou 2017) and the public begins to perceive that this number is becoming too high, public support for immigration could deteriorate in response (Bloemraad 2012).

When asked to note key trends influencing future immigration levels, several respondents to the *2018 Survey of Experts on Future Demographic Trends* mentioned the growth of nationalism, protectionism and populism in many parts of the world.[63] This trend could lead to both greater supply of NPRs—if other countries reduce admissions, for example—and greater demand for NPR in Canada, if anti-immigration sentiments also grow in Canada, leading to increased public support for non-permanent resident admissions over permanent ones. On the other hand, it was mentioned by several experts that technological advancements such as automatization and artificial intelligence could diminish the perceived need for temporary workers to fill anticipated labour shortages.

Methodology

The NPR population is projected in parallel with the permanent resident population. However, unlike the permanent resident population, the NPR population is not subjected to the risks of dying or emigrating during the projection. In addition, immigration does not affect the number of NPRs, since immigrants are, by definition, permanent residents. With regard to births, since children born in Canada are automatically Canadian citizens, regardless of the parents' status (permanent residents, NPR or visitors), the fertility of female NPR only affects the projected population of permanent residents.[64] Consequently, the growth of the NPR population depends solely on the annual net counts, that is, the difference between the number of NPR who enter Canada and the number who leave.

61. The program also introduced a dedicated service channel for companies making significant investments in the Canadian economy, and included new work permit exemptions for highly skilled talent coming for 30 days or less and researchers coming for 120 days or less (IRCC 2018, page 29).
62. In 2016, then-Minister of Immigration, Refugees and Citizenship John McCallum stated "I believe international students are among the most fertile source of new immigrants for Canada…they should be first on our list of people who we court to Canada." (quoted in Zilio and Chiose 2016).
63. For more details, see Chapter 5: Projection of Immigration.
64. For this reason, female NPR are subjected to the fertility component during the projection, and their children join the cohort of newborns in the permanent resident population.

In addition to the flow volumes, the characteristics of people entering and leaving the country must be determined. In this regard, a very simple assumption is made: every person who leaves is assumed to be replaced by a person of the same sex and age and living in the same province or territory. Canada's NPR population is therefore projected as a stable population that does not age and always keeps a similar age structure, even becoming a stationary population, with an invariable count in years when the projected annual net number is zero.

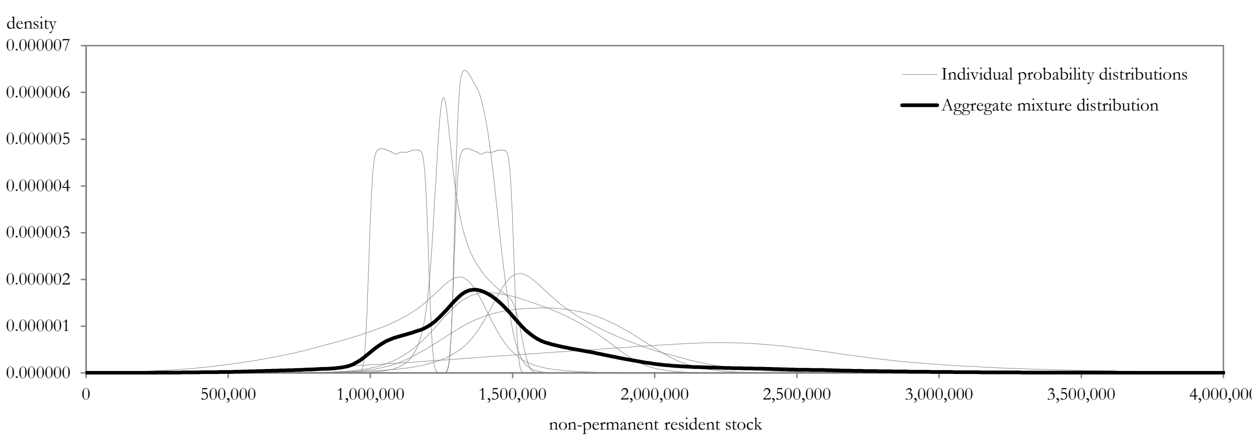
A modified version of the *2018 Survey of Experts on Future Demographic Trends*[65] with questions pertaining to NPR was circulated among select experts within Statistics Canada's Demography Division. In particular, members involved in Statistics Canada's Demographic Estimates Program (DEP) with significant experience working with NPR data were asked to assist in the derivation of long-term projection assumptions.

