# How Accurately does 70% Final Earnings Replacement Measure Retirement Income (In)Adequacy?

*Bonnie-Jeanne MacDonald, PhD FSA, Department of Economics, Dalhousie University,*
*Bonniejeanne_macdonald@hotmail.com, +1 (902) 471-6660*
*Lars Osberg, PhD, McCulloch Professor, Department of Economics, Dalhousie University*
*Kevin D. Moore, PhD, Principal Researcher, Statistics Canada*

*January 8, 2013*

## Abstract

The most commonly advocated benchmark in retirement planning is that 70% of gross final annual employment earnings will sustain an individual's standard of living after retirement. This benchmark has been used by financial planners, pensions plan advisors, academics, public policy makers and much of the research that has predicted that Canadian and American workers will be financially unprepared for an adequate retirement.

This paper examines whether Canadians who hit this target actually can expect to maintain their living standards in retirement. Specifically, we use Statistics Canada's LifePaths dynamic population micro-simulation model to examine the projected living standards before and after retirement of those individuals from the 1951-1958 Canadian birth cohort who attain a 65% to 75% replacement target (as conventionally measured) at retirement.

Because it relies on an inadequate pre-retirement base period, does not incorporate important components of consumption (such as home equity), and ignores household size (particularly children), we find that the conventional final earnings replacement rate concept predicts poorly individuals' retirement standard of living – i.e. this measure has little predictive value concerning living standards in retirement (which implies that the debate around whether a 70% target is too large or too small is misplaced). The paper discusses the optimal construction of a replacement rate measure that might better predict living standards after retirement.

## 1. Introduction

What is the right target to aim for in retirement income? The capacity of retirement income to sustain the standard of living of future seniors is a growing concern in Canada and the U.S. owing to (1) longer life expectancies[i], (2) less secure sources of retirement income [ii], (3) the rising level of divorce rates among seniors (with likely negative financial implications)[iii], (4) a growing ratio of seniors to workers[iv], and (5) an increasing reliance on paid services for the potentially costly expenses associated with chronic health conditions[v]. On the other side, saving too much for retirement also has its disadvantages. Over-saving could be a rational strategy for highly risk-averse individuals who place a high value on contingency income, for individuals anticipating higher expenses after retirement (such as covering medical expenses not covered by the Canadian health care system), and for individuals wishing to leave bequests or improving their living standards in retirement. However, for others it could mean unnecessary "scrimping and saving" during young and healthy years when the welfare of children is possibly involved, and excess wealth that is not necessarily enjoyed much, at the margin[vi], during more advanced ages.

For many years, Canadians have been told to aim for a 70% replacement rate of gross employment earnings in order to maintain their standard of living after retirement. For example, the Baldwin Report (2009: iv) stated, "The common approach to determining whether the elderly are maintaining their standard of living is to compare the income of the elderly population with their pre-retirement earnings. This comparison is called the replacement rate and it is usually expressed as a percentage. Actual replacement rates are compared with a benchmark replacement rate – usually in the range of 70 to 75 per cent of gross pre-retirement earnings – to decide whether people are maintaining their pre-retirement standard of living". Liu, Ostrovsky and Zhou (2013:8) similarly wrote "One approach taken in the literature is to assess the adequacy of retirement income by focusing on the proportion of pre-retirement income that has to be replaced during retirement in order to maintain living standards at the pre-retirement level. A rule of thumb is that post-retirement income should replace at least 70% of pre-retirement income." The same target measure is conventionally advocated in the U.S. – for example, the U.S. Social Security Administration (2008:7) said that "(w)hile Social Security replaces about 40 percent of the average worker's pre-retirement earnings, most financial advisors say that you will need 70 percent or more of pre-retirement earnings to live comfortably"[vii].

What is likely to happen to the standard of living of people who actually achieve this often-advocated target measure?

A number of studies have been skeptical about whether target replacement rates provide an adequate benchmark for assessing the adequacy of an individual's retirement income (e.g. Scholz and Seshadri, 2009; Vanderhei, 2006)[viii]. This paper continues that tradition by examining Canadians born between 1951- 1958 who attain a 65% to 75% replacement target (as conventionally measured) at retirement and asking how well each of such person's working-life living standard is maintained after retirement.

Specifically, for Canadians forecast to retire at age 61[ix] between years 2012 and 2019, we calculate the gross replacement rate for each person and select those for whom the replacement rate is between 65% and 75%. For each of these individuals, we then compare average post-retirement living standards to average pre-retirement living standards.

We use Statistics Canada's LifePaths model[x] to simulate comprehensive individual living standards across the life-course. Life Paths is a dynamic micro-simulation model of the Canadian population that simulates individual life-courses (birth, education, employment, income, taxes, marriage, child-bearing, retirement, etc) of synthetic individuals that are representative of the Canadian population. Using behavioral equations, it simulates each "life-path" year by year and case by case, while incorporating the diversity between individuals and over each person's life-course at the level of detail necessary for this analysis To generate its rich life-course modeling, LifePaths summarizes, incorporates and integrates an enormous range of Canadian data. LifePaths' primary objective is to simulate statistically representative data samples of the history of the Canadian population – hence LifePaths is the best available source of longitudinal simulations based on real data of individual Canadians and their families that is sufficiently comprehensive for this analysis (see Appendix C for additional description of LifePaths). Using LifePaths synthesized data, this paper takes a novel approach to the replacement rate issue by using a comprehensive definition of income that includes non-traditional working and retirement income sources, and going beyond the single year before and after retirement to look over the individual's entire lifetime (year by year at the family level).

Section 2 of this paper reviews the replacement rate measure. Section 3 presents our conceptual and methodological framework of retirement income adequacy and living standards, and outlines our methods. Section 4 analyzes our results and Section 5 concludes.

## 2. Replacement Rates and Replacement Rate Targets – From Conceptual to Practical

The conventional concept for evaluating an individual's likely living standards in retirement relative to working life is the "replacement rate" – i.e. the fraction of his/her pre-retirement annual income replaced by retirement income. Retirement income adequacy is considered achieved if working-life living standards are sustained after retirement[xi].

The apparent simplicity of the replacement rate approach has been a primary reason for its popularity. There exists, however, major inconsistencies in the analysis of replacement rates owing to differences across the literature in the conceptual framing of retirement income adequacy[xii], analytical purpose[xiii], but most of all owing to data constraints.

### 2.1 Data Constraints

From the perspective of the policy analyst, academic, financial planner, employer, and the individual themselves, the most easily obtainable data is before-tax income data at a point in time[xiv] - using this data, for somebody retiring at age 61, the conventional replacement rate formula is[xv]:

$$\text{Conventional replacement rate} = \frac{\text{gross (i.e., before-tax) registered income in first year of retirement (e.g. age 62)}}{\text{gross pre-retirement final year employment earnings (e.g. age 60)}} \quad (1)$$

The "rule-of-thumb" belief is that a 70% replacement rate will sustain an individual's standard of living after retirement –i.e. provide 100% replacement of pre-retirement living standards[xvi], which is based on the idea that retired individuals will generally pay lower taxes, not be saving for retirement, typically have paid off their mortgage, and no longer need to support children and/or pay work-related expenses.

Unfortunately, many components of living standards are either poorly dealt with, or omitted from, Equation (1):

1. household-level differences in consumption needs due to family size (and changes over time in household size and composition);
2. imputed income from owner occupied housing;
3. taxes (specifically the differentials in taxation year by year pre and post retirement);
4. transfers – e.g. unemployment insurance, child benefits and social assistance;

5. the accumulation and drawdown of non-traditional forms of savings (non-registered financial wealth/debt, and home-ownership equity);
6. earnings volatility (earnings at age 60, or over any short period, include both transitory and permanent components);[xvii]
7. retirement income volatility;[xviii]
8. inflation uncertainty and the future real value of pension benefits;
9. pre- and post-retirement risks, such as poor financial market returns, death/divorce of a spouse, longevity, expensive medical conditions, extended care needs, etc.;
10. phased retirement and continuing employment income after retirement;
11. individual preferences (such as risk aversion, the value of leisure, and bequest motives);
12. changes in expenses over the life course;
13. the risk of poverty (income continuity does not necessarily imply income adequacy – i.e. for those who continue to be poor);

Analysts seeking to improve on these methodological weaknesses within the limits of the conventional replacement rate formula have calculated replacement rates in widely different manners (see Appendix B). The biggest obstacle is data since available longitudinal data rarely reports on all components of income, savings, dissavings, and wealth[xix].

As a result, many researchers have turned to micro-simulation modeling. Large-scale, complex, dynamic micro-simulation models are increasingly being used to assess retirement income adequacy, because they can[xx]:

- integrate and extend existing data sources to give the most comprehensive picture of consumption sources;
- enable flexibility in analysis – e.g. analyst can choose alternative measurement periods before or after retirement[xxi];
- generate results that reflect the realistic complexity and diversity within life-courses, and across individuals;
- explicitly model the risk and uncertainty of the future, and the distribution of possible future outcomes.

The present paper overcomes the listed shortcomings #1-10 of conventionally measured replacement rates by building on Statistics Canada's dynamic population microsimulation model *LifePaths*[xxii]. At the individual level, year by year and over the entire life course, we measure the financial flows of all family members (making appropriate adjustments for family size), including major sources of earnings and retirement income as well as imputed house rent, taxes, government transfers, and non-traditional forms of savings. We stochastically model inflation, financial market returns, and mortality (including the death of family members). Individuals exit the workforce in a realistic manner that match Canadian population empirical income source data. However, we do not model differences in individual preferences, changes in expenses over the life course (including higher medical expenses after retirement), nor the risk of poverty – see Appendix B for further discussion.

## 3. Conceptual and Methodological Framework for Retirement Income Adequacy

### *3.1 Living Standards Continuity*

Like the majority of replacement rate studies, this paper thinks of retirement income adequacy as occurring when an individual can sustain his/her material living standards from the consumption of goods and services after retirement. Given that our focus is income adequacy, we do not explicitly model post-retirement savings or bequest behavior, rather we infer what individuals could potentially consume. As is customary in this literature, we convert the stock of wealth into a flow of potential annual consumption by assuming that wealth (net worth = assets-liabilities) is annuitized at retirement (we define retirement in Section 3.2). The payments of this notional annuity are added to other retirement income flows. We measure income flows at the census-family level and adjust for family size using the LIS equivalence scale[xxiii] to compute individual equivalent income.

To evaluate living standards, we measure the flow of equivalent income (or potential income) available to support the individual's standard of living pre and post retirement[xxiv]. Figure 1 presents our framework for determining an individual's living standards each year while working, and their potential living standards in retirement. This flow chart can be summarized as:

Working-Life Living Standards Proxy:

Working Income available for Individual Consumption Expenditure
= disposable income (after taxes and transfers) – net savings (2)

Retirement Living Standards Proxy:

Retirement Income available for Potential Individual Consumption Expenditure
= disposable income (after taxes and transfers) + potential dissavings from net worth (3)

The "potential dissavings from net worth" portion from Equation (3) is the annual potential payout from an inflation-indexed life annuity purchased at retirement with registered and non-registered wealth, plus real estate investments and business equity, less debt (see Figure 1).

Using equations (2) and (3), with an accounting period of one fiscal year, we calculate our primary measure of living standards continuity:

Living Standards Continuity Rate (LSCR)
= *Average Real*[xxv] **Retirement Income for Potential Individual Consumption Expenditure** (4)
*Trimmed Average Real* **Working Income for Individual Consumption Expenditure**

We calculate "Trimmed Average Working Income for Individual Consumption Expenditure" from the 30 years leading up to retirement, removing the lowest and highest five years and averaging the remaining middle 20 years. Trimming the denominator reduces the influence of outlier years – e.g. both abnormally low (possibly negative) and unusually high earning years among the self-employed. In fact, for 92% of the sample, the trimmed average lies between 90-110% of the full 30-year average.

Our measure of annual "Retirement Income for Potential Individual Consumption Expenditure" is averaged from retirement until death. Sources of retirement consumption expenditure such as income from public pensions and employer pension plans tend to be quite stable, and in addition we assume full annuitization of savings. The stability of retirement income sources is particularly high relative to earnings volatility (see Finnie, 1999; Morissette, Zhang and Frenette, 2007; Finnie and Gray, 2011)[xxvi]. Another approach could have been to use a year of retirement that is deemed "representative", such as age 70 (such as in Moore, Robson, and Laurin, 2010), although this would not lose potentially important information over the retirement life.

In our analysis, we use 80%<LSCR<120% as the range of outcomes signaling living standards continuity, without the intention of arguing for or against these strict limits[xxvii].

