Policy Implications of Changing Longevity*

Pierre Pestieau[†] and Gregory Ponthiere[‡]

[†]University of Liège, CORE, TSE and CESifo. E-mail: p.pestieau@ulg.ac.be
[‡]Paris School of Economics and Ecole Normale Supérieure, Paris.
E-mail: gregory.ponthiere@ens.fr

Abstract

Our societies are witnessing a steady increase in longevity. This demographic evolution is accompanied by some convergence across countries, whereas substantial longevity inequalities persist within nations. The goal of this article is to survey some crucial implications of changing longevity on the design of optimal public policy. For that purpose, we first focus on some difficulties raised by risky and varying lifetime for the representation of individual and social preferences. Then, we explore some central implications of changing longevity for optimal policy making, regarding prevention against premature death, pension policies, and long-term care. (JEL codes: H21, H55, I12, I13, J10)

Keywords: Life expectancy, mortality, optimal public policy

1 Introduction

For long economists have been concerned by the consequences of changing fertility on employment, saving, and growth. Particular attention was given to the shift from high fertility to low fertility, or, to put it otherwise, to the transition from baby boom to baby bust.[1] Such a shift was seen as the main factor of society aging. Recently, the focus seems to move away from these fertility considerations toward another demographic evolution, namely the pervasive increase in longevity.

Crucial in that evolution are two factors. First, behind an apparent steady trend, there remains a lot of variability across individuals, or, rather, across groups of individuals segmented according to characteristics such as gender, occupation, location, and education. Hence 'heterogeneity' in individual characteristics affecting survival chances is a central dimension of the problem at stake. Second, a sizeable part of longevity changes is endogenous, that is, triggered by individual and collective decisions. As a consequence, longevity changes can hardly be treated as exogenous shocks affecting the economy, but, rather, can be better viewed as the 'output' of a complex production process.

The goal of this article is to review some major effects that evolving longevity has on a number of public policies, which were initially designed for unchanged longevity. For that purpose, a first, necessary step consists

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[1] See Barro and Becker (1989) and Ehrlich and Lui (1991).

of studying the challenges raised by varying longevity for the description of economic fundamentals, such as individual preferences and the social welfare criterion. Then, in a second stage, we survey some recent theoretical studies on the design of optimal public intervention in the context of varying longevity. Longevity changes affect various dimensions of economic life. As a consequence, the papers and findings that we survey here come from various fields of economics, such as public economics and public finance, and also behavioral economics, social choice theory, and health economics.[2]

The rest of the article is organized as follows. Section 2 presents key stylized facts about longevity increase. It appears that, although life expectancy has significantly grown over time, strong longevity inequalities still persist. Section 3 presents a simple lifecycle model with risky lifetime, and studies the impact of varying and risky longevity on economic fundamentals. It is shown that varying longevity raises serious difficulties for the representation of individual preferences and also when selecting an adequate social objective criterion. Then, in Section 4, we turn to the effects of changing longevity on the design of public policies, particularly the taxation/subsidization of health, saving, and labor. A final section concludes.

2 Empirical facts

Let us first start this survey by presenting some basic empirical facts about human longevity. For that purpose, a widespread way to measure longevity changes consists of computing the mathematical expectation of the duration of life, conditionally on a vector of age-specific probabilities of death observed during a particular period. That mathematical expectation is better known as the (period) life expectancy at birth. Figure 1 shows the evolution of (period) life expectancy at birth, for men and women, in several advanced economies around the world, since 1900.[3]

Figure 1 shows that the average duration of life has, over the period considered, strongly increased, from below 50 years at the beginning of the 20th century, to more than 80 years today. That strong growth has also been accompanied by a convergence process: while significant longevity gaps existed in the early 20th century, those gaps have tended to vanish over time. Note also that, whereas the life expectancy at birth has