Respondents to the elicitation exercise were also asked to provide qualitative arguments to support their quantitative estimates about the future evolution of the NPR population in Canada. Generally, experts expected that the level of non-permanent residents would increase in the future due to several factors, including: likely continued increases in recruitment efforts and intake of international students; population aging driving increases in temporary workers to fill perceived labour shortages and specific roles (e.g., the aging of the large baby-boom cohort is expected to increase demand for formal care providers); possible increase in environmental crises leading to an increase in asylum claimants; increased utilization of non-permanent residency as a means to achieve permanent residency in Canada; and growing mobility of the labour force globally. Nearly all respondents pointed out the large volatility of NPR trends due to its close ties to movements in federal/provincial political climate and economic cycles.

The respondents to the survey were also asked to provide an estimate of the plausible range of the total number of NPR in Canada in the year 2043. As seen in Figure 7.2, respondents provided a considerable range of the future number of NPR in Canada, with somewhat more uncertainty about the potential upper limit (note the right-skewedness of the aggregate distribution).

Long-term low, medium, and high NPR targets were obtained using the 10th, 50th (median), and 90th percentiles, respectively, of the experts' aggregate probability distribution of the plausible range of the number of NPR in Canada in 2043. These long-term targets were combined with short-term targets based on the extrapolation of historical trends by province/territory from 2008 to 2018 to derive final assumptions, as per the approach outlined in Chapter 1: General Approach to Assumption Building.

Figure 7.2 Number of non-permanent residents, Canada, 2043: Individual probability distributions and aggregate mixture distribution of the respondents of the *2018 Survey of Experts on Future Demographic Trends*



Source: Statistics Canada, Demography Division.

65. See Chapter 2: *2018 Survey of Experts on Future Demographic Trends* for more information.

Assumptions

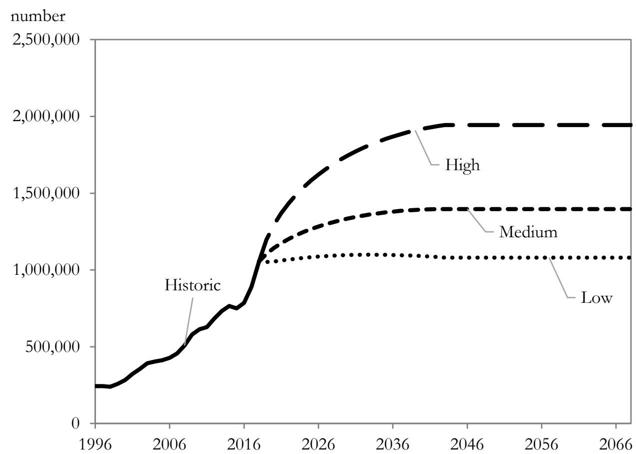
Under the medium assumption, the total number of NPR in Canada would gradually and steadily increase from 1,055,010 in 2018 to 1,397,060 in 2043, a level that is held constant for the remainder of the projection.

Under the high assumption, the total number of NPR in Canada would increase more rapidly to 1,944,400 in 2043, holding constant for the remainder of the projection.

Under the low assumption, the total number of NPR in Canada would increase modestly up to 2033 (1,099,690) before gradually decreasing to 1,080,910 by 2043, holding constant for the remainder of the projection (Figure 7.3).

