We find that linking statutory retirement ages to life expectancy is a promising way to extend working lives and generate enough tax revenues so that generations enjoying longer lifetimes can also pay for the consequent increase in pensions and public health and long-term care (LTC) expenditure. We use a numerical economic model, calibrated to the Finnish economy and demographics, in which mortality affects both retirement ages and per capita use of health and LTC services. Uncertainty in mortality projections and the resulting uncertainties in public finances and retirement policy effects are considered explicitly. (JEL H30, H63, H68, J11)

I. INTRODUCTION AND MOTIVATION

Longer lifetimes are indisputable indicators of positive societal development. Life expectancies throughout developed countries have grown for over a century, resulting in increases measurable in decades. It is not easy, however, for people to realize the magnitude of the change and the possibilities that it opens, and for societies to grasp the many challenges this development provides, not least regarding the organization and financing of pensions, health care, and social care.

We are interested in the influence of longer lifetimes on public finances in a welfare state. We ask whether longer work careers can bring about sufficient increases to tax revenues to offset the negative effects of growing pension and health and care expenditure that longer lifetimes cause. The paper also discusses the potential of pension policies to lengthen working lives.

We elaborate on the idea presented by Andersen (2012, 20): “Sustainability problems are to a large extent driven by underlying trends of which changing demographics are an important contributory factor. An important driver of these changes is increasing longevity (healthy ageing), and for this component it is highly questionable whether it should be addressed by pre-funding or savings” . . . “Increasing longevity is a welfare improvement, and the reason it creates financial problems is that some future generations enjoy increases in longevity, while retirement ages do not necessarily follow, and at the same time various entitlements for services provided by the public sector are used more. This shifts the balance between the years contributing to and benefiting from the scheme, causing a sustainability problem. It is not obvious that current generations should be contributing to the financing of this, or whether the proper response is to change entitlements (e.g. retirement age or pensions).”

To illustrate and quantify the shifts in the balance between the years contributing to and benefiting from the welfare state, caused by variations in longevity, we simulate what happens in the Finnish economy when mortality differs from what is expected in Statistics Finland’s 2012 population projection. We use stochastic mortality simulations, in the form of 500 population paths for Finland from the year 2013 onwards. Each path is a full demographic projection, and differs from the other paths only because mortalities are different.

ABBREVIATIONS

GDP: Gross Domestic Product
LTC: Long-Term Care
OLG: Overlapping Generations
UPE: Uncertain Population in Europe
different. These paths are used as inputs in a general equilibrium economic model. The economic model is run with three different specifications for work career developments and two different specifications for health and LTC expenditures. Thus, the total number of simulations is 3,000. For each simulation, we calculate the sustainability gap as an indicator of the fiscal sustainability of public finances.

Our policy analysis concerns the rules of the pension system. The first work career option is a simple reference outcome where the average effective retirement age follows a fixed path. The second specification describes the current\(^1\) Finnish earnings-related pension system, where there is an adjustment of monthly benefits that depends on cohort-wise life expectancy. It was hoped that this adjustment would lead to postponed retirement, but outcomes have been disappointing. That is why our third specification refers to a reform where cohort-wise pension eligibility ages are linked to life expectancy.

The two different options used in modeling the health and LTC expenditures reflect the fact that there is huge uncertainty concerning the demographic determinants of these expenditures. We prefer a specification where proximity to death has direct effects, but consider also a naïve specification where per capita expenditure is purely age related, because such specifications are common in fiscal sustainability evaluations.

Our stochastic approach is motivated by the fact that the uncertainty in long-term demographic projections, and mortality projections as a part of them, is larger than that grasped by typical high-low variants, and stochastic projections can indicate the probability of different outcomes (see Alho, Cruijsen, and Keilman 2008). The overlapping-generations (OLG) structure in the economic model facilitates the description of population aging and its effects on earnings-related pensions and health and LTC needs in a logical manner. In dynamic general equilibrium models, consistency prevails in market equilibria and intertemporal budget constraints. Here, consistency also concerns the key impacts of longevity, in the sense that changes in mortality have direct effects on households’ working careers, on the length of retirement, and on the per-capita use of health and LTC expenditures, in addition to the macroeconomic effects that come from the changing number of people in different age groups.

Our contribution is, first, to bring together these different effects of longevity in the analysis of fiscal sustainability; second, to analyze in this multidimensional setup the effects of a pension reform that seems to be the most discussed reform option in many countries; and third, to keep the uncertainty in mortalities explicit in all phases of the study, so that we could avoid an unrealistically narrow perception of both the size of potential problems and the effects of a promising reform.

Our work builds on and utilizes heavily the following studies: Auerbach and Kotlikoff (1987) on numerical general equilibrium models with overlapping generations, Alho (2002) on stochastic population simulations, Häkkinen et al. (2007) on the role of mortality in health and LTC expenditures, Määttänen (2014) on the connections between life expectancy, eligibility ages, and working careers, and Lassila and Valkonen (2008) and Lassila, Valkonen, and Alho (2011) on fiscal sustainability.

A similar probability-based approach is applicable also to other countries which have economic models that can use stochastic population projections as inputs; examples can be found in Alho, Jensen, and Lassila (2008). Stochastic population projections have been produced for most European countries in the UPE project,\(^2\) and the United Nations Population Division has recently developed probabilistic projections for all countries and areas of the world (see Raftery, Alkema, and Gerland 2014).