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[2] Given that our focus is here on public policy, we deliberately leave aside the voluminous literature using OLG models to replicate the demographic transition, such as Cervelatti and Sunde (2005, 2011), Galor and Moav (2005), and de la Croix and Licandro (2012). See Boucekkine et al. (2008) for a survey.
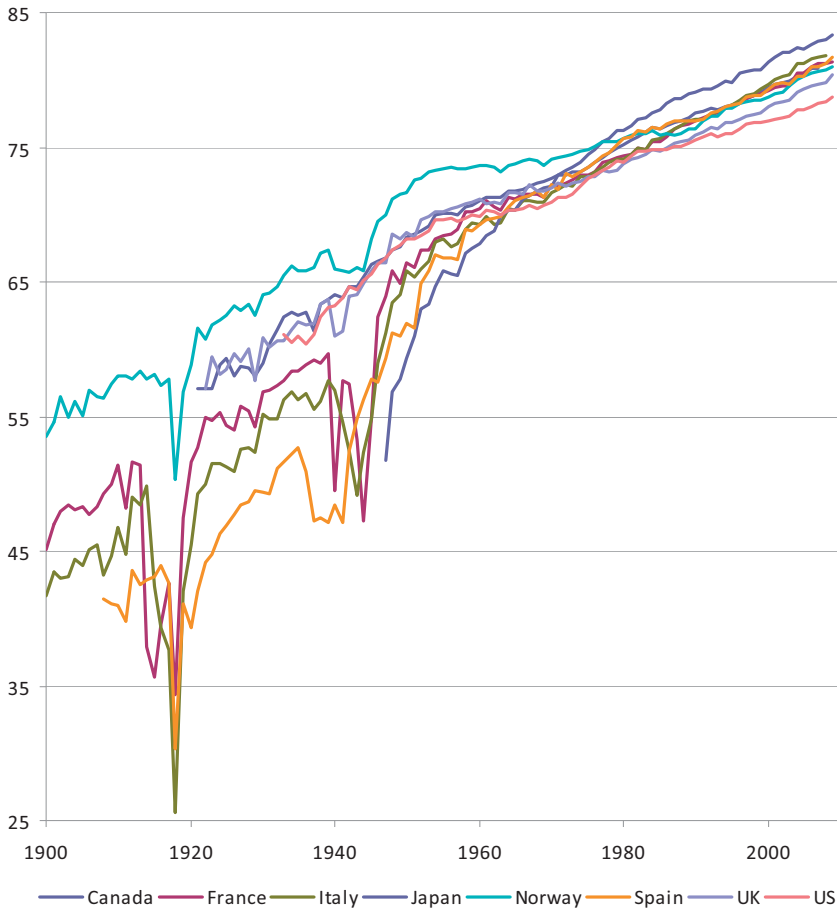
[3] Sources: Human Mortality Database (2012).

Figure 1 Life expectancy at birth (period) in advanced economies, 1900–2010.

exhibited, in many countries under study, a non-linear trend in the two decades following World War II, the rise in longevity now seems to follow a linear trend. Advanced economies exhibit, on average, a 3-month annual gain in life expectancy.

At this stage, it is important to stress that the rise in human longevity is a widespread phenomena, which is not confined to Western Europe and North America. To illustrate this, Figure 2 shows the evolution of (period) life expectancy at birth (for men and women) in eight countries from Eastern Europe, since 1950.[4] Despite some significant differences between

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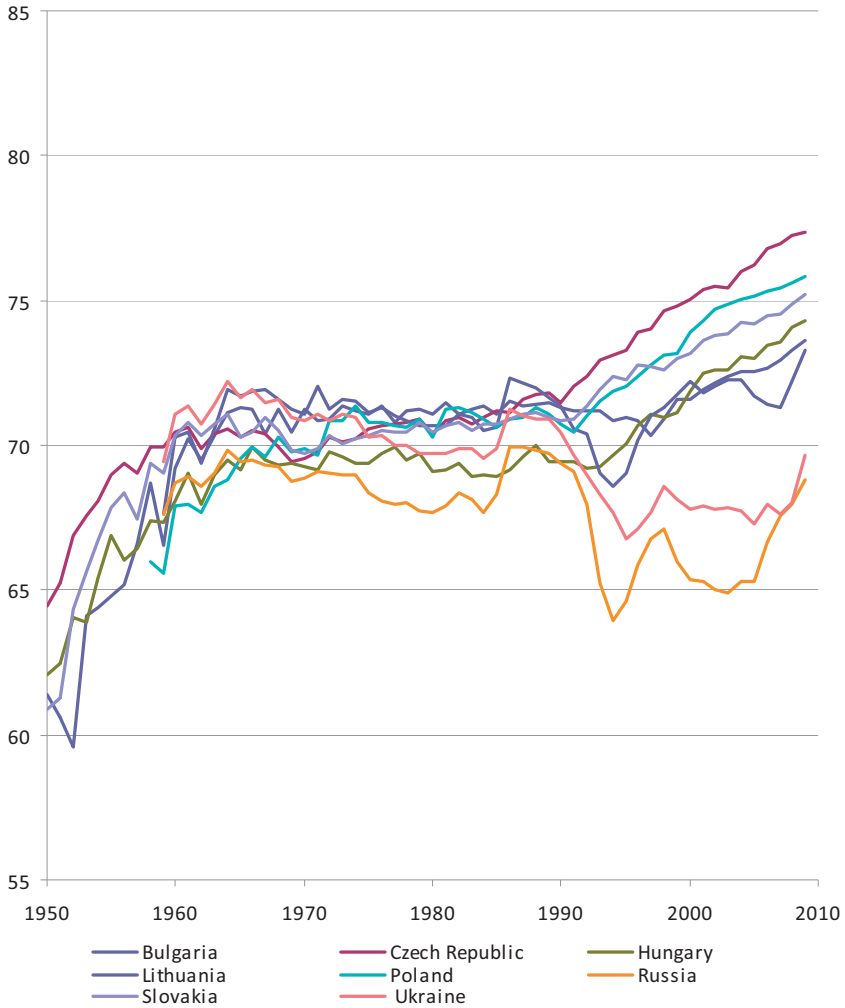[4]   Sources: Human Mortality Database (2012).

Figure 2 Life expectancy at birth (period) in Eastern Europe, 1950–2010.

countries, a similar global pattern can be observed: a growth in life expectancy during the 1950s and the early 1960s, followed by a long period of stagnation, during the 1970s and 1980s. Finally, and after some transitory deterioration of survival conditions during the first part of the 1990s (the moment of the transition to the market economy), most of those countries now exhibit a growing life expectancy.