There are three general categories of improvement between the conventional replacement rate from Equation (1) and the LSCR from Equation (4). The LSCR uses a much broader measurement period in the pre- and post-retirement phase, it includes a much more comprehensive definition of income, and it measures income at the household level rather than at the level of the individual. Starting from Equation (1), the results are:

Conventional replacement rate from Equation (1) = $\frac{gross\ registered\ income\ at\ age\ 62}{gross\ employment\ earnings\ at\ age\ 60}$

↓ *Measure the numerator and denominator over broader measurement period (while accounting for inflation)*

$$= \frac{\sum_{x=62}^{death} real\ gross\ registered\ income\ at\ age\ x}{\sum_{x=30}^{60\ (middle\ 20\ years)} real\ gross\ employment\ earnings\ at\ age\ x}$$

↓ *Use fuller measure of income available for consumption expenditure at the individual level (as outlined in Figure 1, except done only for the individual)*

$$= \frac{\sum_{x=62}^{death} real\ income\ for\ consumption\ expenditure\ at\ individual\ level\ at\ age\ x}{\sum_{x=30}^{60\ (middle\ 20\ years)} real\ income\ for\ consumption\ expenditure\ at\ individual\ level\ at\ age\ x}$$

↓ *Each year, measure at the household level and then adjust for family size*

LSCR from Equation (4)

$$= \frac{\sum_{x=62}^{death} [(real\ income\ for\ family\ consumption\ expenditure)/\sqrt{Family\ size}\ ]\ at\ age\ x\ of\ primary}{\sum_{x=30}^{60\ (middle\ 20\ years)} [(real\ income\ for\ family\ consumption\ expenditure)/\sqrt{Family\ size}\ ]\ at\ age\ x\ of\ primary}$$

Figure 1: Conceptual framework to measure fiscal year "income for individual consumption expenditure" using census family-level data for the individual of analysis.

\+ Market Income =
Employment income (employee income and net-income from self-employment)
\+ Investment Income (dividends, interest and other investment income such as real estate)*
\+ Imputed return on owner occupied dwelling (= imputed rent – repairs/taxes/mortgage interest)

\+ Transfers Received =
Social insurance benefits from employers (e.g. pension plan benefits and workers compensation)
\+ Social insurance benefits (e.g. OAS, GIS, C/QPP benefits, death and survivor benefits)
\+ Social-assistance benefits (e.g. social assistance payments, child benefits, provincial supplements and tax credits)
\+ Cash transfers received from other households and institutions (e.g. alimony, child support, support from other persons not in the household, *inheritance***, etc.)

= **Family Total Income**

\- Taxes, Deductions, Transfers and Work Expenses Paid =
Taxes on income and wealth (other than owner-occupied home)
\+ Employees' social insurance contribution (employer pension plan, C/QPP and EI deductions)
\+ Cash transfers paid to other households and institutions
\+ *Work expenses (travel and child care payments)***

= **Family Disposable Income** → Family Member Retired?

Family Member Working?

\- Net Savings:
- RRSP savings
- Mortgage principal reduction***
- Other savings****

\+ Notional potential dissavings from net worth (assets minus liabilities): individual payment from inflation-indexed life annuity purchased at retirement with
- RRSP/RRIF wealth
- *Housing equity***
- Other savings****

= **Income for Family Consumption Expenditure** → Repeat for each family member

÷ LIS equivalence scale = $(\text{Number of Family Members})^{0.5}$

Individual of Analysis Working? | Individual of Analysis Retired?

= **Working Income for Individual Consumption Expenditure (proxy for *Working Life Living Standards*)**

**Retirement Income for Potential Individual Consumption Expenditure (proxy for *Retirement Living Standards*)**

Notes:
Additional components of consumption not incorporated in Figure 1 that are relevant to retirement income adequacy include: (1) income in-kind – that is, goods produced by households for their own consumption (such as cooking, housekeeping and child-rearing - see Aguiar and Hurst 2005; Brzozowski and Lu 2010 for the importance of food preparation after retirement); (2) the flow of services from durable goods (other than just owner-occupied housing) purchased while working but consumed after retirement ; (3) irregular inter-household transfers in kind (gifts) - the Canberra Report (2001) suggests that they should be treated "as transfers of expenditure in that they are part of the recipient's consumption but the donor's expenditure" (pg.110); (4) social transfers in-kind – i.e. government-provided goods and services such as health and education. Data limitations dictate that these four additional considerations are not incorporated in this paper. Last, we measure at the census-family level (which is the approach of LifePaths), although it could be more appropriate to measure at the level of the economic household.
* If any portion of investment income is saved rather than consumed, that portion would then be added to savings and hence subtracted (having zero net effect).
** The italicized items are those not included in this paper. We do not model work expenses and assume that seniors do not draw down their housing equity to support consumption. We do not explicitly model the receipt of inheritance, although past inheritances are recorded in wealth and therefore are implicitly treated as past savings.
*** Retiring home-owners with a mortgage may also continue to make principal payments into retirement depending of the analyst's treatment of housing equity. For instance, this paper does not assume that the retiree downsizes at retirement by selling his/her home, and therefore s/he continues to benefit from imputed rent and may make mortgage payments. Similarly, retirees who continue to work (even minimally) may also contribute to an employer pension plan.
**** The other savings concept used is marketable wealth (or net worth) other than primary housing. These include the sum of non-registered financial assets (chequing accounts, GICs, trusts, etc), real estate assets (other than primary housing), and business equity, less non-mortgage debt (credit card, lines of credit, car loans, etc).
Acronyms in figure: The Canadian public pension system consists of the universal Old Age Security (OAS), the income-tested Guaranteed Income Supplement (GIS), and the contributory Canadian/Quebec Pension Plans (C/QPP). Registered Retirement Savings Plans (RRSPs) and Registered Retirement Income Funds (RRIFs) are tax-sheltered retirement savings government programs. Employment Insurance (EI) provides temporary financial aid to Canadians who have lost their jobs.

Integrated data that covers all aspects of Figure 1 are not available in Canada. Nevertheless, this study is able to include most components (Figure 1 italicizes the missing elements) by building on Statistics Canada's LifePaths model. LifePaths is vast and Appendix C provides a short description. A more comprehensive overview can be found on the Statistics Canada website: http://www.statcan.gc.ca/microsimulation/lifepaths/lifepaths-eng.htm.

A strongly debated component of potential retirement consumption expenditure that this study chooses not to include is the drawdown of housing equity (i.e. reverse mortgages - see Appendix B for discussion).

We convert wealth stocks into an income-flow at retirement by assuming a life-only inflation-indexed annuity for all individuals (whether single or non-single)[xxviii]. If retirement income flows are taken only in the first year of retirement (see Equation (1)), assuming that personal savings are annuitized enables comparison between employees with defined benefit (DB) pension plans and those with defined contribution (DC) accounts[xxix]. Using inflation-indexed annuities keeps the income flows from wealth on par with those retirement income flows that are also inflation-adjusted (CPP, OAS, GIS, and inflation adjusted employer DB pension benefits)[xxx]. We note, however, that since people generally do not voluntarily annuitize[xxxi], the mortality premium underlying annuity pricing will, on the whole, overstate the observed flow of gross income from wealth. Assuming annuitization also avoids consideration of the post-retirement financial risks that retirees face – such as inflation rate uncertainty, financial market risks, and longevity risk. A challenge for future researchers is to decide how to handle these various risks, either within or outside the replacement rate framework[xxxii].

### 3.2 Sample Population

Because our purpose is to understand whether the traditional 70% target replacement rate can maintain living standards after retirement without continued employment, this paper ignores the growing trend to partial retirement and part-time work among older workers[xxxiii]. We therefore include in our sample only those working individuals who cease employment after retirement (we define this as being employed less than 25%[xxxiv] of any fiscal year)[xxxv]. Our sample population is Canadian early baby boomers (born between 1951 and 1958) who retire at age 61 (the median retirement age in Canada – see Section 1)[xxxvi]. We define retirement as:

- working more than 75% of the weeks of the prior fiscal year; and
- working less than 25% of the weeks of any fiscal year thereafter.

Given this definition of retirement, this paper examines the continuity in living standards (as given in Equation (4) and defined in Figure 1) for individuals with a 65-75% replacement rate (as given in Equation (1) and repeated here):

$$\text{replacement rate} = \frac{\text{gross (i.e., before-tax) retirement income in the first fiscal year of retirement}}{\text{gross pre-retirement final earnings in the last fiscal year before retirement}}$$

where earnings are made up of wages and self-employment gross income, and gross retirement income is made-up of

- the retirement benefits from
  - the Canadian federal pension system (Canada/Quebec Pension Plan, Guaranteed Income Supplement, and Old Age Security),
  - any occupational DB pension plan(s)
- notional annuity income from registered savings - single-life inflation-indexed annuity, purchased at retirement with any registered personal savings (Registered Retirement Savings Plans) and occupational DC pension plan wealth.

The first column of Table 1 presents the broad characteristics of our sample population (1951-1958 Canadian birth cohort retiring at age 61 with a 65-75% conventional replacement rate as given in Equation (1)) – gender, marital status, work sector and education. Among the 1951-1958 birth cohort who are "working" at age 60 (i.e. employed more than 75% of the weeks within the fiscal year), just over 4% are simulated to retire at age 61 (that is, to not work for more than 25% of that fiscal year or any subsequent), and 5.4% of this group have a gross replacement rate between 65-75%. The next two columns of Table 1 present the comparable characteristics of all those members of the 1951-1958 birth cohort who retire at age 61 (with any level of gross replacement rates) and of the entire birth cohort. The group under examination is largely consistent with the more general birth cohort, except its members are somewhat more highly educated and consists of somewhat more public workers (from which we can conclude that the sample is likely more affluent with generally higher employer pension benefits).

Table 1: Characteristics of (1) 1951-1958 Birth Cohort who retire at age 61 with 65-75% Conventional Replacement Rate; (2) 1951-1958 Birth Cohort who retire at age 61; and (3) All Members of 1951-1958 Birth Cohort

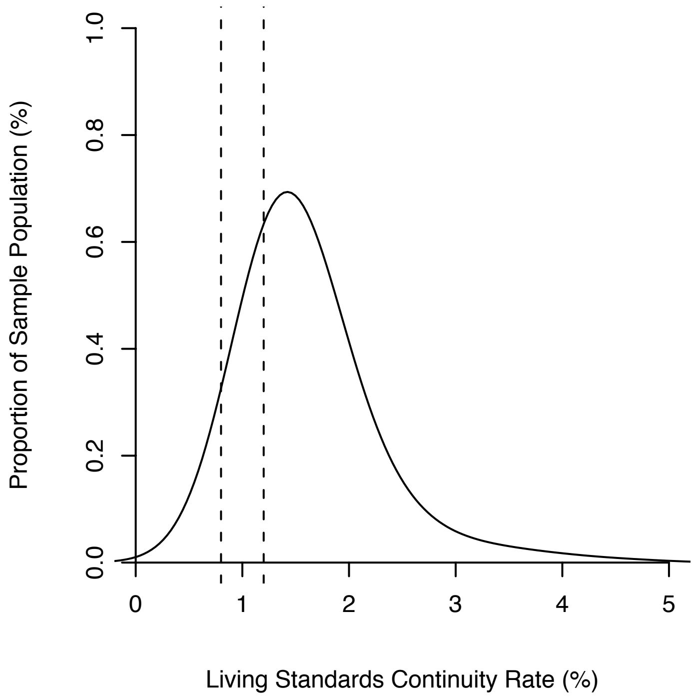
| | 1951-1958 Birth Cohort | | |
|---|---|---|---|
| | those who retire at age 61 with 65-75% conventional replacement rate | those who retire at age 61 | entire birth cohort |
| *Household* | | | |
| Single Male | 11% | 12% | 11% |
| Single Female | 19% | 15% | 14% |
| Member of Couple | 69% | 73% | 74% |
| | | | |
| *Sector* | | | |
| Public | 24% | 18% | 17% |
| Private | 76% | 82% | 82% |
| | | | |
| *Education* | | | |
| Less than High School | 9% | 17% | 23% |
| High School Graduate | 33% | 29% | 25% |
| Certificate (non-university) | 31% | 33% | 29% |
| University degree or certificate | 27% | 21% | 23% |

Note: 1% of the entire birth cohort never worked (therefore, do not receive the private nor public sector classification).

## 5. Results

Figure 2 plots the distribution of the Living Standards Continuity Rate (LSCR) for the 1951-1958 birth cohort of Canadians retiring at age 61 who achieve a 65-75% conventional replacement rate. Its basic message is that retirees satisfying the narrow 65-75% replacement rate criterion can actually expect a large range of changes of living standards continuity after retirement. The two dotted lines mark LSCR at 80% and 120% (the approximate range of living standards continuity – see Section 3.1). As Figure 2 shows, most of those people satisfying the narrow 65-75% replacement rate criterion can actually expect to improve their living standards after retirement (but to various degrees). Specifically, some 80% of the sample will improve their living standards by over 20% after retirement (that is, LSCR > 120%). Figure 2 further indicates that nearly everyone (99%) of those with a 65%-75% replacement rate is able to maintain 80% or more of working-life income for individual consumption.

Figure 2: Distribution of living standards continuity after retirement for the 1951-1958 birth cohort Canadians retiring at age 61 who achieve a 65-75% conventional replacement rate. (Distribution smoothed using a Gaussian kernel with a bandwidth based on normal distribution approximation).