As a historical background, Figure 1 shows that while the life expectancy in Finland has risen steadily during the last 40 years, the average age when people retire is currently a couple of years below what it was 40 years ago. From this perspective, a significant increase in the retirement age is certainly feasible, but one cannot expect that it will take place automatically. Easy access to early retirement routes that provided generous benefits explains the decline in average retirement age during the 1980s, and although many measures have since been reversed, there is a need to reconsider all eligibility ages and rules when aiming for longer work lives.

The rest of this paper is structured as follows. Section II discusses the demographic aspects of longevity and the uncertainty in population projections. Section III concentrates on the effects of

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1. Refers to the rules in effect in 2016.

2. UPE stands for Uncertain Population in Europe. See Keilman, Cruijsen, and Alho (2008) and Alho, Cruijsen, and Keilman (2008).
longevity on length of average working lives and the consequences of pension policies. Section IV studies the effects of longevity on health and LTC expenditure. Section V presents first the economic model and then the simulated sustainability results. Section VI concludes.

II. LONGEVITY AND DEMOGRAPHICS

During the next 50 years, life expectancy is expected to rise to an unprecedented level in Finland. It is, however, very hard to say exactly how high. That is why we resort to stochastic simulations based on statistical analysis of past demographics and forecast errors. We use a stochastic population projection produced by Alho in 2013 by a computer program for error propagation, where population forecasts are carried out using the cohort-component approach and considering future vital rates as random variables (e.g., Alho and Spencer 2005, 287). For their distribution, the scaled model of error assumes that the rates are normal in the log scale. The age-dependent scales were estimated from long data series of errors of naïve forecasts, which assume that the recent decline in mortality continues indefinitely.3 The means of the distributions follow the assumptions of Statistics Finland’s 2012 projection (OSF 2012). As discussed in Alho (1990) and Lee and Miller (2001), the naïve method and related extrapolation methods perform typically equally well as or better than the judgmental official forecasts.

In the simulations, mortalities vary each period in each age group. To give an impression on the resulting variation in the length of life, we use period life expectancy at 30, average of males and females, as a descriptor. We express it as total life expectancy, that is, 30 years plus the remaining life expectancy at 30. Figure 2 shows the predictive distribution4 of the total life expectancy at 30 for the next 50 years. The median life expectancy increases from current 82 years by 7.5 years, to 89.5. There is sizeable predictive uncertainty that increases over time. The 50% probability interval is about 3.5 years wide in the 2060s, and the width of the 80% interval is 7 years.

3. To enhance the stability of the estimates, data from 11 countries (Austria, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom) were used. The estimates were based on the median level of uncertainty in the past, averaged across countries. A more detailed description is in Alho, Cruysen, and Keilman (2008).

4. For a probabilistic interpretation of stochastic population simulations, visit http://www.stat.fi/tup/eupe/sf_interpretation.html. Note that all probabilistic results in this article are conditional on the constant-mortality projection.
For our analysis, we first make a constant-mortality version of Statistics Finland’s 2012 population forecast. The constant-mortality population starts from the prevailing age structure in the beginning of 2013 and assumes a constant inflow of persons below 20 years of age in the future, no net migration, and the latest (2012) observed age-specific mortalities in all future periods. This population evolves so that new young generations are all of the same size, and the cohorts diminish in time by mortality rates that are the same as currently observed. Although we will concentrate on stochastic simulations and do not use the constant-mortality path further, it is worth noting that the expected development in lifetimes would also change the population structure quite a lot (see Appendix A).

In the alternative population paths, we start from the constant-mortality projection but allow future mortalities to deviate from those currently observed. These deviations follow the assumptions used in the stochastic population projection. We will use 500 simulated population paths that differ only due to different mortality developments.5

5. Actually, since there is marginal variation in the surviving number of women in childbearing age, the assumption of stable size of young generations implies that there is marginal variation in fertility rates or net migration.

III. LONGEVITY AND WORKING LIVES

Living longer raises the need to acquire more disposable income during one’s lifetime, simply to finance consumption for more years. More income can be obtained by working more or being better paid in work, the latter often meaning that work is done more productively due, for example, to investments in better education. We concentrate on working more, particularly in the form of higher retirement ages. The same factors that lower future mortality rates are likely to improve health and working ability near the retirement age facilitating the longer working lives.

A. Working Lives under Current Retirement Rules

In the Finnish earnings-related pension system, workers can start drawing old-age pensions flexibly between ages 63 and 68. The system covers also disabilities, and the expected effective retirement age, based on starting pensions for different age cohorts, was 61.1 years in 2015.

There are three factors that define the future retirement ages in our baseline projection. Educational structure is changing and previous pension reforms still have some influence. These two elements, which are independent of the realized mortality projection, are evaluated to increase retirement ages by approximately
9 months between years 2013 and 2060. The third element is the endogenous reactions of the employees to longer lifetimes. According to the estimates of Määttänen (2014), adding 3 years to the life expectancy of a 30-year-old would extend working lives by 6 months, assuming that any health problems are likewise postponed by 3 years. This estimate has been used in our numerical OLG model in such a way that the change in life expectancy automatically affects the length of working lives in accordance with the ratio depicted, even if pension rules were left unchanged. The final result is an increase in the actual retirement age by approximately 2 years over a period of 50 years in the baseline scenario.