Note, however, two significant differences with respect to the advanced economies shown in Figure 1. First, all Eastern economies still exhibit,

nowadays, a lower life expectancy at birth than advanced economies; second, the intragroup longevity gap is here larger, with some countries—Russia and Ukraine—whose life expectancy at birth is still below 70 years. This suggests that although most Eastern economies are converging toward Western economies, convergence takes place at a speed that is strongly varying across those countries. One should thus be cautious before generalizing the rise in longevity.

The general rise in human life duration also hides the existence—and persistence—of significant inequalities within countries. Those intra-country inequalities in the duration of life can be substantial, and sometimes exceed the longevity inequalities between countries. Various factors explain those inequalities in the duration of life: the gender (Vallin 2002) the genetic background (Christensen et al. 2006), the geographic location and environmental quality (Sartor 2002), the education level (Deboosere et al. 2009), the income level (Pamuk 1985; Duleep 1986; Salm 2007), the socio-economic status (Contoyannis and Jones 2004), the employment status (Mullahy and Sindelar 1996), as well as individual lifestyles (Balia and Jones 2008). A simple way to illustrate the existence of strong longevity inequalities within countries is to look at the longevity gap between men and women. For that purpose, Figure 3 compares the life expectancy at birth for men and women in Sweden since 1750.[5]

As shown in Figure 3, the life expectancy at birth for men and women has exhibited, across centuries, similar patterns. But although the two curves exhibit similar fluctuations, the women's curve has remained, across centuries, significantly above the men's curve, illustrating the existence of a gender longevity gap. The size of the gender gap has been varying over time. Nowadays, the gender gap is equal to about 4 years: an expected duration of life equal to 83.71 years for women, against 79.72 years for men. That gender gap is thus sizeable, but it has been decreasing during the last decades: it was equal to about 6 years in 1980 and still equal to 5 years in 1996.

Besides gender differences, there exist various factors explaining why all humans do not enjoy the same lifetime. Identifying those risk factors is the object of various empirical studies. But a simple, intuitive way to represent the size of existing inequalities in longevity, as well as the evolution of those inequalities over time, consists of looking at the survival curves. Each survival curve shows the proportion of a cohort reaching the different ages of life. Given that death is an absorbing state, survival curves are

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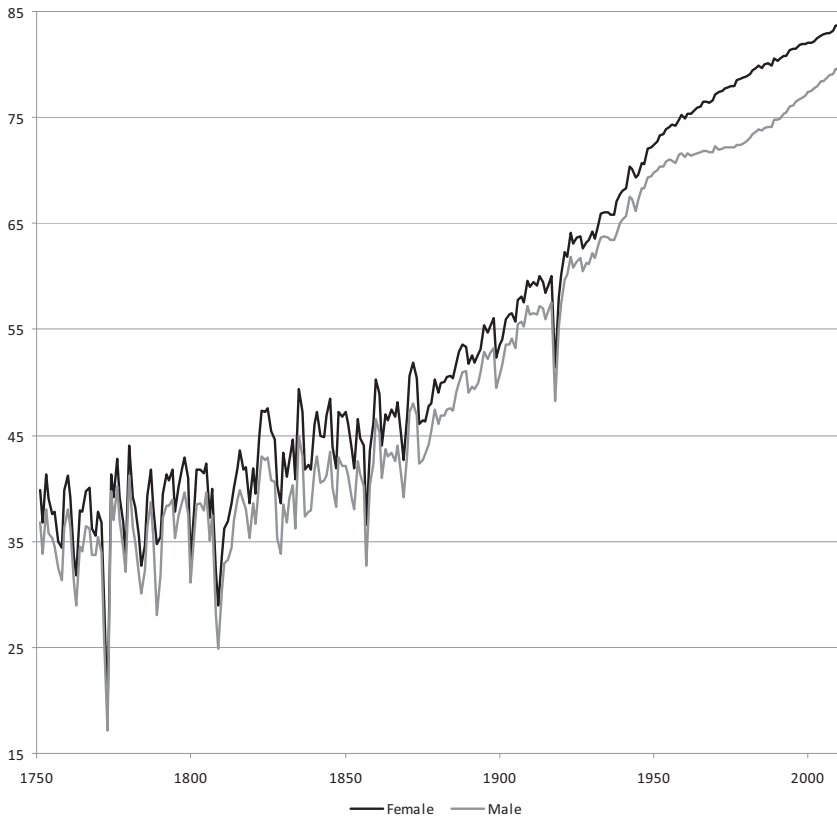[5] Sources: Human Mortality Database (2012).

Figure 3 Life expectancy at birth by gender (period) in Sweden, 1750–2010.

decreasing, and their slope reflects the strength of mortality at the age considered.