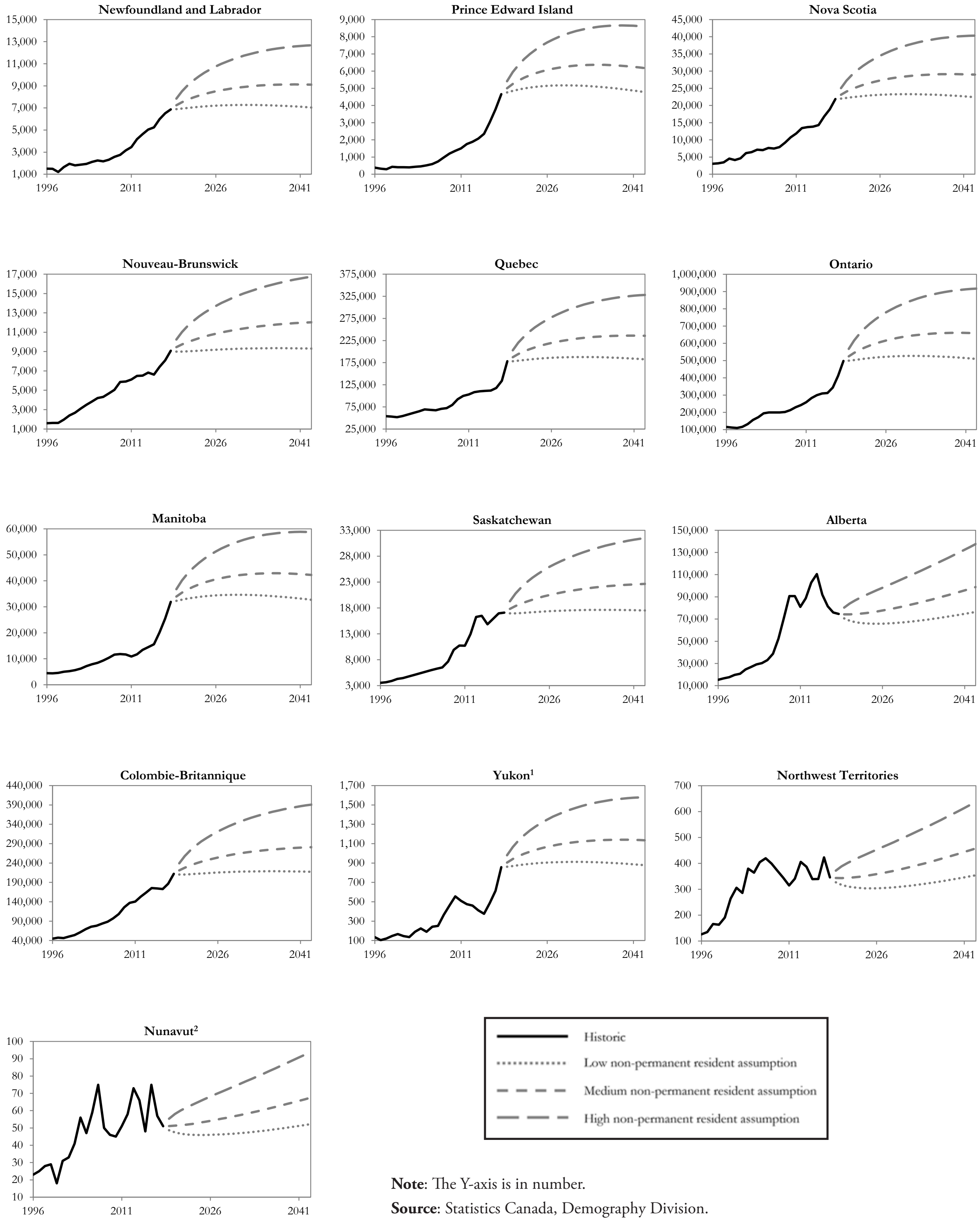
As per our general approach, each province and territory follows its own unique path in the early years of the projection, based on its own recent trends in NPR (Figure 7.4). In the longer-term, each province and territory experiences the same proportional change NPR as that envisioned by the experts at the Canada level.

Figure 7.3 Number of non-permanent residents, Canada, historic (1996 to 2018) and projected (2019 to 2068) according to the low, medium and high non-permanent resident assumptions



Source: Statistics Canada, Demography Division.

Figure 7.4 Number of non-permanent residents, provinces and territories, historic (1996 to 2018) and projected (2019 to 2043) according to the low, medium and high non-permanent resident assumptions



Note: The Y-axis is in number.

Source: Statistics Canada, Demography Division.

Acknowledgements

We would like to thank the following members of Statistics Canada's Demographic Estimates Program: Julien Bérard-Chagnon, David Binet, Patrick Charbonneau, Hubert Denis, Anna Mao and Mélanie Meunier. These individuals offered their time and expertise to complete a modified version of the *2018 Survey of Experts on Future Demographic Trends*, the results of which were used in the formulation of the non-permanent resident assumptions.

References

Advisory Council on Economic Growth. 2016. "Attracting the Talent Canada Needs Through Immigration", https://www.budget.gc.ca/aceg-ccce/pdf/immigration-eng.pdf.

Bauder, H. 2014. "Re-imagining the nation: Lessons from the debates of immigration in a settler society and an ethnic nation", *Comparative Migration Studies*, volume 2, issue 1, pages 9 to 27.

Bloemraad, I. 2012. "Understanding "Canadian Exceptionalism" in immigration and pluralism policy", Transatlantic Council on Migration: A Project of the Migration Policy Institute, https://www.migrationpolicy.org/pubs/CanadianExceptionalism.pdf.