B. Working Lives if Earliest Eligibility Age Is Linked to Life Expectancy

Lassila, Määttänen, and Valkonen (2014) analyzed a retirement age reform in which the earliest pensionable age is linked to the adulthood life expectancy. Adulthood is defined as having begun when the legal coming of age takes place at age 18. The pensionable age adjusts every year to changes in mortality so that it divides the expectancy for time lived as an adult to working lives and retirement years at the same ratio (roughly 2:1). If the life expectancy of a 63-year-old grows by just over 6 years over a period of 50 years, this method of linking would raise the pensionable age by 4 years. The earliest eligibility age for the part-time pension and the unemployment pathway are changed by the same amount as the pensionable age, since, according to Määttänen (2014), simply raising the pensionable age would not really extend working lives due to an increased use of other exit routes, financed from public funds.

In our OLG model analysis, we utilize results from Määttänen (2014), who studied policies aiming to extend working lives on the labor supply decisions and income distribution of employees close to the earliest eligibility age for retirement. He used a stochastic life cycle simulation model that depicts the work-leisure decision-making of wage earners in different situations. Individuals are grouped in the model according to their age, gender, and education. The decision to continue working, or to use one of the various exit routes from working life, is made with an insecure future in mind. Wage earners face the risk of losing their jobs, the risk of becoming disabled, and the risk of a surprisingly long life. The size of these risks has been evaluated based on register data. For instance, people with a low level of education have a higher disability risk and shorter average life cycle than the others. The group-wise stochastic wage processes in the model produce a reasonably realistic wage distribution. A similar type of model has been applied to public pension systems (e.g., Rust and Phelan 1997) and private pensions in the United States (e.g., Stock and Wise 1990).

Linking the retirement age to life expectancy affects the length of working lives. Based on the model used by Määttänen, raising the eligibility ages of the pensionable age, the unemployment pathway and the part-time pension by 2 years would extend working lives by 7 months. This estimate has been calculated in a situation in which life expectancy has already been extended by 3 years from the current situation. Extending working lives are included in the OLG model through the pensioner proportions in different age groups, as the model does not contain pensionable age as a variable, although in other respects contains a detailed description of the pension system.

Määttänen (2014, 49) notes that although empirical research results fully comparable to his simulations do not exist, the orders of magnitude are in line with the empirical analysis on the employment impact of the 2005 pension reform in Finland by Uusitalo and Nivalainen (2013) and on raising the earliest eligibility age for the unemployment pathway by Kyrö (2010). Sjögren Lindquist (2011) reviews empirical studies on pension reforms in Austria, Australia, Norway, Portugal, Switzerland, and the United States, and summarizes the results by concluding that raising the retirement age usually extends working lives by between 20% and 50% of the increase in retirement age. The results of Määttänen (2014) also fall into this range.

If longevity follows Statistics Finland’s 2012 projection, working lives will develop as depicted in Figure 3. The “No change” alternative is used as a reference in calculations later. The retirement age reform raises the average retirement age by over a year by the 2060s, compared to the baseline scenario.
The numerical example above gives good reasons to believe that longer lifetimes themselves will lead to longer work careers, when accompanied with adjustments to disability pension rules so that the effects of better health are fully reflected in a lower number of disabilities. Thus, there is a possibly significant self-correcting mechanism concerning public finances. Furthermore, accompanied by retirement age policies, working lives can be made even longer. The presented Finnish reform example was moderate compared to most European reforms that have been implemented, decided or are discussed.8

Although the Finnish earnings-related pension system already includes the longevity adjustment of benefits (see Appendix B for details), longer working lives would still lower contribution rates on average, after a slight initial increase as Table 1 shows. The main effect on public finances would, however, come from bigger income and consumption tax bases.

IV. LONGEVITY AND HEALTH AND LTC EXPENDITURE

When discussing the links between population aging and health and LTC expenditures, the proper way to start is to acknowledge that rather little is known and uncertainty is large. This concerns the understanding of the driving forces and causalities both currently and in the past. Future projections are thus based on shallow ground, and uncertainties are magnified by the obvious possibility that whatever the current connections are, they may change in the future. The most relevant issues include technological change, Baumol’s disease, income effects, and demographic effects (see, e.g., de la Maisonneuve and Oliveira Martins 2013 and Häkkinen et al. 2007).

### TABLE 1
Predictive Distributions of Pension Contribution Rates under Different Working Lives

|      | d1     | Q1     | Md     | Q3     | d9     |
|------|--------|--------|--------|--------|--------|
| (a)  | 2018   | 25.73  | 25.84  | 25.96  | 26.07  | 26.17  |
|      | 2033   | 27.59  | 27.99  | 28.58  | 29.01  | 29.45  |
|      | 2063   | 26.49  | 27.08  | 27.68  | 28.18  | 28.64  |
| (b)  | 2018   | 25.13  | 25.24  | 25.36  | 25.47  | 25.57  |
|      | 2033   | 27.01  | 27.36  | 27.66  | 27.96  | 28.23  |
|      | 2063   | 25.53  | 25.83  | 26.12  | 26.37  | 26.64  |
| (c)  | 2018   | 25.24  | 25.39  | 25.54  | 25.69  | 25.81  |
|      | 2033   | 25.50  | 25.81  | 26.20  | 26.57  | 26.90  |
|      | 2063   | 23.66  | 23.86  | 24.10  | 24.36  | 24.62  |

*Note:* d1 denotes the first and d9 the ninth decile, Q1 denotes the first and Q3 the third quartile, and Md is the median.