Figure 4 shows the evolution of (period) survival curves for women from the United Kingdom, over the period 1922–2009.[6] Each curve shows the proportion (on the y-axis) of a hypothetical cohort born at that year, who reaches the different ages of life (on the x-axis), from 0 to 120. As such, those curves summarize the tremendous changes observed in terms of survival conditions. A first, major change that occurred is shown on the upper left corner of Figure 4: it is the substantial decline in infant mortality. In 1922, ~6.6% of female babies died during their first year of life in the UK. That proportion has been reduced to 2.6% in 1950, and to less

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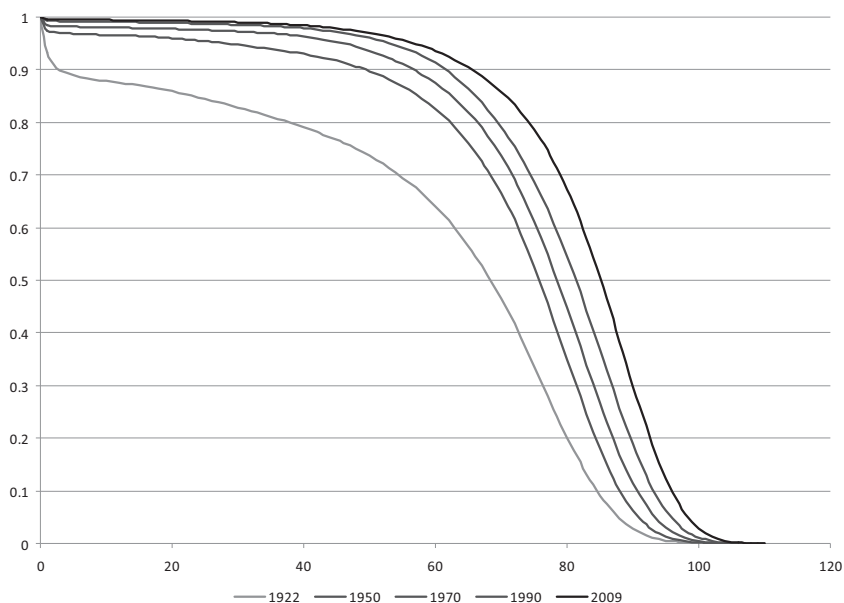[6] Sources: Human Mortality Database (2012).

Figure 4 Survival curves (period) for UK females, 1922–2009.

than 0.5% in 2009. But there have also been substantial changes later on along the lifecycle. While a fraction equal to 64% of the cohort could reach the age of 60 years on the basis of the survival conditions observed in 1922, that proportion has grown to 81% of the cohort in 1950, to 90% of the cohort in 1990, and to 93% of the cohort in 2009.

Figure 4 allows us also to decompose the evolution of the survival curves in two distinct movements. On the one hand, the survival curve has tended, over time, to shift upwards. That change coincides with an increase in the proportion of the cohort who can reach high ages of life. That phenomenon is known as the 'rectangularization' of the survival curve. That phenomenon implies that an increasingly large proportion of cohorts dies on an age interval that becomes shorter and shorter over time.[7] Although 50% of the female cohort dies between ages 68 and 107 years on the basis of survival conditions observed in 1922, that is, on an age interval equal to $107 - 68 = 39$ years, that interval has been reduced strongly in the last decades: on the basis of the survival conditions observed in 2009, 50% of the female cohort will die between ages 85 and 110 years, that is, on an age interval of 25 years. The concentration

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[7] On the measurement of rectangularization, see Kannisto (2000).

of deaths on a shorter age interval is called the rectangularization process, because it coincides with survival curves that become closer and closer to the rectangular.[8] A strictly rectangular survival curve would coincide to the extreme case where all individuals would enjoy exactly the same length of life. In that hypothetical case, longevity inequalities would have disappeared, and life would no longer be risky.

Although a tendency toward rectangularization has been observed during the last century, that phenomenon is not the only one driving the evolution of survival curves. Over time, survival curves have not only shifted upwards but also to the right. That phenomenon consists of the rise in limit longevity, that is, the fact that some persons are nowadays able to reach extremely high ages, which could not be reached in the past. In Figure 4, that distinct movement of the survival curve can be measured by calculating the proportion of the cohort reaching the age of 100 years. Centenarians only represented 0.051% of the cohort on the basis of 1922 age-specific mortality rates, against 0.139% in 1950, 1.156% in 1990, and 2.851% in 2009. That change consists of a multiplication by a factor of 55, in less than 100 years. The shift of survival curves to the right has a very different implication, in terms of inequalities, than the shift upwards (rectangularization). Although rectangularization leads to a reduction in longevity inequalities, the same is not true for the rise in limit longevity, which can increase the dispersion of the age at death.

One of the most relevant differences in longevity for its policy implications is the variation in life expectancy by educational level. Figure 5 gives some striking evidence on this issue for men and women in the USA and for 2 years 1996 and 2006. The gap between those without a high-school degree and those having at least completed a BA degree is striking. For uneducated women, the gap has increased in 10 years and the longevity gap between men and women is impressive.