Conventional replacement rate measured over lifetime at household level with a comprehensive measure of income sources available to the individual for consumption expenditure.

Figure 2 shows the distribution of outcomes of a population who started retirement with a simple replacement rate in the narrow range of 65-75%. The dispersion of outcomes is striking. What is causing it? Figure 3 shows how each improvement to the conventional replacement rate (RR) calculation from Equation (1) affects the distribution of results. Recall that Equation (1) used only a single year before and after retirement, looked only at individual income and had a narrow definition of income. Similarly to how Section 3.1 broke down the evolution of the conventional replacement rate formula into the LSCR formula using three steps, Figures 3a-3d examine the influence of time period, household size and income:

| RR#1: Conventional RR from Equation (1) |
|---|

↓ Measure the numerator and denominator over broader measurement period (as in the LSCR).

| RR#2: Conventional RR measured over lifetime |
|---|

↓ Each year, measure at the household level and then adjust for family size (as in the LSCR)

RR#3: Conventional RR measured over lifetime at household level

↓ Use fuller measure of income available for consumption expenditure (as in the LSCR).

LSCR from Equation (4)

Figure 3(a) shows the distribution of these four replacement rate measures (RR#1, #2, #3, and the LSCR). Figures 3(b), (c), and (d) opens up Figure 3(a) and more clearly show the relative change of moving from one replacement rate concept to the next.

In Figure 3(b), the distribution of the conventional replacement rate (RR#1) is, by definition, limited to 65-75% - but a single year's income is the sum of permanent and transitory income. Hence, broadening the measurement period by moving from RR#1 (single year) to RR#2 (longer period) spreads the distribution of actual replacement due to the influence of transitory income in both the numerator and denominator of RR#1.

To illustrate this, let $y_x$ represent permanent income at age x and $\sigma_x$ represent the transitory component, where $\sigma_x$ is drawn from a mean zero random distribution f(x). Observed annual income at age x equals $y_x + \sigma_x$. When observed annual income is used to define the 70% target at retirement age 61, Equation (1) states that retirement income adequacy occurs when $\frac{y_{62}+\sigma_{62}}{y_{60}+\sigma_{60}}=70\%$. However, if we examine the permanent income replacement rate $\left(\frac{y_{62}}{y_{60}}\right)$ of those individuals who satisfy this 70% criterion using observed annual income, manipulation of the previous equation shows that $\frac{y_{62}}{y_{60}}=70\%+70\%\frac{\sigma_{60}}{y_{60}}-\frac{\sigma_{62}}{y_{60}}$. Since $\sigma_{60}$ and $\sigma_{62}$ are random variables that are uncorrelated by construction, effectively, these transitory components in annual income have a spreading out effect on the observed 'permanent' replacement rate at age 61. $\frac{y_{62}}{y_{60}}=70\%+70\%\frac{\sigma_{60}}{y_{60}}-\frac{\sigma_{62}}{y_{60}}$.

Using the household as the unit of analysis in Figure 3(c) (RR#2 to RR#3) has the effect of marginally shifting the distribution of relative retirement well-being upward. The overall shift of the distribution is due to the incorporation of dependent children over the working-life[xxxvii]. Accounting for dependent children reduces effective working-life consumption, implying that any given amount of retirement income translates into more of an improvement in standard of living after retirement.

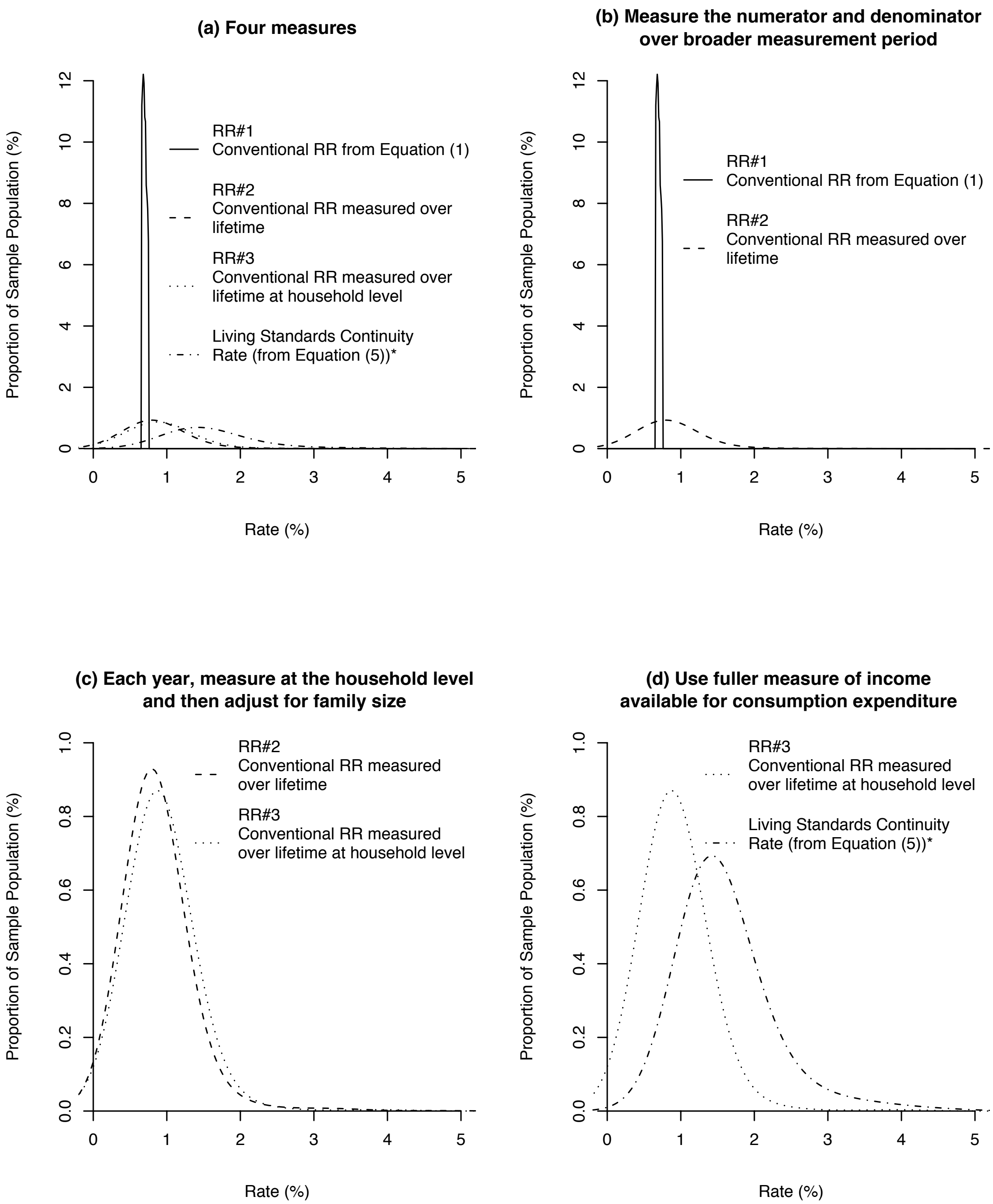
Finally, including all sources of income by moving from RR#3 to LSCR in Figure 3(d) improves the retiree's economic well-being relative to his/her working years because (1) it reflects the preferential tax treatment for Canadian seniors (much of which comes into effect after age 65[xxxviii]); and (2) it incorporates the accumulation and drawdown of other savings, which simultaneously decreases the denominator and increases the numerator. Specifically, consumption is diminished by the accumulation of non-registered savings (which includes mortgage payments) during working-life, while it is elevated by the drawdown of non-registered savings after retirement. Reducing the denominator and increasing the numerator both contribute to improving the overall rate, creating the rightward shift between RR#3 and LSCR.

The shift of the distribution in Figure 3(d) would have been even more significant had we included any drawdown of housing equity. Housing equity is the single largest net asset of most Canadians, and seniors are more likely to own their home without a mortgage than any other age group (Statistics Canada, 2006). Assuming that this asset is drawn upon in retirement would have resulted in even higher LSCRs.

In Figure 3(d), the distribution is wider for the LSCR compared with RR#3 owing to the varying impact of including these various other sources of income in each replacement rate's numerator and denominator. One example is taxation, which is conventionally assumed fixed in replacement rate literature but, in fact, has differential impacts between people and across the life-course owing to differences in:

- the amount of total income,
- tax deductions and tax credits according to personal circumstances,
- the composition of income by source,
- the distribution of income across spouses,
- location (since taxes vary by province),
- and the forms that savings take. For instance, the consumption and saving implicit in home ownership are completely untaxed (or even subsidized[xxxix]), whereas there is substantial complexity and diversity in the taxation of other forms of savings and consumption.

Figure 3: (a) Distribution of four replacement rate (RR) measures for the 1951-1958 birth cohort Canadians retiring at age 61 who achieve a 65-75% conventional replacement rate. Figures (b), (c), (d) opens up (a) and plots each new measure one at a time relative to the previous. (Other than RR#1, distributions smoothed using a Gaussian kernel with a bandwidth based on normal distribution approximation).




* Conventional RR measured over lifetime at household level with a comprehensive measure of income sources available to the individual for consumption expenditure.

It is reasonable to ask if the order of refining the conventional replacement rate affects the impacts. We next reverse the steps by first looking at the influence of income definition on the conventional replacement rate, then household size, and finally measurement period. Beginning again with the conventional replacement rate and ending with the LSCR, we calculate RR#4 and RR#5 using the following procedure:

RR#1: Conventional RR from Equation (1)

↓ Use fuller measure of income available for consumption expenditure (as in the LSCR).

RR#4: Conventional RR with fuller income measure

↓ Each year, measure at the household level and then adjusted for family size (as in the LSCR)

RR#5: Conventional RR with fuller income measure at household level

↓ Measure the numerator and denominator over broader measurement period (as in the LSCR).

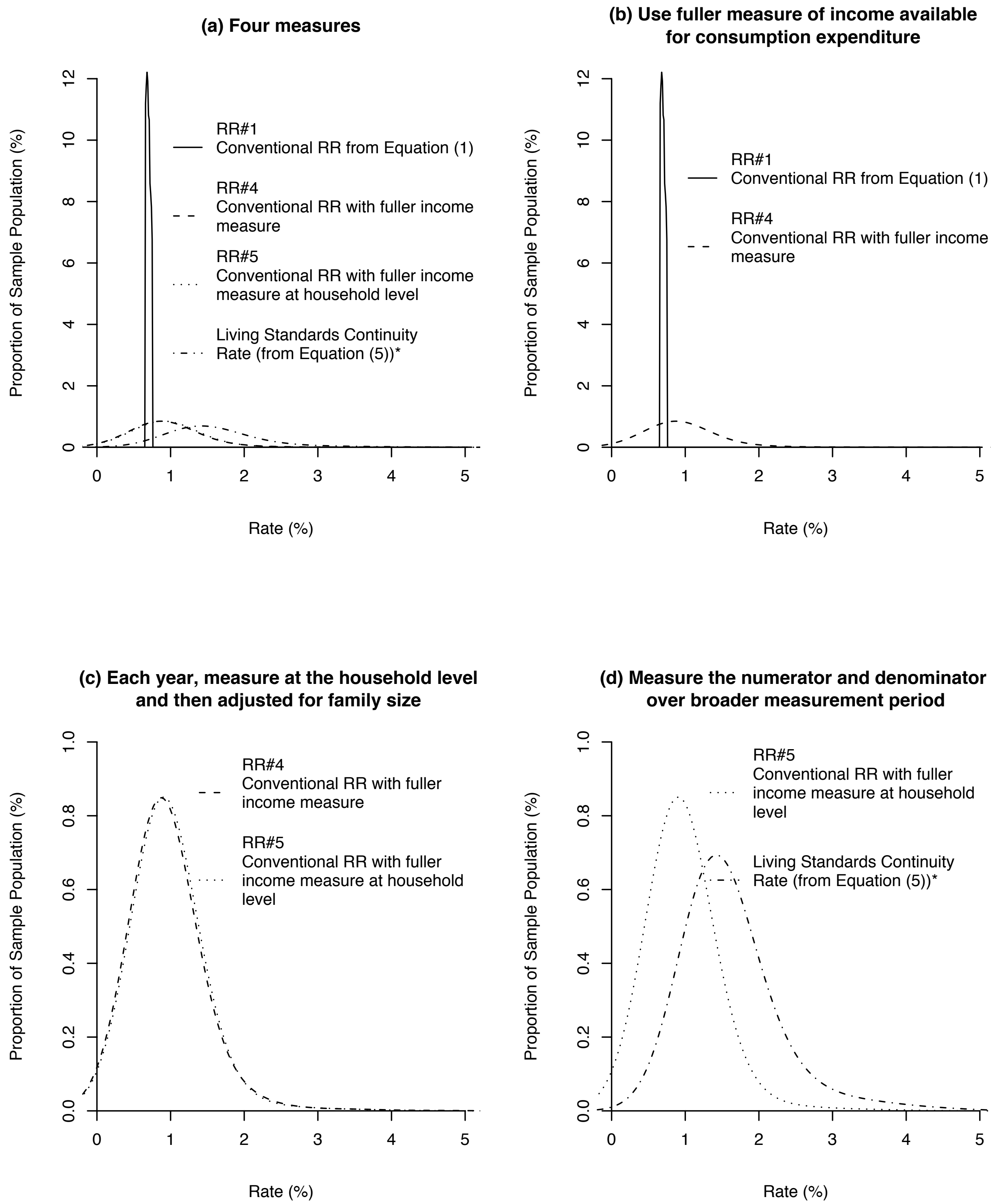
LSCR from Equation (4)

Figure 4 plots our results. Many of the same observations made for Figure 3 can be seen here.