8. In the reform proposal two other changes are also made to the pension system. First, the longevity adjustment of pensions is mitigated by introducing a small increase for deferred retirement age. Second, the current age limits for different accrual rates will change in proportion to the old-age retirement age. See Lassila (2014) for details.
Concerning demographic effects, a basic statistical fact is that per capita health and LTC expenditures are greater in older age groups than in younger. The magnitudes vary between countries and need not be completely monotonic by age, but usually people over, say, 60 years of age use more of these services per person than people under 60. And because population aging usually means that the number of people over 60 grows more rapidly than those below 60, the worry about increasing costs is obvious.

There is a large body of literature discussing the effects of changing age structure on the demand for health and LTC services, reviewed by Lindgren (2016). The literature separates three hypotheses: expansion of morbidity, compression of morbidity, and dynamic equilibrium. The first one claims that gains in longevity are related to additional years with chronic disease and the second one that the number of healthy years increases faster than longevity. The dynamic equilibrium hypothesis suggests that there will be more years with chronic diseases, but years without disability may still increase due to medical progress. The results of the literature review support this hypothesis. Consequently, healthcare expenditure may increase as the population becomes older, but the period when nursing home care is needed is likely to shorten.

We concentrate on issues that can be related to mortality changes. Some illnesses and injuries both hasten the death and increase the health and LTC costs in the last years of life. Thus, when modeling the dependence of health and LTC expenditures on population and its age structure, it is reasonable to include mortality as an explanatory variable. This can be used in long-term projections also, as population forecasts include also mortality, implicitly or explicitly.

Our starting point is Häkkinen et al. (2006), who used individual-level health and care expenditures for a large sample \((N = 285,317)\) of persons aged 65+ in 1998. According to their calculations, 49% of health expenditures and 75% of care expenditures went to persons who died in 1998–2002.

From these figures, one can deduce that 51% of health and 25% of care expenditures were not directly death related because they occurred in persons who were still alive 5 years later. Furthermore, part of the expenditure for those who died during these years obviously had no causal connection with death. A person who died because of lung cancer in 2002 may have been treated for a dislocated shoulder in 1998.

Using mortality data, we can estimate the share of expenditures of those who die within 5 years, assuming that proximity to death has no effect on these expenditures. To do this by age group, we have to use also data for 2006, and implicitly assume that the per capita supply and unit costs of health and care services were the same as in 1998. The weighted average of this share, estimated over 5-year age groups for persons aged 65 and above, was 28% of health expenditures and 48% of care expenditures. These are smaller shares than Häkkinen et al. (2006) report. The difference in the health expenditure share, 21%, can be interpreted as a lower limit for the health cost that proximity to death causes. A corresponding lower limit for care is 27%. Thus, 21%–49% of health expenditures and 27%–75% of care expenditures have links to proximity to death.

Thus, the Finnish data show that there are costs that depend on the proximity to death and costs that do not depend on it. Assuming that the latter, within each age group, are on average the same per capita for those who died and for those who did not, we can calculate the share of the former. This was 29% in health expenditures and 51% in care expenditures. We modeled it to be the same per capita, irrespective of the person’s age. Thus, the total expenditure depends both on the number of people in each age group and the number of people who will die within the next 5 years.

We make two sets of sustainability calculations. As discussed above, it is reasonable to include mortality as an explanatory variable for expenditure, and our first set of sustainability calculations does that. The second sustainability projections are based on per capita costs that stay constant in each age group in the future. These calculations are in line with the expansion of morbidity hypotheses but naïve in the sense that they ignore the concentration of expenditures on the last years of life and assume that the age profile of per capita costs does not change in time. Figures 4 and 5 show the weights that are used. The fall in age-related health costs per capita in very old ages is likely be at least partly due to measurement problems, as it is not easy to separate the health and LTC costs for persons who live in institutions.

The two cost assumptions lead to huge differences in projections of future costs. Figure 6 shows that the naïve method produces an 80% median growth in 60 years, whereas our preferred method, including costs related to proximity to
death, produces a less than 40% median growth, with substantially narrower prediction bands.

V. LONGEVITY AND FISCAL SUSTAINABILITY
A. The Economic Model

The 500 population projections with different mortalities are used as inputs in an economic model. We simulate the sustainability of public finances using a perfect foresight numerical overlapping-generations model of the type originated by Auerbach and Kotlikoff (1987). It is modified to describe a small open economy and calibrated to the Finnish economy. The model consists of five sectors: households, enterprises, a government, pension funds, and a foreign sector. Households make economic decisions according to the life cycle hypothesis. They maximize the utility from consumption and leisure in different periods and the bequest that
they give. The lifetime budget constraint says that discounted lifetime incomes and discounted received bequest and transfers equal discounted consumption expenditure and the given bequest.

Firms choose the optimal amount of investment and labor to maximize the price of their shares. The market value of the firm is determined as a discounted sum of future dividends. The problem can be presented as maximizing at the beginning of the period the dividends distributed during the period plus the value of the firm at the end of the period, subject to the amount of initial capital stock, the cash-flow equation of the firm, the constant elasticity of substitution production function, the accumulation condition of the capital stock, the determination of the firm’s debt, and the investment adjustment costs. The three markets, for labor, goods, and capital, are all competitive and prices balance supply and demand period-by-period. The pretax rate of return on savings and investments is determined in global capital markets. In the trade of goods the country has, however, some monopoly power, which makes the terms of trade endogenous. Foreign economies are assumed to grow with the trend growth rate of labor productivity. There is no money or inflation in the model.