To conclude, although the evolution of human longevity is quite often summarized by a simple indicator—the period of life expectancy—it is crucial to keep in mind that life expectancy, being a mathematical expectation of the duration of life, may hide other important dimensions of human longevity. One of those dimensions is the issue of inequalities, and their evolution over time. The few figures presented here suffice to show that, even if the average longevity has been growing strongly over the last century, longevity inequalities remain substantial. Indeed, even though the life expectancy at birth for women in the UK is as high as 82.27 years in 2009, it is nonetheless the case that about 14% of women in

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[8] On the causes of the rectangularization, see Nusselder and Mackenbach (2000) and Yashin et al. (2001).
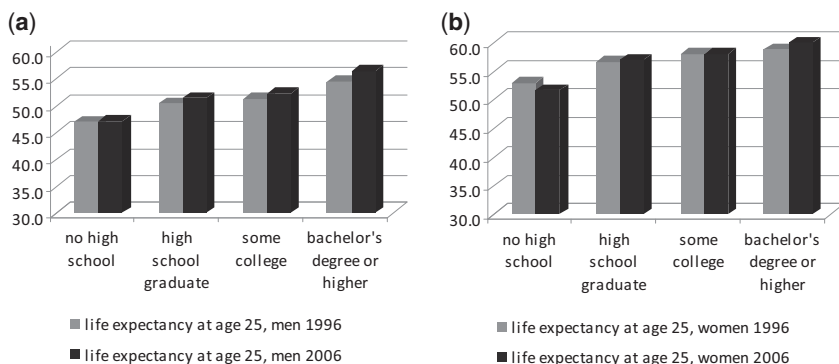
Figure 5 (**a**) Life expectancy at age 25 years by educational level, men (USA). (**b**) Life expectancy at age 25 years by educational level, women (USA). *Source*: CDC/NCHS, National Health Interview Survey Linked Mortality File.

the UK will not, on the basis of the 2009 survival curve, reach the age of 70 years. Thus, for 14% of women, the realized longevity will coincide with the life expectancy prevailing in the UK in 1949.

3 The model

In order to review some of the main challenges raised by those demographic trends for optimal public policy, let us first present the basic model that we will use throughout this article. For simplicity, we rely here on a model with discrete time and try to keep the modeling as basic as possible, to be able to point to the key problems raised by varying longevity for economic analysis.

3.1 Demography

We consider a simple two-period model with risky lifetime. The young age (period 1) is lived with certainty. However, the old age (second period) is reached with a probability π. By the 'law of large numbers', π is also the fraction of the cohort that will enjoy the old age, whereas a fraction $1 - \pi$ will die at the end of the first period of life.

Such a modeling of life captures a key aspect of the problem: life is risky, and no one can anticipate the exact duration of his life. Note, however, that this modeling, which relies on a single longevity dimension, can be completed by adding another dimension, which captures not the proportion of individuals reaching the old age, but, rather, the duration of the old

Table 1 π and ℓ for UK women

	1922	1950	1970	1990	2009
π	0.56	0.76	0.81	0.86	0.91
ℓ	0.31	0.36	0.40	0.45	0.51

age. The duration of the old age can be denoted by the variable ℓ, with $0 < \ell < 1$.

In that framework, life expectancy at birth is

$$E(L) \equiv \pi(1 + \ell) + (1 - \pi)1 = 1 + \pi\ell. \tag{1}$$

That simple two-dimensional modeling allows us to capture the quite distinct causes of an observed rise in life expectancy identified in the previous section.[9] Indeed, the rectangularization process coincides with a rise in π, whereas ℓ is left constant. The extreme situation of rectangularity of the survival curve prevails when $\pi = 1$. On the contrary, a rise in ℓ consists of a rise in limit longevity.

Those changes —i.e. a rise in π or in ℓ—both imply a rise in life expectancy. However, their effects on the inequalities in terms of longevity are not the same. To see this, note that the variance of the length of life is here equal to:

$$\mathrm{Var}(L) \equiv \pi(1 + \ell - (1 + \pi\ell))^2 + (1 - \pi)(1 - (1 + \pi\ell))^2 = (1 - \pi)\pi\ell^2. \tag{2}$$

A rise in ℓ necessarily increases the variance of longevity, whereas a rise in π has that effect only when $\pi < 1/2$, but reduces the variance when $\pi > 1/2$.

That two-dimensional modeling of human longevity is simple, but allows us to represent, in a quite convenient way, the past evolution of survival conditions. To give an idea of the value of those variables, Table 1 shows the evolutions of π and ℓ for UK women, over the period 1922–2009.[10]

Table 1 shows that, whereas the largest part of life expectancy gains were initially caused by a rise in π, nowadays these gains are also driven by the rise in ℓ, which is a source of inequalities.

Finally, note that, those two dimensions of longevity can be modeled not only as parameters but also as variables, whose levels depend on

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[9] On that modeling, see Eeckhoudt and Pestieau (2008) and Ponthiere (2009).