Castles, S. and M.J. Miller. 2009. *The Age of Migration: International Population Movements in the Modern World*, 4th edition, Guilford Press.

Florida, R.L. 2005. *The Flight of the Creative Class: The New Global Competition for Talent*, Harper Business.

Immigration, Refugees and Citizenship Canada. 2017. "2017 Consultations on Immigration Levels, Settlement and Integration – Final Report", https://www.canada.ca/en/immigration-refugees-citizenship/corporate/transparency/consultations/2017-consultations-immigration-levels-settlement-integration-final-report.html.

Immigration, Refugees and Citizenship Canada. 2018. "Annual Report to Parliament on Immigration", https://www.canada.ca/en/immigration-refugees-citizenship/corporate/publications-manuals/annual-report-parliament-immigration-2018/report.html.

Jones, T. 2016. "The role of public opinion in US and Canadian immigration policies", *American Review of Canadian Studies*, volume 46, issue 1, pages 1 to 15.

Lu, Y. and F. Hou. 2017. "Transition from temporary foreign workers to permanent residents, 1990 to 2014", *Analytical Studies Branch Research Paper Series*, Statistics Canada catalogue no. 11F0019M, no. 389.

Statistics Canada. 2016. *Population and Family Estimation Methods at Statistics Canada*, Statistics Canada catalogue no. 91-528-X.

Zilio, M. and S. Chiose. 2016. "Ottawa looks to ease international students' path to permanent residency", The Globe and Mail, March 14, https://www.theglobeandmail.com/news/politics/ottawa-looks-to-ease-international-students-path-to-permanent-residency/article29242266/.

Chapter 8: Projection of Interprovincial Migration

by Patrice Dion

Introduction

Interprovincial migration is the movement of people between Canada's provinces and territories. Economically speaking, interprovincial migration is often seen as a positive phenomenon, contributing to balance labour supply and demand. In this regard, interprovincial migration has been facilitated by the Agreement on Internal Trade (AIT), which was signed by most of the provinces and territories in 1994, with the aim of eliminating barriers to trade, investment and labour mobility (Industry Canada 2019).[66]

Demographically, for some provinces and territories, interprovincial migration is a key factor in growth and influences the composition of populations. Annually, an average of close to 275,000 people changed their province or territory of residence over the past 10 years. The interprovincial migration rate has decreased slightly over time, from approximately 1.7 per thousand in the 1970s to 0.8 per thousand in the last decade. Population aging seems to account for part but not all of this trend (Dion and Coulombe 2008). In Canada, the reduction of differences in the employment and labour productivity rates between the provinces and territories, following a period of relative prosperity, is also thought to have contributed in part to the decline in interprovincial migration (Basher and Fachin 2008; Coulombe 2006). This pattern has also been observed in the United States (Cooke 2013; Molloy et al. 2011), where it has been associated with several major trends: the increase in the labour force participation rate of women and associated number of dual-earner couples, the increase in debt levels, and the widespread adoption of information and communications technologies. Given that these trends, also present in Canada, are expected to persist, it seems very unlikely that we will witness a return to higher migration rates.

The net interprovincial migration of provinces and territories are more variable than the total interprovincial migration rate, fluctuating largely in response to shifting labour market opportunities (Finnie 2000; Bernard et al. 2008). For example, in the past few years, Alberta attracted many workers, then saw its net migration slump in 2015/2016 and 2016/2017 when crude oil prices fell (Saunders 2018). That being said, the knowledge that interprovincial migration flows fluctuate based on economic variables, such as employment, wages or the price of resources, is actually of little value in projecting future trends, as the future evolutions of these phenomena are highly uncertain and difficult to predict (Makridakis et al. 2009). These considerations largely explain why, among all the components of population growth, interprovincial migration is often the primary source for discrepancies in projected versus actual population evolutions for the individual provinces and territories (Dion and Galbraith 2015). This is why Statistics Canada prefers a pragmatic approach to building assumptions about future interprovincial migration flows, with emphasis on the uncertainty associated with projecting this component.