Including all sources of income by moving from RR#1 to RR#4 in Figure 4(b) shifts and expands the distribution owing to the varying, and generally favorable, impacts of these other sources of income on the replacement rate.

There is minimal impact of using the household as the unit of analysis in Figure 4(c). This occurs because the measurement period is only the year before retirement (age 64), and therefore the most important household impact, namely dependent children, is not included. It is in Figure 4(d) that the improving impact of dependent children is realized once the measurement period is expanded (which also widens the distribution owing to the varying impact of income in these other years).

Figure 4: (a) Distribution of four replacement rate (RR) measures for the 1951-1958 birth cohort Canadians retiring at age 61 who achieve a 65-75% conventional replacement rate. Figures (b), (c), (d) opens up (a) and plots each new measure one at a time relative to the previous. (Other than RR#1, distributions smoothed using a Gaussian kernel with a bandwidth based on normal distribution approximation).

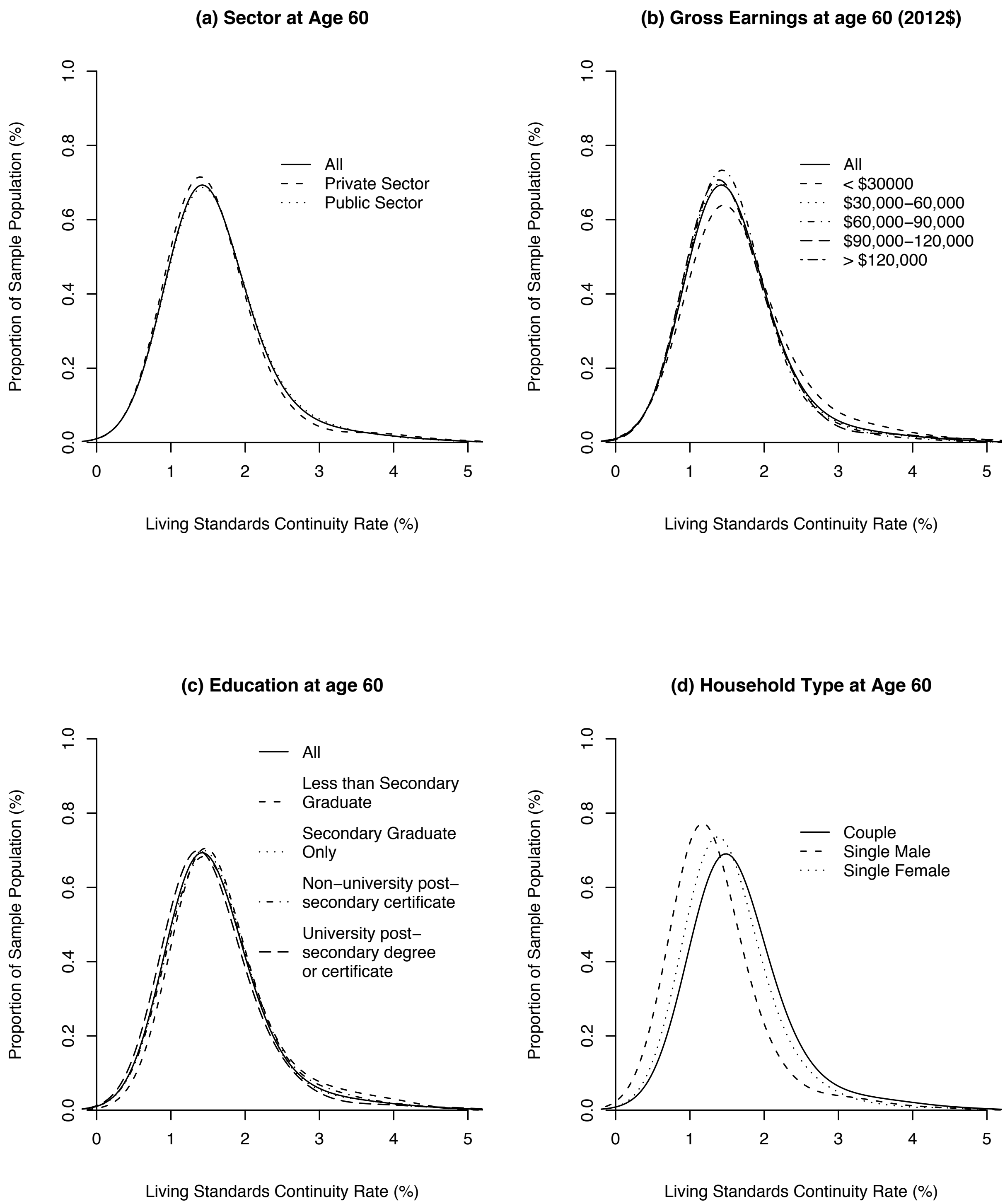


Figures 3 and 4 both show that the conventional replacement rate is not a robust indicator of living standards continuity - for example, it is immensely affected by improving the measurement period (comparing RR#1 to RR#2), or the income concept (comparing RR#1 to RR#4). It is commonly remarked that there is a wide range of previous findings with regard to retirement income adequacy across the replacement rate literature - whether in determining the 'correct' target replacement rate or the proportion of the population prepared for retirement (where, "within the economics profession, there is a lot of disagreement" (Munnell, 2005: 3)). This is not surprising given that analysts heterogeneously make various improvements to the replacement rate measure, which can have enormous impact on the results (as shown in Figures 3 and 4).

One of the most common improvements to the conventional replacement rate is to classify targets by marriage. Accounting for household composition by moving from RR#4 to RR#5 in Figure 4(c) has little effect on the replacement rate distribution if using the standard pre-retirement measurement period of one year. It is only when income is measured over years when children are dependent that the replacement rate distribution is appreciably affected by household composition (moving from RR#5 to LSCR in Figure 4(d)). As emphasized by Scholz and Seshadri (2009), the role of children in determining pre-retirement living standards is crucial, although nearly universally ignored in this line of research. Dependent children should not only be, moreover, a consideration during the pre-retirement period, but also after retirement given the increasing number of young adults living with their parents. For example, between 1981 to 2011, the ratio of young adults (aged 20 to 29) living with their parent(s) increased from 26.9% to 42.3% (Statistics Canada, 2011).

Figure 5 examines whether there is a specific characteristic(s) within the sampled population driving the wider distribution. It indicates that this is not the case by segmenting the population by work sector, household type, education, and individual gross earnings at age 60. None of these characteristics drive the wider distribution. The only noticeable impact is between singles and couples, where the distribution is shifted to the right, which is again a product of the more likely support of children that reduces the well-being of couples relative to singles before retirement, thus producing higher LSCRs.

Figure 5: Distribution of living standards continuity rate after retirement for the 1951-1958 birth cohort Canadians retiring at age 61 who achieve a 65-75% conventional replacement rate, by (a) work sector at age 60; (b) gross earnings at age 60; (c) education attainment at age 60; and by household at age 60. (Distributions smoothed using a Gaussian kernel with a bandwidth based on normal distribution approximation).



Does the traditionally measured 70% replacement rate offer much guidance as a retirement income adequacy target for living standards continuity? We conclude not. Only 22.5% of our sample population who achieved a 65-75% gross replacement rate achieved living standards continuity after retirement (defined as 80% < LSCR < 120%). On the other hand, looking at the entire population from the 1951-1958 birth cohort retiring at age 61 (that is, without filtering on the 65-75% gross replacement rate), we found that 28.5% achieved living standards continuity after retirement. Testing people who achieved lower (60%) and higher (80%) gross replacement rate targets produced similar results - between 20-30% of them achieved living standards continuity. This suggests that the gross replacement rate target has little information content.

Is there a better measure? Clearly, the closer the measure resembles our living standards continuity framework, the better it will perform according to the LSCR (by definition). For example, a target that is calculated using income for individual consumption, measured at the household level (as given in Figure 1), averaged over a sufficiently wide period, would perform better according to our measure. As observed above, however, all three simultaneous improvements (better measurement period, more comprehensive income concept, and all done at the family level) are necessary. For example, with regard to living standards, we observed in Figure (c) that using a longer measurement period is unhelpful without accounting for family size (and vice versa).

## 6. Conclusion

Overall, we find that people who attain the conventionally measured 65-75% gross final earnings replacement rate will experience a large range of changes of average living standards after retirement, which suggests that the 70% replacement rate poorly predicts living standards continuity in retirement. A reduced living standard after retirement is clearly problematic, while an improved living standard could result from an over-sacrifice of working-life welfare.

Rather than the 70% target value, we find that the problem lies in the conventional gross final employment earnings replacement rate measure itself, which relies on an inadequate measurement period (particularly in the pre-retirement phase), does not incorporate important components of consumption, and ignores household size. We find that refining the conventional replacement rate measure requires the simultaneous improvement in all three of these spheres since the full effect of improving one may not emerge without the others.

The "one-size-fits-all" 70% final gross earnings replacement rate is a widespread benchmark to determine retirement income adequacy, commonly used by public policy analysts, sponsors of defined contribution and defined benefit pension plans, academics, financial advisors, and individuals making retirement financial planning decisions. Unfortunately, it does not predict living standards continuity in retirement very well at all.

### Acknowledgements

We would like to thank Malcolm Hamilton, James Davis, Deborah Ng, and Rob Brown who provided valuable feedback on various drafts. This project began in response to a call for proposals by the

Society of Actuaries' Pension Section and we gratefully acknowledge their financial support and the feedback given by the project oversight group. This paper was funded by the Rotman International Center for Pension Management at the Rotman School of Management, University of Toronto, for whom we thank. We thank the ICPM review committee for their valuable feedback.

## Appendix A

Rather than use rules of thumb, some studies estimate average target gross replacement rates using survey data. This includes Palmer (1988, 2008), who produced universal target gross replacement rates for workers classified by earnings level, region, and family configuration[xl] by implicitly employing Equations (2) and (3). He estimated its components for subgroups of workers using data from the U.S. Consumer Expenditure Survey and matched workers and retirees with similar disposable incomes in the survey year. To provide a basic overview of his approach, for each subgroup of workers, he:

A. determined the average annual gross income, taxes, savings rate and dissavings rate for the working members of the subgroup.
B. determined the average annual savings rate less dissavings rate for retired members of the subgroup with similar income levels.
C. solved for annual **retirement gross income and taxes** (retirement gross income and taxes were solved simultaneously since one affects the other) by setting:

***retirement gross income –retirement taxes*** *– retirement savings* + dissavings**
= working gross income** –taxes** –savings** + dissavings**,

where
* calculated in step C
** calculated in step A

Finally, with the "retirement gross income" calculated, he estimated the target gross replacement rate for the sample:

= retirement gross income/working gross income.

Palmer further produced a second set of replacement rate targets, which incorporated the impact of period-specific expenses that do not exist in both pre- and post-retirement, such as those associated with employment and senior aging.

Mitchell and Moore (2000) and Munnell et al. (2006) took conceptually similar approaches to estimate target gross replacement rates, but they further evaluated whether current workers (future retirees) appear to be on track to achieving them.

## Appendix B: Methodological Issues of the Conventional Replacement Rate

This section discusses the methodological issues of the conventional replacement rate and gives examples of the various approaches employed by analysts (the examples given are not comprehensive, but are intended to provide samples).

### *B-1 Household-level differences in consumption due to family size*

The conventionally measured replacement rate is done at the individual level. Economists have long recognized, however, that most individuals live in households and share consumption with others, implying that household or family income should be used when determining living standards. In the current context, this also implies that parents need less income in retirement to maintain their pre-retirement standard of living than childless individuals with similar pre-retirement income because a large fraction of their pre-retirement budget has been devoted to supporting children.

A widely accepted method of taking family size and economies of scale into account is to assigning each person in the family an amount of income equal to the square root of the total family income. Known as the LIS equivalence scale, this is the approach used by Statistics Canada's Low Income Measure.

In applying the replacement rate to analysis, the literature has been diverse in terms of unit of analysis.