[10] Sources: Human Mortality Database (2012). π is computed as the proportion of women reaching the age of 65 years, while ℓ is the life expectancy at that age (normalized by the length of each period, i.e. 40 years).

various 'inputs'. Those inputs in the survival process can take different forms. Some of these are factors on which individuals have no influence at all, such as the genetic background.[11] Other inputs are factors on which no individual can have a significant impact on his own, but which are nonetheless socially determined (e.g. pollution). Moreover, other factors are under the control of agents: these 'behavioral' factors are often coined as healthy or unhealthy lifestyles (e.g. alcoholism, smoking, food diet, physical activity, and sleeping patterns).[12]

The identification of those inputs in the production of survival conditions, as well as the measurement of their relative contribution to human longevity, is an empirical issue. On the theoretical side, we can represent the production of survival conditions as follows:

$$\pi \equiv \pi(\varepsilon, P, e), \tag{3}$$

$$\ell \equiv \ell(\varepsilon, P, e), \tag{4}$$

where ε denotes the genetic background, P denotes the pollution, and e denotes the individual longevity-improving effort. We have: $\pi_\varepsilon > 0$, $\pi_P < 0$, $\pi_e > 0$, as well as $\ell_\varepsilon > 0$, $\ell_P < 0$, $\ell_e > 0$. Note, however, that nothing imposes *a priori* that the contributions of those different types of inputs are of the same magnitudes for the improvement of π and ℓ. Moreover, the relationship between those different inputs can be of various kind. For instance, there can be complementarity (respectively, substitutability) between effort and environmental quality: $\pi_{eP} < 0$ (respectively, $\pi_{eP} > 0$).

Finally, note that those different inputs can be affected by various characteristics of economic agents. For instance, the amount of health-improving effort e depends on the preferences of the agent (e.g. taste for jogging), on his degree of ignorance of the survival process (e.g. myopia) and also on his budget constraints. Hence, the input e is itself the product of lots of different factors. The economic analysis of longevity requires thus a particular attention to be paid to a—usually neglected—production process: the production of human lifetime.

3.2 Individual preferences

Besides the modeling of survival conditions and their production, another key building block consists of the modeling of human preferences. Given the risky nature of human life, those preferences are defined on lotteries of life, whose different possible scenarios coincide with different possible

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[11] See Christensen et al. (2006).
[12] See Balia and Jones (2008).

durations of life. The standard modeling strategy consists of assuming that individuals have well-defined preferences on lotteries of life, which satisfy the expected utility (EU) hypothesis, whereas the lifetime utility is modeled as the mere sum of temporal utilities. Hence, when the utility of being dead is normalized to 0, the expected lifetime welfare of an agent is

$$U \equiv \pi[u(c) + \beta \ell u(d)] + (1 - \pi)[u(c) + \beta 0] = u(c) + \beta \pi \ell u(d), \quad (5)$$

where $u(\cdot)$ is the standard temporal utility function, with $u'(\cdot) > 0$ and $u''(\cdot) < 0$, $0 < \beta < 1$ is a standard time preference parameter, whereas c and d denote consumption at the young age and at the old age, respectively.

That standard representation of individual preferences invites some remarks.

A first thing to note is that, within that representation, the time preference parameter β appears to be redundant with the survival probability π. Indeed, the EU hypothesis leading to utility functions that are linear in probabilities, the additivity of lifetime welfare makes β and π play a very similar role. Impatient individuals will save little resources, and individuals with very low survival chances will do exactly the same. One can thus regard the survival probability π as a form of 'natural discount factor', and get rid of pure time preferences, by supposing $\beta = 1$.

A second point to observe concerns the shape of the temporal utility function $u(\cdot)$. Although it is common, in the literature, to assume that the temporal utility function keeps the same form during the whole lifecycle, this assumption is a simplification. When individuals become old, the enjoyment of resources may not have the same flavor as at the young age, everything else being unchanged. Moreover, in the case of old-age dependency, individuals will not enjoy resources as when they were healthy. Those observations invite an alternative modeling, based on state-dependent utility functions. According to this, the expected lifetime welfare would become, in case of (certain) old-age dependency:

$$U \equiv \pi[u(c) + \beta \ell H(d)] + (1 - \pi)[u(c) + \beta 0] = u(c) + \beta \pi \ell H(d), \quad (6)$$

where the function $H(\cdot)$ is still increasing and concave (i.e. $H'(\cdot) > 0$ and $H''(\cdot) < 0$), but can be quite different from the temporal utility function at the young age, $u(\cdot)$. That difference may play a crucial role when considering the challenges raised by long-term care for policy makers.

Another important point to be stressed here is that the above functional forms are not purely abstract things, disconnected from the real world, but can on the contrary be easily calibrated, to be in line with what the data show. For that purpose, a simple way to proceed is to rely on the

voluminous empirical literature on the value of a statistical life (VSL).[13] The VSL is defined as the shadow price of a reduction of the risk of death per unit of risk. In the present, two-period framework, the VSL can be computed as the marginal rate of substitution between the survival probability and first-period consumption, for particular temporal utility functions $u(c)$ and $u(d)$[14]:

$$\text{VSL} \equiv \frac{\partial U/\partial \pi}{\partial U/\partial c} = \frac{\ell[u(d) - du'(d)]}{u'(c)}. \tag{7}$$

The numerator is the effect of a marginal rise in the survival probability on expected lifetime welfare. It is composed of two terms. The first term of the numerator is the utility gain from surviving, i.e. $u(d)$, while assuming that the survival has not affected second-period consumption. The second term of the numerator, $-du'(d)$, captures the negative effect of a higher proportion of survivors on old-age consumption possibilities. Provided $u(d) - du'(d) > 0$, the VSL is increasing with the remaining lifespan in case of survival ℓ. The denominator corresponds to the marginal utility loss, at the young age, resulting from giving up some consumption for the sake of increasing one's survival chances. From that expression, it appears that the consumption one is willing to sacrifice for a rise in π depends on the welfare level at the old age (a low $u(d)$ reduces the VSL *ceteris paribus*), while a higher consumption c, by reducing the marginal welfare loss from spending on health, leads to a higher VSL.[15]

Having presented the standard way to represent individual preferences on lotteries of life, as well as a simple way to relate that representation to the empirical literature, it should nonetheless be stressed that this classical representation has been, in the recent years, questioned on several distinct grounds.