Methodology

Statistics Canada's projection model is multiregional; in other words, it classifies individuals not only into cohorts (age) and by sex, but also by place of residence. The multiregional model is used to apply interprovincial migration rates based on origin and destination and ensures that the sum of the inputs is always equal to the sum of the outputs (Rogers 1990). The rates are calculated using historical data, with various scenarios reflecting distinct historical periods. This approach is beneficial, given the lack of strong predictive models, because it captures the essence of the spatial structures that persistently underlie a large majority of migration flows (Ledent 1983; Rogers et al. 2002). In Canada, the degree of linguistic homogeneity (Termote and Fréchette 1980), the spatial configuration of cities and their physical distance (*idem*. 1980; Simmons 1980), and the economic structure and sociocultural fabric (Simmons 1980) are all factors that determine the migration flows with a certain consistency. This largely explains why the multiregional model has proven superior to other models for projecting internal migration (Snickars and Weibull 1977; Rees 1997). Finally, one advantage of the multiregional model is its matrix formulation, allowing users to add interprovincial migration rates to the rates associated with the other population growth components applied to the cohorts (Le Bras 2008).

66. Similarly, the New West Partnership Trade Agreement, signed in 2015 by the governments of British Columbia, Alberta, Saskatchewan and Manitoba, includes additional measures to ease restrictions on labour mobility, particularly by standardizing the certifications required for workers (see New West Partnership 2019).

However, applying fixed rates in the multiregional model leads to adverse latent effects since projected flows therefore depend only on the size and structure of the regions of origin, regardless of the characteristics of the destination regions (Plane 1993; Le Bras 2008; Dion 2017). In Canada, the use of fixed rates causes a province that grows relatively rapidly, such as Ontario, to see its projected net migration decrease (mechanically) to the benefit of other regions with lower growth, resulting in implausible and converging migration flows in all projection scenarios (Werschler and Nault 1996; Dion 2017). Unfortunately, for the reasons stated above, it is very difficult to project how migration rates will change over time.

For this reason, Statistics Canada implements temporal adjustments over the course of the projection that reflect the differences in relative population growth among the provinces and territories. As a result, the projected net migration and net migration rates of the provinces and territories are more stable, reflecting those observed during the selected historical periods. In addition to providing more transparency, this stability allows interprovincial migration scenarios to be produced with results that are not automatically consistent with the differential growth of the regions, and therefore represent a more plausible range of projection results. Dion (2017) describes the method and its advantages in more detail.

Assumptions

To account for the high uncertainty associated with internal migration projection, five assumptions are proposed, each based on a distinct reference period, and constituting the basis for a distinct scenario. Together, these assumptions demonstrate the high volatility of this component over time. Assumption M1, which can be considered an average scenario to some extent, is based on the longest period for which data are available for all provinces and territories (after the creation of Nunavut), from 1991/1992 to 2016/2017.[67] Assumptions M2 to M5 reflect shorter intervals within the aforementioned period. Reference periods were selected so that each province and territory has at least one past period of relatively favourable net interprovincial migration, and another past period of relatively unfavourable net interprovincial migration. Table 8.1 presents the average annual net migration rates recorded during the various reference periods used for the construction of the assumptions.

Adjustments to the multiregional migration rates mean that the projected average net migration rates are fairly close, but not identical, to the rates observed over the selected reference periods. Indeed, the adjustments help to reduce the gaps related to the effects of population growth (unequal) in the provinces and territories, but do not correct for other effects that may influence migration flows, such as changes in the population age structure. Moreover, the adjustments cannot mathematically guarantee a perfect match with the observed net migration rates, and are instead a compromise to significantly reduce the gaps in all regions equally.

Table 8.1 Average net interprovincial migration rates observed during various reference periods, by province and territory

Region	1991/1992 to 2016/2017 period			Average net migration rates for each scenario				
				M1	M2	M3	M4	M5
	Average	Average (-)	Average (+)	1991/1992 to 2016/2017	1995/1996 to 2010/2011	2003/2004 to 2008/2009	2009/2010 to 2016/2017	2014/2015 to 2016/2017
	percent							
N.L.	-0.49	-0.67	-0.27	-0.49	-0.62	-0.29	0.04	-0.07
P.E.I.	-0.10	-0.22	0.01	-0.10	-0.12	-0.36	-0.25	-0.05
N.S.	-0.14	-0.20	-0.09	-0.14	-0.15	-0.24	-0.09	0.04
N.B.	-0.19	-0.24	-0.13	-0.19	-0.18	-0.21	-0.19	-0.15
Que.	-0.13	-0.15	-0.11	-0.13	-0.12	-0.12	-0.12	-0.14
Ont.	-0.03	-0.06	0.00	-0.03	-0.01	-0.12	-0.03	0.03
Man.	-0.39	-0.43	-0.34	-0.39	-0.36	-0.43	-0.38	-0.43
Sask.	-0.30	-0.44	-0.17	-0.30	-0.27	-0.09	-0.12	-0.43
Alta.	0.53	0.36	0.70	0.53	0.72	0.76	0.31	-0.07
B.C.	0.24	0.08	0.37	0.24	0.05	0.26	0.22	0.46
Y.T.	-0.21	-0.61	0.45	-0.21	-0.45	0.40	0.65	0.81
N.W.T.	-0.97	-1.25	-0.65	-0.97	-1.21	-1.32	-0.81	-0.64
Nvt.	-0.31	-0.42	-0.20	-0.31	-0.28	-0.48	-0.24	-0.46