Some replacement rate studies have used individuals (VanDerhei, 2006; Ostrovsky and Schellenberg, 2009), while others include spouses (Mitchell and Moore, 1998; Munnell et al., 2006). Some studies have used individuals as the unit of analysis, but calculate per-capita income at the level of couples (Butrica et al., 2003) (for example, if the consumption of one spouse is $100,000 and the other zero, each spouse would be assumed to have consumed $50,000). Studies that use longitudinal data have to contend with the fact that marital status changes through time. For example, it is not obvious whether a man who marries in the year leading up to his retirement should be considered married or single for the purposes of computing his replacement rate. Smith (2003) discussed these issues (including transitions to widowhood) between pre-retirement and post-retirement, and adjusted replacement rates accordingly by using an equivalency scale.

While analysts often incorporate marital status, children are routinely not considered (Scholz and Seshadri, 2009:3). Examples of replacement rate studies that construct replacement rate measures where pre-retirement consumption is explicitly reduced to reflect the costs of supporting dependent children include Larochelle-Cote, Myles and Picot (2008), Scholz and Seshardri (2009), Moore et al. (2010), and MacDonald et al. (2011).

### *B-2 Components of income*

Early literature tended to restrict the included sources to those found in income data (Boskin and Shoven, 1987) (Palmer, 1988), and this approach continues in studies that rely exclusively on this data source (Smith, 2003) (Larochelle-Cote, Myles and Picot, 2008) (Ostrovsky and Schellenberg, 2009). Although some sources of income are adequately captured in traditional income data or administrative data, others are not. For example, the drawdown (or dissavings) of non-registered assets, such as savings held in bank accounts, bonds, mutual funds, stock markets, and certain annuities, is not captured in traditional income data sources; typically only the annual yield on such capital is identified as "income".

For savings in the form of home ownership, neither the imputed rent, mortgage payments, nor the consumption represented by its drawdown is visible in such data.

Instead of using earnings to solely determine the replacement rate denominator, Munnell and Soto (2005) and Munnell et al. (2006) included pre-retirement investment income in the replacement rate denominator. Smith (2003), LaRochelle-Cote, Myles and Picot (2008) and MacDonald et al. (2011) incorporated investment income as well as government transfers (such as social assistance, employment insurance and child benefits).

“Imputed rent” has been considered by Munnell and Soto, 2005; Munnell et al., 2006; Moore et al., 2010; MacDonald et al., 2011; and Wolfson, 2011. Imputed rent can be regarded as a form of investment income – the return from savings that are held in the form of real property, rather than in financial assets. Including imputed rent in the replacement rate denominator recognizes that homeowners who have some equity in their homes are enjoying a flow of services that is an important source of household consumption (Brown, Hou and Lafrance, 2010). The importance of imputed rent continues to apply in retirement, particularly given that the cost of shelter is the largest expenditure from among a healthy senior’s basic costs of living (MacDonald et al., 2010) and that seniors are more likely to own their home than any other age group (in Canada, see Statistics Canada (2006)).

With regards to pre-retirement savings, Palmer (1988) developed target gross replacement rates using a measure that reasonably captured most forms of savings, but appeared to omit the savings represented by paying down one’s mortgage. The target gross replacement rates developed by Mitchell and Moore (1998), Munnell et al. (2006) and Brady (2010), on the other hand, included the reduction of mortgage principal in pre-retirement savings. Using microsimulation modeling, Moore et al. (2010) and Wolfson (2011) incorporated pre-retirement savings in the form of employer-sponsored pension plans, registered retirement savings plans, and paying down mortgages. MacDonald et al. (2011) took a somewhat more comprehensive approach by also measuring non-registered wealth and debt accumulation (including financial assets/debts, real-estate investments and equity in businesses owned).

Personal wealth includes equity in an owner-occupied home, which therefore could be seen as a component of retirement savings. Many argue that homes are a special case, however, and that an assessment of the replacement adequacy of the retirement income system should not assume that retirees sell their homes or otherwise deplete their home equity. Excluding this asset class, which for most Canadians is the single largest net asset (Statistics Canada, 2006), clearly distorts important differences in financial security between homeowners and renters, and between homeowners with very different amounts of home equity. Gustman and Steinmeier (1998), Moore and Mitchell (2000), Munnell et al. (2006) and Munnell, Webb and Golub-Sass (2007a; 2007b) explicitly included the drawdown of all housing wealth in addition to financial assets. Moore et al. (2010) included both imputed rent and the drawdown of registered assets, and also explored the impact of drawing down different proportions of home equity. Engen, Gale, and Uccello (1999) included half of home equity (this half-way point was supported by Munnell (2005)). MacDonald et al. (2011) included imputed rent and the drawdown of registered and non-registered wealth, but did not include home equity, which they assumed is not consumed in retirement.

Replacement rate studies are divided on the issue of employment earnings as a component of retirement income. In most of the literature, earnings are expressly excluded on conceptual grounds that the purpose of a "replacement rate" is to evaluate the extent that employment earnings have been replaced after retirement (where retirement is the cessation of employment) (Mitchell and Moore, 1998; Munnell et al., 2006; Biggs and Springstead, 2008; Moore et al., 2010; MacDonald et al., 2011). In other studies, earnings are either purposely included in the numerator, or are included in a broader "total income" variable (Boskin and Shoven, 1987; Smith, 2003; Larochelle-Cote, Myles and Picot, 2008).

Income taxes should be subtracted from gross pre- and post-retirement income. This is done directly for each individual if individualized targets are being employed (such as in MacDonald et al. (2011)). Otherwise, when averages are used to determine target gross replacement rates (see Appendix A), differentials in income taxes pre- and post-retirement are incorporated into the target gross replacement rates.

### *B-3 The volatility of earnings and retirement income*

One of the most central methodological issues in designing a replacement rate measure is the choice of measurement period for the denominator.

The "replacement rate" goal is the preservation of pre-retirement living standards, but this leads to the question: pre-retirement living standards measured over what period? Much of the consumption literature finds that the average shape of consumption over an individual's life has a distinct "hump" shape (Gourinchas and Parker, 2002; Fernandez-Villaverde and Krueger, 2007). On average, annual consumption early in an individual's career closely tracks earnings and typically rises at a relatively rapid pace. After an individual reaches their "prime" working years, however, annual consumption increases much more gradually or even levels off completely. Consumption tends to peak in late middle-age, and starts declining gradually thereafter, even as annual earnings remain flat or continue to increase.

The most important complications arise, however, because replacement rate denominators are typically calculated using gross earnings and not income for consumption expenditure (see Equation (1)). Annual earnings have considerable year-over-year variation (Morrison, 2000), which creates complex and diverse earnings histories across individuals. Many individuals exhibit tremendous "earnings mobility"[xli], and consequently occupy quite different rankings in the distribution of earnings over the course of their careers (Finnie, 1999) (Beach and Finnie, 2004). Overall, it cannot be assumed that any narrow measurement period is "representative" of earnings since it will reflect different things for different individuals.

Further, much of the theoretical literature relating to life-cycle income and consumption suggests that the relationship between an individual's standard of living and his/her earnings measured over any particular short-term period may be quite weak (Modigliani and Brumberg, 1954). This literature suggests that individuals prefer a relatively consistent standard of living, so they smooth their consumption over long time horizons, such as their entire lifetimes, rather than making current consumption decisions based primarily on current income (ibid).

The measurement period used to calculate pre-retirement earnings can have an enormous impact on the resulting replacement rate, leading to quite different conclusions about replacement adequacy, as observed in Biggs and Springstead (2008), Munnell and Soto (2005) and Boskin and Shoven (1987).

In the applied replacement rate literature, there is tremendous diversity in the measurement periods used to calculate the pre-retirement denominator. As we discuss below, this diversity applies both to the part of the life-course chosen, and the number of years averaged in the calculation.

Some studies use only one year of data. For example, Palmer's work (1988) (2008) relied on a single cross-sectional year of data with individuals between ages 50 and 64, whom he averaged across to produce the denominator. Mitchell and Moore (1998) essentially used final earnings, but the denominator was calculated deterministically by taking a single year of data (an individual's earnings in 1992) and assuming constant real wage growth until retirement. Munnell et al. (2006) similarly began with data on a household's pre-retirement income in a single year, 2003, and projected it forward to retirement age according to an average earnings profile. Using only one year of data, and projecting any remaining years from this one observation in a highly stylized manner, ignores the substantial variation in many individuals' earnings.

Brady (2010) calculated average career earnings from ages 30 to 67, but relied on a handful of illustrative individuals with stylized earnings histories.

Using longitudinal earnings data, Smith (2003), LaRochelle-Cote, Myles and Picot (2008) and Ostrovsky and Schellenberg (2009) all averaged the earnings of each sampled individual from ages 54 to 56, which were characterized as “peak” and “permanent” earnings. Given the substantial variability in employment and earnings across many individuals' life-courses, average earnings for this age range will represent neither peak nor permanent earnings for a significant number of individuals (Finnie 1999) (Morissette, Zhang and Frenette, 2007) (Finnie and Gray, 2011).

Munnell and Soto (2005) used approximately forty years of longitudinal micro-data on individual earnings to calculate both career-average and final average (best 5 of final 10) measures for the denominator. Boskin and Shoven (1987) similarly used 23 years of longitudinal earnings microdata to calculate career average and final average (best 3 of final 10) measures. The impact of the chosen measurement period had a substantial impact in both studies.

As noted in Section 2.1, studies that use large-scale, dynamic microsimulation models have nearly complete flexibility in choosing the pre-retirement measurement period in the denominator - such as in Butrica et al. (2003), Moore et al. (2010), MacDonald et al. (2011), and Biggs and Springstead (2008).

Relative to earnings, retirement income sources tend to be much smoother, although there are some exceptions (see Section 3.1). This suggests that a broad "retirement average" measurement period should be preferred for post-retirement income or consumption, rather than a narrow measurement period (such as the first year after retirement).

Most of the literature has used a single, cross-sectional snapshot of post-retirement income (Smith, 2003) (Ostrovsky and Schellenberg, 2009; Palmer, 1988). Conventionally, replacement rate studies have tended to look specifically at income in the first year of retirement (GAO, 2001).

Some researchers have applied adjustments to contend with the short post-retirement measurement period of one year in conventional replacement rates. For example, Steinberg and Lucas (2004) suggested increasing conventional targeted replacement rates by 10 to 15 percentage points to account for the lack of inflation indexing in many retirement benefits (the lower range would be for low-income seniors, who rely largely on inflation-indexed Social Security benefits). Alford, Farnen and Schachet (2004) made similar adjustments.

Some studies have taken snapshots of replacement rates at several different ages post-retirement (Biggs and Springstead, 2008).

Larochelle-Cote, Myles and Picot (2008) stands out in this regard, as it used longitudinal data to follow individuals and couples through their retirement years, from ages 55 to 80, with a particular focus on the evolution of their replacement rates over time and the stability of their retirement income.

### *B-4 Pre-and post-retirement financial risks*

Workers and seniors face different risks. The major income source risks for workers are labor market risk and the investment rate risk. For a senior, it's generally investment rate risk, inflation risk, generating an expensive medical condition, and living 'too long' (that is, outliving their financial resources). Unlike workers, seniors have much less opportunities to react to these risks – for example, it is usually less feasible to return to the labor market if investments perform poorly. Consequently, post-retirement risks are an important area of study[xlii].

Typically, replacement rate measures have not explicitly accounted for important risks of retirement that can affect a senior's financial well-being – namely, the risk of accelerating inflation, the death of a spouse, divorce, insurer default, low investment returns, annuitization rates, longevity, developing a health condition that generates significant out-of-pocket expenditures, increase in public taxes, and changes in retirement benefits by government and private plan sponsors (such as reductions in pension income, retiree medical benefits, pension cost-of-living adjustments, and other plan design features[xliii]). A challenge for future researchers will be to decide whether these various risks should be handled outside of the replacement rate framework, or if they should be a component of the study of replacement rate adequacy.

There has been acknowledgment in recent literature that retirement income adequacy measures should recognize post-retirement risks. For example, Schieber (2004) wrote that "singular rules of thumb for replacement rates are naive and that estimates should take into account the unforeseen risks that individuals face" (abstract). How to incorporate these risks is unclear, however, particularly for conventional replacement rate measures where the typical post-retirement measurement period is the first year of retirement. Choosing average or median costs is problematic – for example, an individual either has a major health condition or does not, and therefore incorporating the median cost of any particular illness in a replacement adequacy measure will be insufficient for half of the sample and cause the other half to unduly reduce their pre-retirement standard of living in order to save for an event that does not occur. The VanDerhei (2006) study offers one possible approach – he explicitly modeled the risk of catastrophic medical expenses, low investment returns, and longevity, and used microsimulation to simulate the distribution of possible future outcomes in order to demonstrate the uncertain financial impact of each contingency on retirement income adequacy targets. VanDerhei explained that the individual could choose the target that most appropriately fit his or her level of risk aversion (for example, a highly risk-averse person might choose the target replacement rate providing a 90% likelihood of maintaining a specified standard of living in retirement).

Holmer (2009) provided a further approach, by calculating replacement rates from expected risk-adjusted retirement income flows based on five hundred different macroeconomic projection scenarios (rather than expected average retirement income flows)[xliv].