A first line of attack has been formulated by Bommier in various works (2006, 2007, 2010). Bommier argued that the standard way to represent agents' preferences over lotteries of life is fundamentally wrong. The reason has to do with the attitude toward the risk of death that follows implicitly from that standard modeling. Bommier argues that the double additivity assumption (i.e. EU hypothesis + time-additive preferences) amounts to postulate that agents are, in the absence of pure time

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[13] See Viscusi (1998).
[14] We assume $\beta = 1$ and we also suppose the existence of a perfect annuity market, so that d depends negatively on a rise in π. Formally, we rewrite (5) as: $U = u(w - s) + \pi\ell u(s/\pi\ell)$, where s is saving and $1/\pi\ell$ is the rate of return of annuities given a zero interest rate. Clearly, $\partial U/\partial \pi = \ell(u(d) - du'(d))$.
[15] This is in line with the empirical evidence showing a rise in VSL over time (Costa and Kahn 2004).

preferences, 'risk-neutral' with respect to the length of life.[16] In other words, it is assumed that individuals are strictly indifferent between two lotteries of life, as long as these exhibit the same consumption per period, and the same life expectancy.

According to Bommier, such a corollary is not plausible at all. To see this, take the following example, which involves two lotteries of life, denoted lotteries A and B, with the same consumption per period $c = d = \bar{c}$, the same life expectancy, equal to $1 + \pi\ell$, but which differ in the variance of longevity: whereas the lottery A involves a certain survival (i.e. $\pi = 1$) to a second period of length $\ell = 1/2$, lottery B involves an uncertain survival (i.e. $\pi = 1/2$) to a second period of maximum length (i.e. $\ell = 1$). In the two cases, life expectancy is equal to $1 + 1/2 = 3/2$. In the two cases, the expected lifetime welfare is the same, and equal to: $3/2 \times u(\bar{c})$. But few individuals would claim to be strictly indifferent between those two lotteries of life. Probably, many persons would opt for the riskless lottery, i.e. for lottery A.

Bommier not only pointed out toward a major weakness of the standard modeling of individual preferences on lotteries of life but also proposed his own solution: relaxing the time-additivity assumption. Under that alternative representation, the lifetime welfare is now an increasing transform $V(\cdot)$ of the sum of temporal utilities. The transform $V(\cdot)$ can take various forms: if linear, we are back to the standard modeling, which involves risk neutrality with respect to the length of life; if concave, agents will now exhibit risk aversion with respect to the length of life. Indeed, the utilities assigned to lotteries A and B become, under that alternative representation of preferences:

$$V\left[\left(\frac{3}{2}\right)u(\bar{c})\right]$$

for lottery A and

$$\left(\frac{1}{2}\right)V(2u(\bar{c})) + \left(\frac{1}{2}\right)V(u(\bar{c}))$$

for lottery B. By concavity of $V(\cdot)$, the expected lifetime welfare assigned to lottery A exceeds the one assigned to lottery B, in line with risk aversion with respect to the duration of life.

Thus, modifying the representation of individual preferences on lotteries of life enables us to rationalize risk aversion with respect to the duration of life. Note, however, that such a modification has also strong influences on

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[16] To be precise, Bommier evokes the concept of 'net risk-neutrality' with respect to the length of life, i.e. net of pure time preferences.

optimal tax/transfer policy, as studied in Bommier et al. (2011a,b). In particular, assuming a non-additive lifetime[17] welfare tends to qualify classical utilitarianism's tendency to redistribute resources from short-lived toward long-lived individuals.

Besides Bommier's critique, another line of attack has consisted in questioning the EU hypothesis. Criticisms against the EU hypothesis are not new. These date back to, at least, Allais's (1953) questioning of its reliance on the independence axiom, according to which a preference ordering on two lotteries is preserved when those two lotteries are combined with a third one. That criticism is general and applies thus also to lotteries of life. Since the 1970s, various non-EU, theories of behavior in front of risk were developed (see Starmer 2000; Schmidt 2004; Machina 2008). These are most relevant when studying preferences on lotteries of life.

A first alternative approach consists of arguing that individuals facing risks do not rightly evaluate the probabilities of occurrence of the different scenarios of life, following Kahneman and Tversky (1979). Individuals have, in general, a tendency to overestimate the probability of occurrence of events with low probability, and to underestimate the probability of occurrence of events with high probability. Moreover, the extent to which humans misperceive the likelihood of events depends also on what the events are: the probability of positive (respectively, negative) events is generally overestimated (respectively, underestimated).