Notes: Average (-) and Average (+) represent average net migration rates recorded in the 1991/1992 to 2016/2017 period excluding, in the case of Average (-), the five years with the highest gains (or lowest losses) and, in the case of Average (+), those with the highest losses (or lowest gains), and this, specifically for each province and territory.

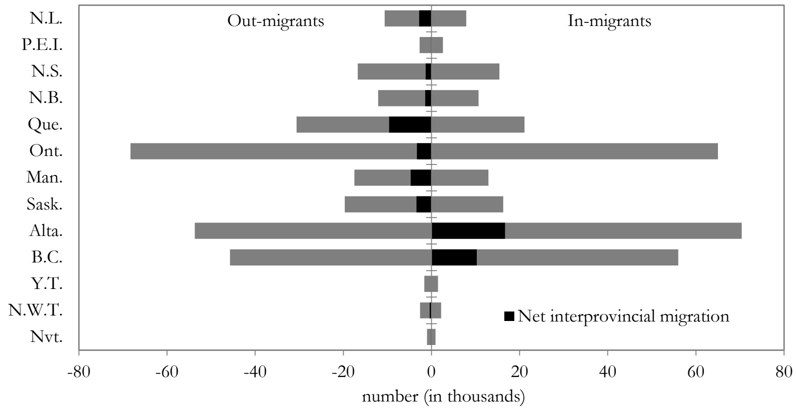
Source: Statistics Canada, Demography Division.

67. Note that the estimates of interprovincial migration flows for the 2017/2018 period are "preliminary" and could be subject to substantial revisions. For this reason, this period is not considered when developing assumptions.

Assumption M1

Assumption M1, which could also be referred to as a historical assumption, is based on the past 26 years, from 1991/1992 to 2016/2017. During this period, only Alberta and British Columbia experienced positive net migration (Figure 8.1), while Ontario posted a slightly negative net migration rate.

Figure 8.1 Average annual number of interprovincial in- and out-migrants and net interprovincial migration, 1991/1992 to 2016/2017

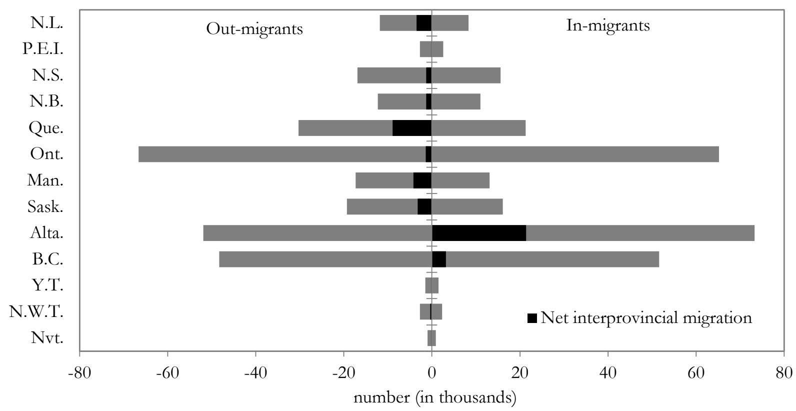


Source: Statistics Canada, Demography Division.

Assumption M2

Assumption M2 refers to the years 1995/1996 to 2010/2011. Compared with other periods, these years were relatively favourable to Alberta, Ontario and Manitoba, and relatively unfavourable to Newfoundland and Labrador, British Columbia, Yukon, and the Northwest Territories (Figure 8.2).