### B-5 Purchasing power differences of income before and after retirement

How do replacement rates account for the fact that the denominator will be measured at a different time than the numerator (the former is before retirement and the latter is after retirement)? Most studies express the numerator and denominator in constant dollars using the consumer price index. An alternative method is to use wage indexation, which is the approach traditionally taken by the U.S. Social Security Administration (SSA, 2004) in its calculation of social security replacement rates, and was also used by Butrica et al. (2003) and Wolfson (2011). Using a consumer price index compares an individual's retirement income to the absolute level of pre-retirement consumption he/she actually experienced, while using a wage index also incorporates a comparison to the consumption of currently working generations. For most purposes, replacement rates are used to evaluate whether retirees' own consumption falls after retirement, rather than to make intergenerational comparisons and, for this reason, price indexation is used.

### B-6 Individual preferences for risk aversion, leisure, and bequest

As noted in Section 1, an alternative conception of retirement income adequacy employs a utilitarian framework (such as in Engen, Gale, and Uccello (1999), Scholz and Seshadri (2009), and Liu, Ostrovsky and Zhou (2013)). Although a utilitarian framework suffers from complexity in modeling true individual preferences, it is considered an ideal framework in the study of living standards as it has the capacity to "reflect differences in leisure as well as all forms of potential consumption, including home production and publicly provided goods; … account of differences in constraints faced both by people living in the same country, and differences in constraints faced by people in different countries; … (and) account for differences in the ability to smooth income across periods" (Canberra Group, 2001: 2). Mitchell and Moore (1998: 375) explained that "(w)hile the life cycle model is useful in theory, implementing it is complex in practice. Many in the financial advisory community suggest computing a number known as the "replacement rate," or the ratio of household income needed to finance desired retirement consumption divided by annual pre-retirement income. The number is a spiritual descendent of life cycle theory, but implicitly assumes that post-retirement consumptions should be equated to some fraction of the sum of pre-retirement consumption plus retirements saving".

### B-7 Changes in expenses over the life course

Replacement rates are concerned only with the replacement of pre-retirement consumption expenditure in post-retirement. There can be, however, period-specific consumption that does not need to be replaced in post-retirement and/or new post-retirement consumption that does not occur in pre-retirement. Consequently, an individual with an unchanging standard of living before and after retirement could in fact have different consumption levels owing to the effects of aging and the cessation of employment.

For example, expenses associated with employment generally cease after retirement (such as professional development fees, commuting to work costs, and the expense of special clothing). Further, retirees are better able to “stretch their dollar” owing to senior discounts and greater time for home production, consequently a dollar of retirement income could be more valuable than a dollar while working – for instance, it has been observed in both Canada (Brzozowski and Lu, 2010) and the U.S. (Aguiar and Hurst, 2005) that retirees spend less on food but still maintain the same quality of diet owing to more efficient shopping and cooking more at home. On the other hand, medical expenses are likely to rise with age, particularly those associated with a chronic health condition (see MacDonald et al. (2010) for a further discussion).

Should period-specific consumption be incorporated in the study of retirement income adequacy? The cost of medical care is likely the most material since it is both a necessary cost and a potentially significant one depending on the public/private nature of the health care system and the coverage afforded by the retiree’s employer. This is particularly true at advanced ages when the likelihood of suffering from acute and chronic health conditions is much higher. For instance, for those who need it, the expense of home care is a great concern since the onset of a chronic illness can be sudden and beyond the individual’s control, and the out-of-pocket cost can become quite substantial in both the U.S. (Russells et al., 2006) and Canada (MacDonald et al., 2010).

Analysts have the option to either integrate period-specific consumption (all components or those that are deemed most important) or to treat them as a topic outside of a replacement rate framework. For instance, new and significant retirement expenses (notably medical) could be investigated separately such as through a precautionary saving, or insurance type analysis. Alternatively, period-specific consumption could be built into a replacement rate analysis by being subtracted from the income for consumption expenditure from Figure 1.

In past replacement rate literature, the topic of period-specific consumption has been either not addressed, or done so very loosely in a wide variety of manners. For instance, Dexter (1984) included all components as a one-off net change in consumption requirements at retirement when developing target replacement rates. Building on Dexter (1984), Palmer (1988) defined this variable as:

Work-related expenses + Net Change in Age-Sensitive Expenditures

Palmer then developed two sets of target replacement rates – those with and without age- and work-related changes in consumption. McGill et al. (2010) took a similar approach, but modeled these two categories of expenses using regression analysis.

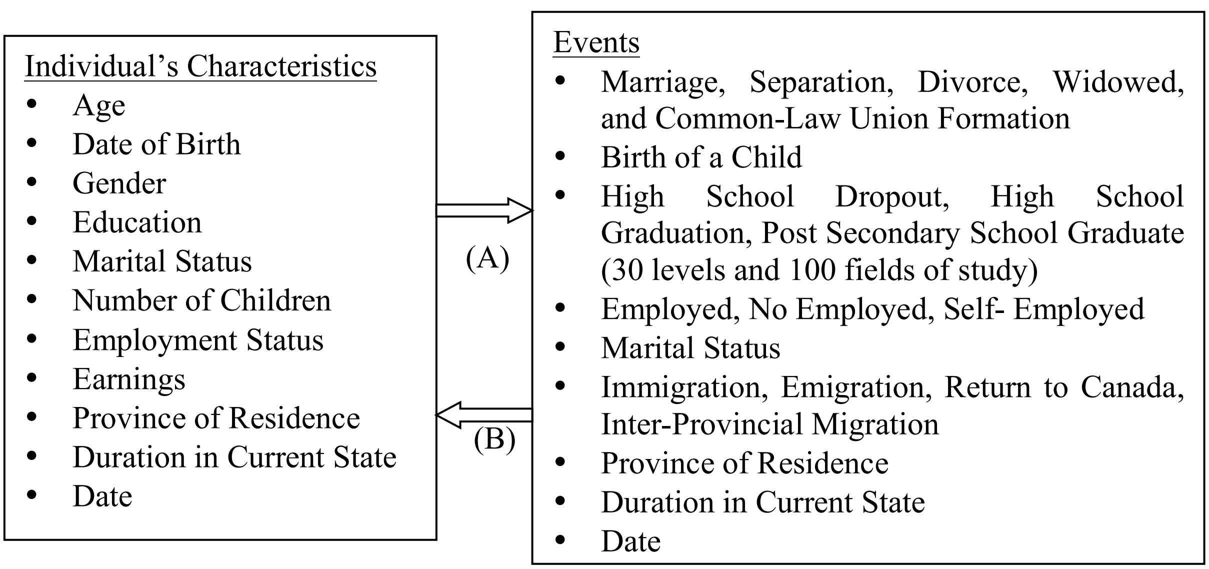
More recently, some of the literature has highlighted the cost of medical expenses after retirement when assessing the adequacy of retirement resources, and has integrated these expenses into replacement rate analysis. Steinberg and Lucas (2004), Alford, Farnen, and Schachet (2004), and Schieber (2004) used a conceptually similar approach as Palmer (1988) and subtracted net retiree medical costs from post-retirement income in the conventional gross replacement rate calculation. VanDerhei (2006) explicitly modeled medical expenses over the lifetime of the retiree to assess the adequacy of conventional gross replacement rates. As noted above, however, most replacement rate studies do not address period-specific consumption.

## Appendix C: LifePaths –Tool of Analysis

Statistics Canada's LifePaths is one of the world's largest dynamic microsimulation models of society. By integrating many data sets within Statistics Canada, LifePaths builds entire synthetic populations by simulating the detailed life-courses of virtual Canadians case by case. These virtual individuals attend school, make educational choices, leave home, form families, migrate, become parents, divorce and remarry, lose and find jobs, earn money, acquire homes, save, pay taxes, contribute to pension schemes, receive benefits and pensions, become disabled, and eventually die. LifePaths simulations aggregate to historical data over the past half-century and allow for detailed projections into the future (projections that incorporate the realistic complexity and diversity both across individuals and within life-courses).

*"Figure (4) represents the evolution of a simulated life in LifePaths. This is a simplified flow chart for illustration purposes, and is not intended to convey the true complexity of LifePaths. We list only some of the components of LifePaths—marital status, fertility, education, employment, and migration. For each simulated life, LifePaths tracks the individual's relevant characteristics, such as those listed in the first box. These characteristics enter as explanatory variables to determine the times until the occurrence of each possible event (arrow A). The event with the shortest wait time "wins" and, once it occurs, the individual's characteristics are updated (arrow B). These characteristics then enter again as explanatory variables to determine the next event (arrow A). This continues until death, thus creating a complete life course with all of the necessary details for millions of simulated Canadians*." (MacDonald et al., 2010, pg.76).

Figure 4: Illustration of LifePaths' simulation of a Canadian life-course.




Source: MacDonald et al. (2010) Figure 1.

LifePaths is strongly empirically-based. The model simulates detailed and diverse individual life courses using a variety of statistical methods, with particular emphasis on statistical event-history equations estimated from a broad array of data sources. Microdata with a longitudinal component are taken advantage of wherever possible. Methods such as quantile regression are often used to ensure that full distributions of outcomes are reproduced. This is combined with a detailed accounting model of the

Canadian tax-benefit and social insurance system, and its evolution over time. A multitude of census, survey and administrative sources of data have been used to estimate the behavioural equations, as well as to calibrate and validate the simulations to ensure that model outcomes are consistent with the distributions of socio-economic outcomes seen in historical data. As an indication, LifePaths relies heavily on historical demographic estimates and projections, on Census microdata from 1971 to 2006, and on a longitudinal version of the Labour Force Survey that integrates microdata from 1976 to 2009. Other important data sources used in LifePaths' development include the Family History Surveys from 1984-2001, administrative microdata on post-secondary education students, longitudinal income tax records, and the Surveys of Financial Security and their predecessor surveys. Many other sources of data have also been used in LifePaths' development.

As one tangible example, in the modelling of RRSP saving and wealth, the equations for individual annual RRSP behaviour, as well as its longitudinal persistence across the life-course, were estimated using longitudinal tax microdata from 1990-2001. Cross-sectional tax data from 1968-2010 were used to calibrate annual outcomes. Market rates of return to various financial assets classes were taken or derived from Bank of Canada Financial Market Statistics for 1927-2011. Finally, the 1999 and 2005 Surveys of Financial Survey, as well as earlier wealth surveys, were used to calibrate RRSP wealth, and/or to validate the distributions of RRSP wealth produced by LifePaths at the household level.

LifePaths is publicly-available and has been under development for nearly two decades. A basic overview can be found at the Statistics Canada Modeling Division (2010). We carried out our analysis by building on LifePaths Model version 5.1.4.4. The assumptions and calculations underlying the simulation results were prepared by the authors and the responsibility for the use and interpretation of these data is entirely that of the authors. In addition to working code that collects and calculates our measures of interest, we developed and integrated into LifePaths an improved annuity price calculator that realistically incorporates the relevant personal and financial market inputs akin to actual Canadian annuity providers. We also updated the financial market model up to the end of 2012.

## Bibliography

Alford, S., D.B Farnen, and M. Schachet. 2004. "Affordable Retirement: Light at the End of the Tunnel." Benefits Quarterly (4th Quarter, 2004): 7-14.

Aguiar, M. and E. Hurst. 2005. "Consumption Versus Expenditure." Journal of Political Economy 113(5):919-48.

Avery, M. and R.J. Morrison. 2009. "Spending Down One's Retirement Assets in an Uncertain World." Prepared for the June 2009 Meetings of the International Microsimulation Association, Ottawa, Ontario, Canada

Baldwin, B. 2009. "Research Study on the Canadian Retirement Income System: Final Report", Prepared for the Ministry of Finance, Government of Ontario

Beach, C. and R. Finnie. 2004. "A Longitudinal Analysis of Earnings Change in Canada." Canadian Journal of Economics. 37(1): 219-240.

B. Douglas Bernheim and others. 2000. “How Much Should Americans Be Saving for Retirement?” American Economic Review, vol. 90, no. 2 (May).

Biggs, A. and G. Springstead. 2008. “Alternate Measures of Replacement Rates for Social Security Benefits and Retirement Income.” Social Security Bulletin, 68(2).

Binswanger Binswanger, J. and D. Schunk. 2012. “What is an adequate standard of living during Retirement?” Journal of Pension Economics and Finance 11 (2): 203-222

Boskin, M. and J.B. Shoven. 1987. “Concepts and Measures of Earnings Replacement During Retirement.” In Zvi Bodie, John B. Shoven and David A. Wise, eds., Issues in Pension Economics. Chicago: University of Chicago Press.

Brady, P. 2010. “Measuring Retirement Resource Adequacy.” Journal of Pension Economics and Finance. 9(2): 235-262.

Brown, J.R. 2009. "Understanding the Role of Annuities in Retirement Planning." In Overcoming the Saving Slump, by A. (Editor) Lusardi. Chicago: University of Chicago Press.

Brown, S.L., & Lin, I.-F. “The gray divorce revolution: rising divorce among middle-aged and older adults, 1990–2010.” *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 67(6), 731–741. 2012.