The driving forces of the model economy are the transitions in the demographic and educational structure of the population and the trend growth of labor productivity. The population is aging due to longer lifetimes, low fertility rates, and the transition of baby boomers from working age to retirement. The educational level improves somewhat in the future since the current middle-aged generations have on average lower levels of education than the young ones. The improvement raises the productivity of labor. Each household generation is divided into three educational groups with different lifetime productivity profiles determined by empirical observations of recent wage profiles. The educational shares are supposed to develop in the future in line with the official projections.

The labor input is determined partly by exogenous assumptions and partly due to endogenous adjustments in the model. Hours of work are decided by households. The average retirement age follows the period life expectancy at 30 as described earlier, and in the model, this is achieved by changing in each age group the share of those retired. Exogenous factors are the trend growth of labor productivity (1.75% per annum in private goods production), educational gains, and the unemployment rate. The model is calibrated so that the trend labor productivity growth and the following higher wages do not affect
the otherwise endogenous labor/leisure choice of the households.

The growing number of people in old age and near death increases the demand for health and old age care, as described earlier. We assume that these demography-driven additional services are produced in the private sector, but production costs are paid totally by the public sector. These services are produced using labor and intermediate goods as inputs, and there is no productivity growth. The shares of employees in private and public sectors are kept constant.

The real wage adjusts to equalize the value of marginal product of labor and labor costs in the production of private goods and services. The rest of the workers, who provide tax-funded services produced in private and public sectors, earn the same wage. Our model thereby includes the Baumol effects. The price of the health and long-term services evolves so that the increase in labor costs constitutes roughly two-thirds of the price change, and the gross domestic product (GDP) price change constitutes one-third.

Public expenditures have a strong connection to the age of individuals in Finland. The provision of public services is allocated mainly either to the early part of the life cycle (day care and education) or to the last years (health care and old age care). Similarly, income transfers are distributed mainly either to young families or to retired individuals. This is why the changes in the demographic structure are so important for the public expenditures. We assume that all income transfers (except the earning-related pensions) are fully indexed to wages because any other assumption would have dramatic consequences for income distribution in the very long-term analysis. Other than age-related expenditure is assumed to grow at the same rate as the GDP.

Revenues of the public sector originate from two types of sources in the model. The majority of the receipts are accumulated by income taxes, consumption taxes, and social security contributions. Another noteworthy revenue source is the yield of the public sector wealth. The yield of the wealth is particularly important for the pension funds, but the Finnish central government has also a substantial amount of financial assets.

We assume that the modeled main subsectors of the general government, such as the municipal sector, the public and the private sector pension fund, and the national social security institute, have their own budgets, which are balanced either by social security contributions or earned income taxes. The only exception is the state budget, which is balanced by borrowing until 2145, and after that by using a lump sum transfer. Earned income tax brackets are adjusted with the growth of the economy. The pension funds follow their current prefunding plans, and pension contributions are endogenous. Households are modeled to react to the income and substitution effects of taxation, social security contributions, and pension accrual rules. The model is described in more detail in Lassila and Valkonen (2007).

B. Calculating the Sustainability Gap

In the OLG model simulations, state tax rates are fixed. Tax revenues vary due to the extent of tax bases and the progressiveness of earnings. The financial assets of the state are kept at a constant ratio to GDP, and the net debt and the gross debt are flexible. Local government debt remains at a standard ratio to GDP. The pension funds of the private sector fluctuate in accordance with current funding regulations. The ratio of the state and municipal pension fund to the public wage sum has been fixed. The municipal tax rate is endogenous and balances the economy of municipalities together with state aid to municipalities. Earnings-related pension contributions are endogenous. As a whole, the tax rate and net indebtedness of the large public sector are determined endogenously.

The sustainability gap looks at the expected long-term disparity between public revenues and expenditure determined according to current tax rates and current procedures and consolidates that into a single figure. The gap is the difference between the current ratio of total tax revenues to GDP (the situation at the time of the calculation) and a hypothetical constant total tax ratio. The hypothetical tax rate is such that if taxes were raised to the said level immediately and permanently, they would be sufficient to finance public expenditure for the next 100 years and return the public net debt in relation to the GDP to the initial level. This would occur when (1) surpluses collected during different years are invested in government bonds, and deficits are covered by selling bonds, (2) the discounted surpluses and deficits cancel each other out, (3) the financial assets of the state and the net assets of local governments remain in a standard ratio to the overall production, and (4) pension funds develop in accordance with current funding rules. Note that in our simulations, the state debt is endogenous, and thus the public net debt in relation to the GDP does not usually return to the initial level. That is taken
into account in the sustainability gap calculation by the debt terms in Equation (1).

The sustainability gap in Equation (1) is calculated from the model simulation results. It is based on a hypothetical total tax rate. It does not take into account the effect that the immediate and permanent raising of taxes—necessary for reaching a standardized tax rate—would have on the labor supply, household savings, and the decisions of companies. If one wanted to take these effects into account, the size of the sustainability gap would depend on which taxes would be raised to close the deficit gap. Since the model is a general equilibrium model, the gap estimates exclude any structural deficits that may exist in the start period. The gap does include an effect from the recession that started in 2008 only in the form of an exogenous increase in the public debt in the period 2013–2017. This effect is very small, and the gap figures can be interpreted as the effects of changes in the demographic and educational structure of the population.