Figure 8.2 Average annual number of interprovincial in- and out-migrants and net interprovincial migration, 1995/1996 to 2010/2011

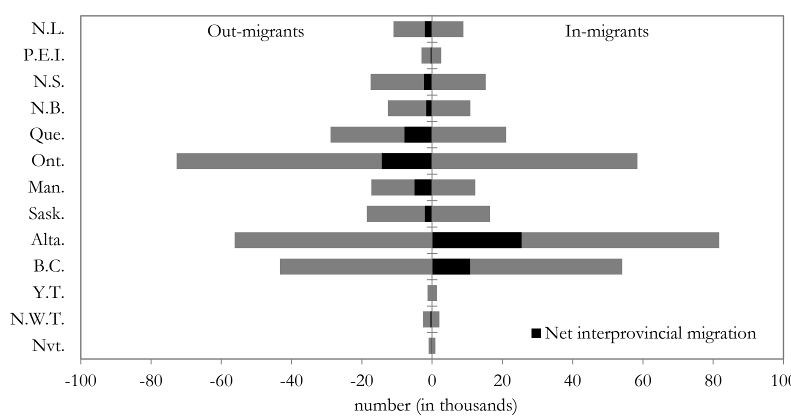


Source: Statistics Canada, Demography Division.

Assumption M3

Assumption M3 is based on the period 2003/2004 to 2008/2009, which was generally unfavourable to the Atlantic provinces and Manitoba. Alberta, British Columbia and Yukon experienced positive net migration during this period (Figure 8.3).

Figure 8.3 Average annual number of interprovincial in- and out-migrants and net interprovincial migration, 2003/2004 to 2008/2009

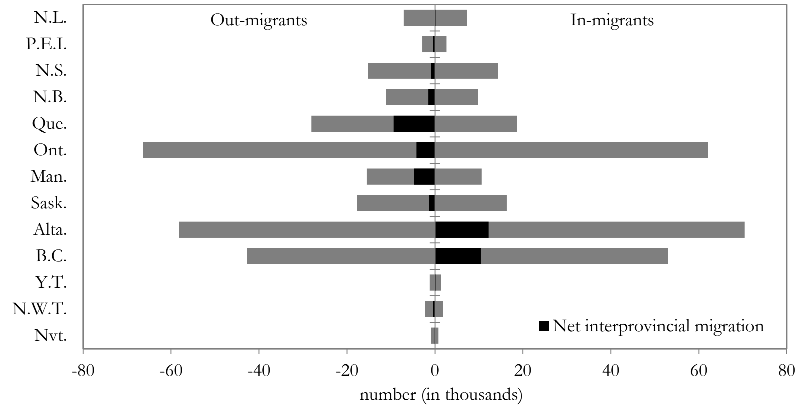


Source: Statistics Canada, Demography Division.

Assumption M4

Assumption M4 is based on the period from 2009/2010 to 2016/2017, which was characterized by migration flows that, although positive, were relatively less favourable to Alberta (Figure 8.4). This is also a relatively unfavourable scenario for Ontario and Prince Edward Island. Conversely, this period was more favourable than average for Nova Scotia, Saskatchewan, Nunavut and (marginally) Quebec.

Figure 8.4 Average annual number of interprovincial in- and out-migrants and net interprovincial migration, 2009/2010 to 2016/2017

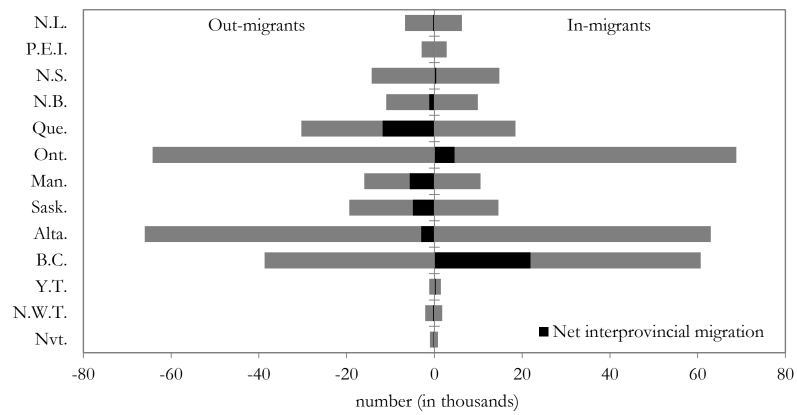


Source: Statistics Canada, Demography Division.

Assumption M5

Assumption M5 is based on a short period of three years, from 2014/2015 to 2016/2017. It illustrates the most recent interprovincial migration trends and reflects a substantial departure from general trends in Canada. First, the level of migration to Alberta decreased largely, leading to negative net migration for the province (Figure 8.5). Nunavut and (marginally) Quebec also recorded above-average losses during this period. In contrast, the Atlantic provinces, British Columbia, Yukon and the Northwest Territories experienced more favourable (or less unfavourable) net migration.