Brown, W., Hou, F., and A. Lafrance. 2010. “Incomes of Retirement-age and Working-age Canadians: Accounting for Home Ownership.” Statistics Canada Economic Analysis Research Paper Series. Ottawa: July.

Brzozowski, M., and Y. Lu. 2010. "Home Cooking, Food Consumption, and Food Production among Retired Canadian Households." Canadian Public Policy. Vol. 36. No. 1. p. 107−128.

Buhmann, B., L. Rainter, G. Schmaus and T. Smeeding. 1988. “Equivalence Scales, Well-being, Inequality and Poverty: Estimates Across Ten Countries Using the Luxembourg Income Study Database.” Review of Income and Wealth 34.2:115-142.

Butrica, B., H. Iams and K. Smith. 2003. “The Changing Impact of Social Security on Retirement Income in the United States.” Social Security Bulletin, 65(3).

Dexter, M. 1984. “Replacement Ratios: A Major Issue in Employee Pension Systems”. National Committee on Public Employee Pension Systems. Washington, DC.

Dodge, D.A., A. Laurin, and C. Busby. 2010. “The Piggy Bank Index: Matching Canadians’ Saving Rates to Their Retirement Dreams.” E-brief no. 95, March 18. Toronto: C.D. Howe Institute. http://www.cdhowe.org/pdf/ebrief_95.pdf

Fernandez-Villaverde, J. and D. Krueger. 2007. “Consumption Over the Life Cycle: Facts From Consumer Expenditure Survey Data”. The Review of Economics and Statistics. 89(3): 552-565.

Fidelity Research Institute. 2007. The Fidelity Research Institute Retirement Index. Research Insights Brief; March.

Finnie, R. 1999. “Earnings mobility of Canadians, 1982-1992”. Perspectives on Labour and Income. Statistics Canada Catalogue No. 75-001.XPE: 9-15.

Finnie, R. and D. Gray. 2011. “Labour-Force Participation of Older Displaced Workers in Canada: Should I Stay or Should I Go?” IRPP Study No. 15.

Gourinchas, P-O. and J. Parker. 2002. “Consumption Over the Life Cycle”. Econometrica. 70(1):47-89.

Government Accountability Office (GAO). 2001. “Social Security: Program’s role in helping ensure income adequacy.” Report No. GAO-02-62. Washington, D.C.:GAO (November).

Gustman, A. and T. Steinmeier. 1998. “Effects of Pensions on Savings: Analysis with Data from the Health and Retirement Study,” Working Paper No. 6681 Cambridge, MA.: National Bureau of Economic Research (August).

Holmer, M. 2009. “Projecting Future U.S. Pension Benefits.” Washington, D.C.: Policy Simulation Group.

*Human Mortality Database. 2013.* University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). Available at www.mortality.org or www.humanmortality.de (data downloaded on [06/01/2013]).

James, E. and Song, X. "Annuity markets around the world: money's worth and risk intermediation." CERP Working Paper 16/0, 2001.

Keefe, J., Légaré, J., Charbonneau, P., and Décarie, Y., (2012). Intergenerational support to older Canadians by their adult children: Implications for the future.(Pp 141-158) In De Santis, G (Ed.), *The family, the market or the State? Intergenerational support under pressure in ageing societies.*International Studies in Population, Vol. 10. Springer Publisher.ISBN 97-94-007-4338.

Kotlikoff, L. 2006. “Is Conventional Financial Planning Good for your Financial Health.” Unpublished paper, February 2006.

LaRochelle-Cote, S., J. Myles and G. Picot. 2008. “Income Security and Stability During Retirement in Canada.” Analytical Studies Branch Research Paper Series. Cat. No 11F0019M. Ottawa: Statistics Canada.

MacDonald, B-J., Andrews, D., and R. Brown. 2010. “The Canadian Elder Standard - Pricing the Cost of Basic Needs for the Canadian Elderly.” Canadian Journal on Aging / La Revue canadienne du vieillissement 29.1: 39-56.

MacDonald, B-J., Moore, K., Chen, H., and R. Brown. 2011. “Canadian National Retirement Risk Index: Employing Statistics Canada’s LifePaths to Measure the Financial Security of Future Canadian Seniors.” Journal of Canadian Public Policy 37(1): 73-94.

Mackenzie, G. A. (Sandy), 2010. "The Decline of the Traditional Pension," Cambridge Books, University Press, number 9780521518475.

McGill, D., Brown, K., Haley, J. and S. Schieber. "Fundamentals of Private Pensions, 9th Edition." Oxford University Press: 2010.

Milevsky, M.A. and Young, V.R. "Annuitization and Asset Allocation." *Journal of Economic Dynamics and Control* 31, no. 9 (2007): 3138–77.

Milevsky, M. A., and L. Shao. "Annuities and their Derivatives: The Recent Canadian Experience." Pension Research Council Working Paper. Pension Research Council, University of Pennsylvania. Philadelphia. Retrieved from http://ssrn.com/abstract=1706893. (2010).

Mills, M. and M. Young. 2004. "Facing the New Facts of Retirement Income Adequacy." Benefits Quarterly (4th Quarter, 2004): 40- 47.

Mitchell, O. and J. Moore. 1998. "Can Americans Afford to Retire? New Evidence on Retirement Saving Adequacy." Journal of Risk and Insurance. 65(3): 371-400.

Modigliani, F. and R. Brumberg. 1954. "Utility analysis and the consumption function: an interpretation of cross-section data." In K. Kurihara, (ed.), Post-Keynesian Economics. New Brunswick: Rutgers University Press.

Moore, James F. and Olivia S. Mitchell. 2000. "Projected Retirement Wealth and Savings Adequacy in the Health and Retirement Study," in Olivia S. Mitchell, P. Brett Hammond, and Anna M. Rappaport, ed. Forecasting Retirement Needs and Retirement Wealth. Philadelphia: Pension Research Council and the University of Pennsylvania Press: 68-94.

Moore, K., Robson, W. and A. Laurin. 2010. "Canada's Looming Retirement Challenge: Will Future Retirees Be Able to Maintain Their Living Standards Upon Retirement?" C.D. Howe Institute Commentary No. 317.

Morissette, R., Zhang, X. and M. Frenette. 2007. "Earnings Losses of Displaced Workers: Canadian Evidence from a Large Administrative Database on Firm Closures and Mass Layoffs." Analytical Studies Branch Research Paper No. 291. Catalogue No. 11F0019MIE. Ottawa: Statistics Canada.

Morrison, R. J. 2000. "Assessing the Quality of DYNACAN's Synthetically-Generated Earnings Histories." Paper presented at the 6th Nordic Conference on Microsimulation, June, 2000, Copenhagen, Denmark.

Munnell, A. H. 2005. (May). Do people save enough for retirement? TIAA-CREF Trends and Issues.

Munnell, A. and M. Soto. 2005. "What Replacement Rates Do Households Actually Experience in Retirement?" Boston: Center for Retirement Research .

Munnell, A., Webb, A. and F. Golub-Sass. 2007a. "What Moves the National Retirement Risk Index? A Look Back and an Update." Center for Retirement Research at Boston College. January. Issue Brief Number 7-1.

Munnell, A., Webb, A. and F. Golub-Sass. 2007b. "Is There Really a Retirement Savings Crisis? An NRRI Analysis." Center for Retirement Research at Boston College. August. Issue Brief Number 7-11.

Munnell, A., Golub-Sass, F., and A Webb. 2011. "How Much to Save for a Secure Retirement." Center for Retirement Research at Boston College. August. Issue Brief Number 11-13.

Munnell, A., Webb, A., and L. Delorme. 2006. "A New National Retirement Risk Index" Chestnut Hill, MA: Center for Retirement Research at Boston College.

Organization for Economic Co-operation and Development, OECD. "Private Pensions and the Financial Crisis: How to Ensure Adequate Retirement Income from Defined Contribution Pension Plans?" Working Party on Private Pensions. 2009.

Ostrovsky, Y., and G. Schellenberg. 2009. "Pension Coverage, Retirement Status, and Earnings Replacement Rates Among a Cohort of Canadian Seniors." Statistics Canada Analytical Studies Branch Research Paper Series. Ottawa: December.

Palmer, B. 1988. The Impact of Tax Reform on Wage Replacement Ratios. Atlanta, Georgia: Center for Risk Management and Insurance Research at Georgia State University.

Palmer, B. 2008. 2008 GSU/Aon RETIRE Project Report. Atlanta, Georgia: Center for Risk Management and Insurance Research at Georgia State University.

Quinn, J. P. 1999. Retirement patterns and bridge jobs in the 1990's. EBRI Issue Brief 206. Washington, DC: Employee Benefit Research Institute.

Schieber. 2004. "Retirement Income Adequacy: Good News or Bad?" Benefits Quarterly (4th Quarter, 2004): 27-39.

Scholz, J. and A. Seshadri. 2009. "What Replacement Rates Should Households Use?" Working Paper WP 2009-214. Wisconsin: Michigan Retirement Research Center.

Schwartz, D. 2010. "Will a retirement boom start in 2011?". CBC News. December 31, 2010. http://www.cbc.ca/news/canada/story/2010/12/30/f-boomers-retire.html

Skinner, J. 2007. "Are You Sure You're Saving Enough for Retirement?" Journal of Economic Perspectives. 21(3):59-80.

Smith, J. 2003. "Trends and projections in income replacement during retirement." Journal of Labor Economics. 21(4): 755-781.

Social Security Administration. 2008. The future of Social Security. SSA Publication No. 05-10055, ICN 462560. Washington, DC: SSA.

Springstead, G. and A. Biggs. 2008. "Alternate Measures of Replacement Rates for Social Security Benefits and Retirement Income." Social Security Bulletin, 68(2).

Statistics Canada Demography Division. 2010. "Population Projections for Canada, Provinces and Territories 2009 – 2036". Cat. No. 91-520-X

Statistics Canada. 2006. "The Wealth of Canadians: An Overview of the Results of the Survey of Financial Security 2005". Pension and Wealth Research Paper Series. Ottawa, Statistics Canada, 2006. (Cat. No. 13F0026MIE-No. 001)

Statistics Canada, 2011 Census.*Living arrangements of young adults aged 20 to 29.*2011 Census in Brief. Ottawa: Statistics Canada, 2012 (Cat. No. 98-312-X2011003).

Steinberg, A. and L. Lucas. 2004. "Shifting Responsibility: The Future of Retirement Adequacy In America." Benefits Quarterly (4th Quarter, 2004): 15-26. Adapted from: Hewitt Associates. 2004. "Total Retirement Income at Large Companies: The Real Deal"

Steuerle, C., Spiro, C. and A. Carasso. 2000. "Do Analysts Use Atypical Workers to Evaluate Social Security?" Straight Talk on Social Security and Retirement Policy, (19). Washington DC: The Urban Institute.

TD Economics. 2010. "Retirement Income Security Reform: Rush Prudently, Don't Run Blindly." Special Report. http://www.td.com/economics/index.jsp.

The Canberra Group, 2001. Expert Group on Household Income Statistics: Final Report and Recommendations, Ottawa, Canada.

Vincent, G. K., & Velkoff, V. A. 2012. US Census Bureau. The next four decades the older population in the United States: 2010 to 2050. Population estimates and projections P25-1138. Washington, DC: US Dept. of Commerce, Economics and Statistics Administration, US Census Bureau; 2010.

VanDerhei, Jack. 2004. "Measuring Retirement Income Adequacy, Traditional Replacement Ratios, and Results for Workers at Large Companies." EBRI Notes, no. 9 (Employee Benefit Research Institute, September 2004).

VanDerhei, J. 2006. "Measuring Retirement Income Adequacy: Calculating Realistic Income Replacement Rates." Washington DC: Employee Benefit Research Institute.

Wolff, Edward N. 2011. "Pensions in the 2000s: the Lost Decade?" NBER Working Paper No. 16991.

Wolfson, M. 2011. "Projecting the Adequacy of Canadians' Retirement Incomes: Current Prospects and Possible Reform Options." IRPP Study 17. Montreal: Institute for Research on Public Policy.

[i] From 1950 to 2009, the average life expectancy of a 65 year-old grew from 15.0 to 21.7 years for female Canadians, 13.3 to 18.6 years for male Canadians, 15.1 to 20.5 years for female Americans, and 12.8 to 17.3 years for male Americans (Human Mortality Database, 2012).

[ii] This uncertainty has arisen from (1) the shift among the design of employer pension plans from defined benefit (DB) (where the risk of the benefit payments is the responsibility of the employer) to defined contribution (DC) (where the risk lies with the individual) in the U.S. and Canada (MacKenzie, 2010), (2) increases in normal retirement ages, which removes guaranteed benefits during the delayed period (such as the approved future delay in Old Age Security universal benefits for Canadian seniors and the prominent proposal to delay U.S. Social Security benefits to ensure the solvency of the program), (3) the 2008 financial crisis and its immediate impact of reducing personal retirement savings (Wolff, 2011) and the continuing low interest rate environment that reduces the accumulation of personal savings, heightens the cost of annuitization, and drives sponsors of underfunded DB pension plan sponsors to freeze and/or close pension plans.