The GDP in period \( t \) is denoted as \( Y(t) \) and the total tax rate with the term \( \tau(t) \), public net debt (i.e., the debt of the central and local governments) at the end of the period is denoted as \( V(t) \), and the net tax rate at the starting point is denoted with the term \( \tau(t(0)) \). The interest rate \( r \) is assumed to be constant. The forward-looking sustainability gap (\( s2 \)) calculated from period \( t(0) \) to \( T \) by period is then

\[
\begin{align*}
s2(t(0) , T) = & \sum_{t=t(0)}^{\pi(0)+T} [\tau(t) - \tau(t(0))] Y(t) D(t) + \left[ V(t(0) + T) - V(t(0)) - 1 \frac{Y(t(0)+T)}{Y(t(0))} \right] D(t(0) + T) \\
& \sum_{t=t(0)}^{\pi(0)+T} Y(t) D(t)
\end{align*}
\]

where the discount term \( D(t) \) is

\[
D(t) = (1 + r)^{-t-t(0)}.
\]

The first term of the numerator in the first formula describes the effect that changing pension contributions and municipal taxes have on the sustainability gap, and the second term describes the contribution of the change in net public debt.

Figure 7 and Tables 1 and 2 present simulation results from the Finnish OLG general equilibrium model. The simulations are based on 500 population projections in which mortality differs from Statistics Finland’s 2012 projection. The model has been run with three different work career developments. In two of them, the career length (measured by average effective retirement age) varies endogenously with the total life expectancy at 30, as described earlier. In “No change in careers,” the average effective retirement age is always the one shown in Figure 3. The model is run with two different types of modeling the health and LTC expenditures (proximity to death included and naïve). With three career types, the total number of simulations is 3,000.

In Figure 7 each dot represents one population path. With a constant length of working lives, that is, the “No change in careers” alternative, sustainability gaps would be larger the longer the life expectancy would become. Under current pension rules, working lives would be extended, and gaps would rise less with life expectancy. With pension reform, it appears that sustainability gaps would not react to changes in life expectancy.

We note that the relationship between sustainability gaps and life expectancy in Figure 7 has variations. Life expectancy does not uniquely define what happens in different age groups in the population, and using the expectancy calculated for one period leaves out variations in other periods. To concentrate on the average dependencies, we put the data in Tables 2 and 3.

The numbers in the cells in Tables 2 and 3 are averages and standard deviations within quartiles of life expectancy. In each quartile \( Q1, \ldots, Q4 \) there are 125 observations for which the means and standard deviations are calculated.

Table 2 shows that if life expectancy increases but working lives do not, public finances will certainly experience difficulties, even if the proximity of death is fully accounted for in expenditure projections. In this alternative, the higher the life expectancy, the larger the sustainability gap will be. In Finland, the costs would mostly be financed by higher municipal taxes and pension contributions, so public debt would not necessarily be a problem, but the total tax ratio would be 3%–5% points higher than before the current recession.
FIGURE 7
Total Life Expectancy at 30 in 2063 and Sustainability Gaps under Different Working Lives. Proximity of Death Influences Care Need

TABLE 2
Selected Economic Variables under Different Working Lives, by Life Expectancy Quartiles. Care Need Estimates Take Account of the Proximity of Death

| Total Life Expectancy at 30 in 2063 (TLE) | Q1 TLE < 87.3 | Q2 87.3 < TLE < 89.3 | Q3 89.3 < TLE < 90.9 | Q4 TLE > 90.9 |
|-----------------------------------------|---------------|---------------------|---------------------|-------------|
|                                         | Mean  | SD     | Mean  | SD     | Mean  | SD     | Mean  | SD     |
| Average effective retirement age       |       |        |       |        |       |        |       |        |
| No change in careers                   | 60.9  | 0.0    | 60.9  | 0.0    | 60.9  | 0.0    | 60.9  | 0.0    |
| Current retirement rules               | 61.6  | 0.23   | 62.0  | 0.11   | 62.3  | 0.10   | 62.7  | 0.22   |
| Retirement age reform                  | 62.4  | 0.52   | 63.2  | 0.26   | 63.8  | 0.21   | 64.7  | 0.48   |
| Sustainability gap, %                  |       |        |       |        |       |        |       |        |
| No change in careers                   | 2.5   | 0.22   | 2.8   | 0.18   | 3.0   | 0.16   | 3.4   | 0.22   |
| Current retirement rules               | 2.0   | 0.15   | 2.2   | 0.16   | 2.3   | 0.14   | 2.4   | 0.13   |
| Retirement age reform                  | 1.5   | 0.09   | 1.4   | 0.10   | 1.4   | 0.09   | 1.4   | 0.09   |
| Public debt/GDP, %, 2067               |       |        |       |        |       |        |       |        |
| No change in careers                   | 40.9  | 3.18   | 39.7  | 3.15   | 39.9  | 2.93   | 40.9  | 2.68   |
| Current retirement rules               | 38.4  | 3.48   | 35.4  | 3.04   | 34.3  | 2.73   | 33.3  | 2.70   |
| Retirement age reform                  | 33.9  | 3.92   | 28.7  | 2.41   | 26.1  | 2.20   | 23.4  | 2.61   |
| Total taxes/GDP, %, 2063–2067           |       |        |       |        |       |        |       |        |
| No change in careers                   | 45.7  | 0.44   | 46.4  | 0.34   | 46.8  | 0.30   | 47.5  | 0.41   |
| Current retirement rules               | 45.3  | 0.36   | 45.7  | 0.33   | 46.0  | 0.30   | 46.4  | 0.35   |
| Retirement age reform                  | 44.7  | 0.25   | 44.9  | 0.29   | 45.0  | 0.29   | 45.3  | 0.31   |

Note: Q1, … , Q4 denote the quartiles of the distributions ordered on life expectancy.