Figure 8.5 Average annual number of interprovincial in- and out-migrants and net interprovincial migration, 2014/2015 to 2016/2017



Source: Statistics Canada, Demography Division.

References

Basher, S.A. and S. Fachin. 2008. “The long-term decline of internal migration in Canada – Ontario as a case study”, *MPRA Paper*, no. 6,685.

Bernard, A., R. Finnie and B. St-Jean. 2008. “Interprovincial mobility and earnings”, *Perspectives on Labour and Income*, volume 9, issue 10, Statistics Canada catalogue no. 75-001-X.

Coulombe, S. 2006. “Internal Migration, Asymmetric Shocks, and Interprovincial Economic Adjustments in Canada”, *International Regional Science Review*, volume 29, issue 2, pages 199 to 223.

Cooke, T. 2013. “Internal migration in decline”, *The Professional Geographer*, volume 65, issue 4, pages 664 to 675.

Dion, P. and S. Coulombe. 2008. “Portrait of the mobility of Canadians in 2006: Trajectories and characteristics of migrants”, *Report on the Demographic Situation in Canada*, Statistics Canada catalogue no. 91-209-X.

Dion, P. and N. Galbraith. 2015. “Back to the future: A review of forty years of population projections at Statistics Canada”, *Canadian Studies in Population*, volume 42, issue 1-2, pages 102 to 116.

Dion, P. 2017. “An alternative to fixed transition probabilities for the projection of interprovincial migration in Canada”, *Population Research and Policy Review*, volume 36, issue 6, page 871 to 901.

Finnie, R. 2000. “Who Moves? A Panel Logit Model Analysis of Inter-Provincial Migration in Canada”, *Analytical Studies Branch Research Paper Series*, Statistics Canada catalogue no. 11F0019MPE, no. 142.

Industry Canada. 2019. “Agreement on Internal Trade: Summary of the Agreement”, https://www.ic.gc.ca/eic/site/ait-aci.nsf/eng/h_il00064.html#chap_7.

Le Bras, H. 2008. *The Nature of Demography*, Princeton NJ, Princeton University Press.

Ledent, J. 1983. “Une analyse log-linéaire des courants migratoires interprovinciaux: Canada, 1961-1983“, *Cahiers Québécois de Démographie*, volume 12, issue 2, pages 233 to 250.

Makridakis, S., R.M. Hogarth and A. Gaba. 2009. “Forecasting and uncertainty in the economic and business world”, *International Journal of Forecasting*, volume 25, issue 4, pages 794 to 812.

New West Partnership. 2019. The Agreement, http://www.newwestpartnershiptrade.ca/the_agreement.asp.

Molloy, R., C.L. Smith and A. Wozniak. 2011. “Internal Migration in the United States”, *The Journal of Economic Perspectives*, volume 25, issue 3, pages 173 to 196.

Plane, D.A. 1993. “Requiem for the fixed-transition-probability migrant”, *Geographical Analysis*, volume 25, issue 3, pages 211 to 223.

Rees, P. 1997. “Problems and solutions in forecasting geographical populations”, *Journal of the Australian Population Association*, volume 14, issue 2, pages 145 to 166.

Rogers, A. 1990. “Requiem for the net migrant”, *Geographical Analysis*, volume 22, issue 4, pages 283 to 300.

Rogers, A., F.J. Willekens, J. Little and J. Raymer. 2002. “Describing migration spatial structure“, *Papers in Regional Science*, volume 81, issue 1, pages 29 to 48.

Saunders, D. 2018. “Internal Migration: Overview, 2015/2016”, *Report on the Demographic Situation in Canada*, Statistics Canada catalogue no. 91-209-X.

Simmons, J.W. 1980. “Changing migration patterns in Canada 1966-1971 to 1971-1976”, *Canadian Journal of Regional Science*, volume 3, issue 2, pages 139 to 162.

Snickars, F. and J.W. Weibull. 1977. “A minimum information principle: Theory and practice”, *Regional Science and Urban Economics*, volume 7, issue 1-2, pages 137 to 168.

Termote, M.G. and R. Fréchette. 1980. “Le renversement récent des courantes migratoires entre les provinces canadiennes, essai d’interprétation”, *Canadian Journal of Regional Science*, volume 3, issue 2, pages 163 to 192.

Werschler, T. and F. Nault. 1996. “Projecting interregional migration balances within a multiregional cohort-component framework”, *Environment and Planning A*, volume 58, issue 5, pages 769 to 782.