[iii] Divorce rates more than doubled between 1990 and 2010 from 4.87% to 10.05% for Americans aged 50 and above (while U.S. population-wide divorce rates have declined) (Brown and Lin, 2012).

[iv] The ratio of Canadians/Americans aged 65 and over to those ages 20-64 in 2010 was 22% – growing by 2030 to 35% in the U.S. and 41% in Canada (Statistics Canada, 2010; Vincent and Velkoff, 2012).

[v] People aged 85 and above are most affected by chronic health conditions and their share of the population is rapidly growing (in 2010, there were three American seniors aged 85 and above for every working-aged American – this is projected to grow to eight by 2050 (Vincent and Velkoff, 2012)). While caregivers have historically been family and friends (see Akbari (2011)), this will decline owing to fewer children, greater mobility of family members, greater workforce participation of women, and changing expectations of care within families (Keefe, Charbonneau, Décarie, & Légaré, 2012).

[vi] Smith et al. (2009) found that retirees consume their personal savings at a very slow rate (the personal wealth of the upper income quintile actually continued to accumulate after retirement).

[vii] Moreover, the assumption that 70% gross replacement after 35 years of service is the appropriate retirement income target underlies both the design of most employer pension plans and the limits relating to retirement savings in the Canadian Income Tax Act. At the individual level, it is currently the "staple of web-based financial planning products" (Scholz and Seshadri, 2009).

[viii] Using longitudinal data from the *Health and Retirement Study* and a life-cycle consumption and savings model, Scholz and Seshadri (2009) found that target gross replacement rates covered a very wide range - concluding "What is clear from this discussion is that the substantial variation in optimal target replacement rates presents a challenge for developing sensible replacement rate rules of thumb. Conventional advice may overstate optimal targets by a factor of two, or understate retirement consumption needs by a factor of three depending on the idiosyncratic experiences of households." (pg 21). VanDerhei (2006) is a second study that found that "a simple one-size-fits-all replacement rate will not work for most Americans" (pg.5). After simulating 1,000 life-paths of stylized 65-year-old retirees and testing the adequacy of gross replacement rate targets, he concluded that "the huge variation in the range of replacement rate targets—depending on the individual's income, degree of annuitization for initial retirement wealth, and the asset allocation of the post-retirement investments—call into question whether the use of a single rule-of-thumb measure is realistic to use in the retirement planning process" (pg.5). Indeed, as explained by Engen, Gale, and Uccello (1999) nearly a decade earlier, the existence of risk necessarily creates a distribution of target replacement rates whose mean or median can only be interpreted as such, and not as a minimum single target.

[ix] The median retirement age in Canada between 2001 and 2009 has ranged from 60.6 to 61.9 years (Schwartz, 2010).
[x] The opinions expressed and conclusions reached by the authors are their own and do not represent any official position or opinion of Statistics Canada. We take full responsibility for the assumptions underlying the projection scenario used.
[xi] Examples of studies that prescribe or depend on replacement rates to signal retirement income adequacy (in terms of living standards continuity) include Dexter, 1984; Boskin and Shoven, 1987; Palmer, 1988; 2008; Gustman and Steinmeier, 1998; Mitchell and Moore,1998; Moore and Mitchell, 2000; Alford et al. 2004; Schieber, 2004; Steinberg and Lucas, 2004; Vanderhei, 2004; Munnell and Soto, 2005; Haveman, Holden, Wolfe and Sherlund, 2006; Munnell, Webb and Delorme, 2006; Munnell, Webb and Golub-Sass, 2007a; 2007b; OECD 2009; Brady, 2010; Dodge, Laurin, and Busby, 2010; McGill et al., 2010; TD Economics, 2010; and Munnell et al., 2011.
[xii] Sustaining living standards after retirement is the most prevalent definition of retirement income adequacy in the replacement rate literature (see footnote 12), although not the universal. Engen, Gale, and Uccello (1999) and Scholz and Seshadri (2009) are examples of authors who employ replacement rates but apply a utility maximization framework in an augmented life-cycle model. They argue that retirement income adequacy occurs when the discounted marginal utility of consumption is smoothed over time.
[xiii] While replacement rates are most commonly used as a prescriptive target for retirement income adequacy, they have also been used as a descriptive statistic to examine trends over time and between groups of people (e.g. Boskin and Shoven, 1987; GAO, 2001; Smith, 2003; Butrica et al., 2003; Fidelity, 2007; LaRochelle-Cote, Myles and Picot, 2008; Ostrovsky and Schellenberg, 2010).
[xiv] For example, current-year before-tax earnings data are generally readily available: current year earnings are commonly collected in public surveys; a client who visits their financial planner typically brings his/her income tax return for the current year; and employers who sponsor a pension plan have the current year payroll for their employees.
[xv]Since retirement generally occurs partway through a financial year (the most popular month being June in Canada (Schwartz, 2010)), incomes are calculated for the full years preceding and following the age of retirement.
[xvi] Studies that differentiate the target replacement rate by broad characteristics such as earnings level, region, and family configuration include Palmer, 1988; 2008; Mitchell and Moore, 1998; Munnell et al., 2006, Munnell, Webb, and Golub-Sass, 2007a; 2007b. Appendix A describes how these target replacement rates are computed. Another approach is to estimate replacement rate targets using stylized illustrative individuals (such as in Brady, 2010; and Schieber, 2004). The problems associated with stylized individuals have been discussed by, among others, Steuerle et al. (2000).).
[xvii] Short and long-term earnings volatility has been well documented (see Finnie, 1999; Morissette, Zhang and Frenette, 2007; Finnie and Gray, 2011). As a consequence, a replacement rate's measurement period has a substantial impact on retirement income adequacy results (see, for example, Boskin and Shoven (1987) and Munnell and Soto (2005)).
[xviii] The increasing proportion of defined contribution pension plans leaves retirees more exposed to financial market volatility, both in capital value and returns to assets owned.
[xix] Limited data, such as cross-sectional data from a single year, often constrains analysts to projections using highly stylized assumptions that do not capture the realistic variability across and among the lifecourses of individuals. Examples include Palmer, 1988; 2008; Mitchell and Moore, 1998; Munnell et al., 2006. In comparison, replacement rate studies that employed longitudinal data include Boskin

and Shoven, 1987; Smith, 2003; Munnell and Soto, 2005; LaRochelle-Cote, Myles and Picot, 2008; and Ostrovsky and Schellenberg, 2009.

[xx]ESPlanner (Bernheim et al., 2000; Kotlikoff, 2006) and Ballpark E$timate (VanDerhei, 2006) in the U.S., and Ruthen (Avery and Morrison (2009)) in Canada are examples of personal dynamic microsimulation models for individual financial planning purposes.

[xxi] Rather than depend exclusively on earnings at age 64 - for example, Butrica et al. (2003) measured and averaged pre-retirement income from ages 22 to 62. Biggs and Springstead (2008) compared the different results that follow from using various measurement periods for earnings, including a variety of career-average and final average earnings measures.

[xxii] Moore et al. (2010), MacDonald et al. (2011), and Wolfson (2011) are examples of studies that also used *LifePaths* to project the retirement preparedness of Canadians by directly estimating the continuity of income available for consumption using comprehensive life-course simulations of longitudinal income and wealth, thereby side-stepping the need to construct and rely on conventional replacement rate targets.

[xxiii] To capture the income pooling and economies of scale that individuals experience within a household, a commonly used equivalence scale is the square root of family size (Buhmann et al., 1988), i.e., if two individuals had the same level of consumption ($X), but one was single and the other fully supported a spouse and two children, then the family-adjusted equivalent income of the first would be $X, while the second would be $X/√4.

[xxiv] Our measure of living standards considers only personal consumption, and not those goods provided by the public sector such as police, parks, safe roads, etc.

[xxv] Or "constant dollar", which means that we index the income flows with the consumer price index (we use the Canadian All-Items Consumer Price Index).

[xxvi] There are, however, several exceptions. Using couples or families as the unit of analysis, the two spouses may retire in different years, and assessing their replacement rate with a single annual snapshot of retirement income becomes problematic. In addition, pension income that is not indexed to inflation, such as some employer pensions or most private annuities, can fall substantially in real value over the course of an individual's retirement. Similarly, marital transitions during the retirement years, especially to widowhood, affect retirement consumption.

[xxvii] Binswanger and Schunk (2012: 217), using individually tailored internet surveys in the U.S. and Netherlands, found that "a large majority of individuals aims to achieve a spending profile where, under normal circumstances, old-age spending exceeds 80 percent of working-life spending". A drop in necessary expenditure after retirement to sustain pre-retirement living standards is also supported by research explaining the "retirement consumption puzzle", which found that retirement provides additional leisure time for home-production, which lowers the expense of maintaining working life living standards (Aguiar and Hurst, 2005; Brzozowski and Lu, 2010). We therefore use an 80% LSCR as the minimum level to sustain living standards.

[xxviii] For annuities purchased with non-registered funds, we assume the 2012 taxation treatment of "prescribed annuities" (calculating the taxed amount as a proportion of the annuity payment). Owing to the inflation indexation assumption, however, the appropriate tax rate would depend on the more complex treatment of "non-prescribed annuities" (see Milevsky (2010) for further information). However, the impact is trivial in size empirically.

[xxix] As noted in Vanderhei (2004) and Scholz and Seshadri (2009), the shift from DB to DC pension plans among employers has complicated the replacement rate measurement since calculating an

"income" from a DC account requires behavioral drawdown assumptions (while the income from a DB pension benefit is prescribed).

[xxx] Our methodology is similar to Gustman and Steinmeier (1998), Munnell, Webb and Delorme, 2006; Munnell, Webb and Golub-Sass, 2007a; 2007b.

[xxxi] Voluntary annuitization is extremely rare - see Milevsky and Young (2007) and Brown (2009) for U.S. evidence, and James and Song (2001) for international.

[xxxii] Assuming a one-year measurement period in retirement, Steinberg and Lucas (2004) suggested increasing conventional targeted replacement rates by 10 to 15 percentage points to account for the lack of inflation indexing in many retirement benefits (similar adjustments were made in Alford, Farnen and Schachet (2004)). VanDerhei (2006) and Holmer (2009) used longitudinal microsimulation modeling to explicitly model various financial risks in their measurement of replacement rates (see Appendix B).

[xxxiii] For example, Quinn (1999) estimates that 33-50% of older Americans use bridge jobs between a full-time career and complete retirement.

[xxxiv] For the purpose of federal employment insurance benefits, Canadians are considered 'attached' to the labor force if they have worked 490 hours in the previous year (which is 24% of the year assuming a standard 40 hour work-week). Source: www.servicecanada.gc.ca/eng/ei/types/regular.shtml#Number

[xxxv] Arguably, the very purpose of a concept of "replacement rate" is to evaluate the extent that employment earnings have been replaced after retirement (where retirement is the cessation of employment) and therefore precludes including "post-retirement" employment earnings.

[xxxvi] We do not include immigrants who arrive after age 35, as this would create missing years in the economic well-being continuity rate estimates, as well as residents who left the country for more than a year during working-years or at all after retirement.

[xxxvii] Although incorporating spouses affects replacement rates at the individual level. For example, it reflects the fact that low-income spouses who relied on their spouse during working-years (such as for child-rearing) will receive senior benefits from the government that will improve the household's standard of living after retirement. On the flip side, there will also be individuals whose measured replacement rate will decrease once their higher-income spouse is accounted for.

[xxxviii] In 2013, these advantages included: the splitting of certain types of income from pensions and registered savings between Canadian spouses; up to $6,854 of personal federal income tax exemption for people 65 years plus with corresponding provincial/territorial exemptions; a tax-exemption for the first $2,000 of pension income; and the exemption of Guaranteed Income Supplement (low-income senior benefit) to income taxes.

[xxxix] This could arise if the interest portion of mortgage payments is tax deductible or when low income social programs do not consider housing wealth when determining eligibility.

[xl] The methodology underlying Palmer's empirical measure of target gross replacement rates was first developed in Dexter (1984). For an illustration and additional explanation of the conceptual model of building target gross replacement rates, see McGill et al. (2010, Chapter 7).

[xli] "Earnings mobility refers to changes in the relative earnings of individual workers through time" (Beach and Finnie, 2004, pg. 5).

[xlii] See, for example, the line of research by the Society of Actuaries Committee on Post-Retirement Needs and Risks at http://www.soa.org/research/research-projects/pension/research-post-retirement-needs-and-risks.aspx

[xliii] See Mills and Young (2004) for a discussion of such changes over the past decade in U.S. employer pension plans.

[xliv] For the 1990 American birth cohort, for example, he found that "the risk-adjusted pension benefit is substantially smaller than the risk-adjusted social security benefit, even though the average (non-risk-

adjusted) pension benefit is roughly the same as the average social security benefit" (abstract).