But even with current retirement rules (if disability rules are adjusted for better health), the lengthening of the careers would make the sustainability situation much better. And with the described retirement age reform, the sustainability gap would not be sensitive to life expectancy. Note that we are not talking about drastic changes in pension policies or retirement behavior. With Statistics Finland’s 2012 projection, the retirement age reform’s effect on the average effective retirement age would be 1 year and 3 months, over a period of 50 years when the
TABLE 3
Selected Economic Variables under Different Working Lives, by Life Expectancy Quartiles. Naïve Care Need Estimates

| Quartile | Total Life Expectancy at 30 in 2063 (TLE) | Q1 | Q2 | Q3 | Q4 |
|----------|------------------------------------------|----|----|----|----|
|          |                                          | Mean | SD  | Mean | SD  | Mean | SD  | Mean | SD  | Mean | SD  |
| Average effective retirement age | No change in careers | 60.9 | 0.0 | 60.9 | 0.0 | 60.9 | 0.0 | 60.9 | 0.0 |
|                          | Current retirement rules | 62.4 | 0.52 | 63.2 | 0.26 | 63.6 | 0.18 | 64.7 | 0.48 |
|                          | Sustainability gap, % | 4.2 | 0.65 | 5.2 | 0.53 | 5.9 | 0.47 | 7.0 | 0.67 |
|                          | No change in careers | 3.8 | 0.56 | 4.5 | 0.48 | 5.1 | 0.41 | 5.9 | 0.53 |
|                          | Current retirement rules | 2.8 | 0.44 | 3.4 | 0.41 | 3.9 | 0.35 | 4.4 | 0.38 |
| Public debt/GDP, %, 2067 | No change in careers | 67.8 | 10.38 | 78.6 | 9.67 | 88.0 | 9.23 | 102.6 | 10.89 |
|                          | Current retirement rules | 64.9 | 9.63 | 73.4 | 9.11 | 80.7 | 8.49 | 92.3 | 9.42 |
|                          | Retirement age reform | 58.2 | 8.25 | 64.8 | 7.97 | 70.4 | 7.30 | 79.2 | 7.83 |
| Total taxes/GDP, %, 2063–2067 | No change in careers | 46.9 | 0.34 | 48.2 | 0.67 | 49.2 | 0.58 | 50.6 | 0.87 |
|                          | Current retirement rules | 46.5 | 0.73 | 47.5 | 0.64 | 48.2 | 0.56 | 49.3 | 0.75 |
|                          | Retirement age reform | 45.6 | 0.63 | 46.5 | 0.58 | 47.0 | 0.52 | 47.8 | 0.62 |

Q1, …, Q4 denote the quartiles of the distributions ordered on life expectancy.

Life expectancy of a 30-year-old is expected to increase by 7.5 years. The resulting average effective retirement age would still be lower than during the 1970s (see Figure 1), even though the life expectancy would have increased by over 16 years. Still the policy effects would be hugely important for fiscal sustainability and the link between earliest pension eligibility ages and life expectancy would insur e public finances against unexpected developments in future mortalities.

If health and LTC expenditures depended entirely on age, as the naïve modeling assumes, Finnish public finances would be in deep trouble; see Table 3. Sustainability gaps would be higher in alternative work career scenarios, and they would be increasing with longevity even if the retirement age reform is carried out. Although naïve modeling is against the research results discussed earlier, this type of outcome could be interpreted to come from income elasticity that exceeds unity, or the use of new expensive technologies. It is important to note that these other explanatory factors are easier to control by policy than changes in demography.

VI. CONCLUSIONS

Auerbach and Hassett (2001, 74) condense the policy question that population aging poses as “how and when to deal with long-term fiscal imbalances that are at once very significant and very uncertain.” Linking retirement age to longevity is a measure that answers both the “how” and the “when,” the latter in an automatic way. We have analyzed this policy in a Finnish setting with an economic model where mortality affects both working careers and per capita use of health and LTC services. The uncertainty in mortalities is kept explicit in all phases of the study, to avoid an unrealistically narrow perception of the size of potential problems and to provide probabilistic assessment of the effects of the reform.

Our results show that it is quite possible that longer working lives bring about sufficient increases to tax revenues to offset the negative effects of growing health and care expenditure that longer lifetimes cause. It requires active policies, however, so that healthy individuals have good incentives to work longer when they can expect to live longer. In the Finnish case, the required changes in pension eligibility ages and retirement behavior seem to be rather modest, compared with the expected increases in life expectancy. Still the policy effects would be very important for fiscal sustainability and the link between earliest pension eligibility ages and life expectancy would insur e public finances against unexpected developments in future mortalities. Beside the pension age link, the policies should in practice also include adjustments to disability benefit rules and health and LTC admission practices, so that better health can be
fully reflected in longer working lives and public finances.

Our simulations confirm the result of several other studies that the proximity of death is an important factor in projections for public health and old age costs. This means that the link between age and expenditure is much weaker than in naive projections based on per capita costs that stay constant in each age group. The future cost increases are therefore less unavoidable and cost-containing policy has more room.

Long-term demographic projections are very uncertain, and that is also the case in all quantitative estimates of future public expenditure. The effects of this uncertainty can perhaps be reduced by better continuous monitoring, data collection and research, and that should definitely be done.

Currently, however, we cannot be sure of the magnitudes to say with any confidence that longer working lives can in practice fully pay for longer lifetimes in a welfare state. But it is not implausible and, as longer working lives seem to be an especially apt response to many economic issues brought about by longer lifetimes, policies such as linking pension ages to longevity should be tried.

APPENDIX A: POPULATION AGING IN THE EXPECTED CASE

Figure A1 shows how the ratio of the population aged 60 years or more to those in ages 20–59 would develop in the official population projection (SF2012), in the constant-mortality projection (Pcons), and in a scenario (Pmort) where mortalities develop according to SF2012 but otherwise it follows the constant-mortality path. The age ratio related to the constant-mortality scenario peaks around 2030 due to the ageing of the baby boom generations, then declines and gradually stabilizes to a higher level than currently. The contribution of the projected increase in life expectancy can be found by comparing age ratios related to scenarios Pcons and Pmort. Thus, it is certainly reasonable to assume that longevity will have significant effects on public finances and on the economy. Note that the differences between SF2012 and Pmort are due to differences in the sizes of new young cohorts and in net migration.

Figure A2 depicts the effect of longevity on the number of persons over 80—the age after which LTC needs begin to increase rapidly. Compared to what current mortalities would produce, longer lifetimes will mean a bigger 80+ population by over 70% in 2063.

APPENDIX B: THE FINNISH EARNINGS-RELATED PENSION SYSTEM

The earnings-related pension system aims to provide sufficient retirement income to cover consumption comparable to the levels enjoyed during working years and to current workers’ consumption. It covers risks related to old age, disability, and the death of family earners. If the earnings-related public pension is absent

**FIGURE A1**
Projected Age Ratios, 60+/20–59
or insufficient, the national pension guarantees a minimum income. Both of these first-pillar systems are mandatory. Voluntary pensions are of minor importance in Finland. A recent description and evaluation of the Finnish pension system is Barr (2013).

**Benefits.** The pensions can be thought of as consisting of both disability pensions and old-age pensions. Every year’s earnings and accrual rates directly affect the future pension. The accrual rate is 1.5% per year between the ages of 18 and 53 and 1.9% between the ages of 53 and 62. Between the ages of 63 and 68, the accrual is 4.5% per year, aiming to reward later retirement in a cost-neutral way. Employee’s contributions are deducted from wages in this calculation. There is no cap in pension benefits. Both pension rights and benefits are index linked, with 80–20 weights on wages and consumer prices respectively during working years and 20–80 weights after retirement, irrespective of the retirement age. Employee’s contributions are deducted from wages in this calculation as well.

If retirement occurs due to disability, the pensioner is compensated for lost future accruals. The compensation depends on the age at the time of the disability event. After receiving the disability pension for 5 years there is a one-time level increase in the pension.

**Longevity Adjustment.** The pensions are adjusted for increasing life expectancy simply by taking the increasing longevity into account in the value of the annuity. The adjustment coefficient is a ratio of two present values of a unit pension, calculated at two different periods. The present value of a unit pension, which begins in period \( t \) and is calculated forward from age 62, is as follows:

\[
A(t, 62) = \sum_{s=63}^{100} S(t - 1, 62, s) / (1.02)^{s-62}.
\]

The present value of a unit pension is a discounted sum of terms generated during various retirement years. The terms have two parts. The first term, \( S \), expresses the survival probability from age 62 to age \( s \), and the first subscript of the term demonstrates that the probability is evaluated using information available in period \( t \), when the latest observed mortalities are from period \( t - 1 \). The survival probabilities are actually 5-year moving averages. The second term is the discount factor where the discount rate is 2% per year. In the model, individuals die at the age of 100 at the latest.

The pension of a person born in period \( t - 62 \) is multiplied by the longevity adjustment coefficient \( E(t, 62) \) after age 62. The coefficient is a ratio of two \( A \)-terms as follows:

\[
E(t, 62) = A(2009, 62) / A(t, 62).
\]

**Prefunding.** The Finnish earnings-related system has collected substantial funds, amounting currently to about 85% of the annual GDP, to smoothen the contribution increases due to population ageing in the future. In the public sector, the funds act as buffers. In the private sector, funding is collective but based on individual pension rights. Individual pension benefits do not depend on the existence or yield of funds. Funds only affect contributions. When a person receives a pension after the age of 65, his or her funds are used to pay that part of the pension benefit that was prefunded. The rest comes from the PAYG part in the contribution rate.

**Contribution and Replacement Rates.** Since 2005, employees aged 53 and over have paid contributions that are about 1.27 times that of younger employees, reflecting their higher accrual. Employee contributions were 5.55% of wages for younger workers and 7.05% for older workers in 2014. In addition to employees, employers must also pay contributions, based on the wage bill. In 2014, employer contributions were, on average, 17.75%. Future changes have
been agreed to be shared 50–50 between employers and employees.

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