Within the present framework, it means that individual preferences on lotteries of life are not represented by $u(c) + \beta\pi\ell u(d)$, but, instead, by

$$u(c) + \beta\hat{\pi}\ell u(d), \tag{8}$$

where $\hat{\pi}$ denotes the perceived probability of survival, which may differ from the actual probability of survival, π. Various perception biases may be at work, and these can be modeled by means of a simple parameter, as follows:

$$\hat{\pi} = \alpha\pi. \tag{9}$$

Overestimation of the survival probability occurs when $\alpha > 1$, whereas underestimation occurs when $\alpha < 1$.

Introducing such misperceptions of risk can enrich the representation of individual behavior significantly. It can help, among other things, to explain why individuals may prefer lottery A over lottery B, since a decreasing deformation of the probability π in lottery B makes agents prefer A over B, even with additive lifetime welfare. But introducing misperceptions of the survival chances has also some impact on optimal

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[17] Namely $U(c,d)$ is such that $U_{cd} \neq 0$.

policy, since $\alpha \neq 1$ can be interpreted as leading to behavioral mistakes, against which governments should protect individuals.

Besides the introduction of misperceptions in the risk of death, another way to enrich the modeling of individual behavior consists of generalizing the EU framework, to make it sensitive to what Allais called the 'dispersion of psychological values'. Taking into account the first moment (mean) and the second moment (variance) of the distribution of utilities on all states of natures, one possibility is to assume that individual preferences on lotteries of life are represented by a function having the 'mean and variance' utility form[18]:

$$U \equiv \bar{u} - \gamma \text{var}(u), \tag{10}$$

where $\bar{u}$ is the expected lifetime welfare, while var(u) is the variance of lifetime welfare. Substituting for $\bar{u}$ and var(u), one obtains[19]:

$$U \equiv u(c) + \pi \ell u(d) - \gamma \big[[\ell u(d)]^2 (1 - \pi)\pi \big]. \tag{11}$$

When $\gamma = 0$, that utility function collapses to the standard EU model. However, under $\gamma > 0$, agents tend, *ceteris paribus*, to prefer lotteries with a lower degree of variance in welfare. That preference is also directly relevant to rationalize the strict preference for lottery A over lottery B in the above example. Indeed, expected lifetime welfare under lotteries A and B are here equal to:

$$\left(\frac{3}{2}\right)u(\bar{c}) > \left(\frac{3}{2}\right)u(\bar{c}) - \gamma \left[[u(\bar{c})]^2 \left(\frac{1}{4}\right) \right]$$

under $\gamma > 0$. Thus, adopting that 'moments of utility' approach is another simple way to account for risk aversion with respect to the length of life.

In sum, we discussed here the baseline representation of human preference on lotteries of life and highlighted some criticisms against it, as well as some—among many others—modeling alternatives. Despite those modeling alternatives, the baseline model remains widely used nowadays, because of its simplicity (small number of parameters), which makes it more convenient in comparison to alternative frameworks. Note, however, that such an analytical convenience has also its costs, and should be kept in mind when drawing policy conclusions.

3.3 Social preferences

As shown above, the representation of individual preferences raises, in the context of risky lifetime, specific difficulties, which can legitimate a

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[18] See Leroux and Ponthiere (2009).
[19] We assume here $\beta = 1$.

significant departure from standard modeling. But the introduction of risky lifetime has also key implications for the selection of a social objective function. As we shall now discuss, the evaluation of situations involving risky and unequal longevities may well require, here again, to depart from common practices.

The problem can be formulated as follows.[20] When facing situations involving risks, the standard normative approach consists of adopting the point of view of a social planner, who evaluates the distribution of individual 'expected' outcomes before the uncertainty about the state of nature has been revealed. Such an approach can be coined the '*ex ante*' approach to normative economics.

That common approach is not the unique possible one. Another approach, consists of adopting the point of view of a social planner, who evaluates the distribution of individual 'realized' outcomes, i.e. after the uncertainty about the state of nature has been revealed. That alternative approach can be coined the '*ex post*' approach to normative economics.

Note that, in some cases, the *ex ante* and *ex post* approaches are very similar and yield the same social optimum. To illustrate this, let us consider a simple allocation problem, where the social planner must distribute a resource W among a population facing risky lifetime (i.e. a proportion π of the population enjoys old age, while a proportion $1 - \pi$ dies after period 1). The social planning problem consists of selecting consumptions c and d, in such a way as to maximize the social objective, subject to the resource constraint $c + \pi d \leq W$.

All individuals are identical *ex ante*. Their expected lifetime welfare is $u(c) + \pi u(d)$. Hence, from an *ex ante* point of view, the social planner's problem is

$$\max_{c,d} u(c) + \pi u(d) \text{ s.t. } c + \pi d \leq W. \tag{12}$$

The first-order conditions imply $u'(c) = u'(d)$, so that the planner should equalize consumption at all periods:

$$c = d = \frac{W}{1 + \pi}. \tag{13}$$

Let us now adopt an *ex post* perspective. Suppose that the social planner, instead of maximizing the expected lifetime welfare of

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[20] Note that we focus here on a particular issue, which is the distinction between *ex ante* and *ex post* normative approaches. Another issue, not discussed here, concerns the philosophical difficulties raised by the idea of 'a life worth being lived', which plays a significant role in economic calculations in context of risky and unequal lifetime (see Broome 2004).

individuals, want now to focus on individual realized lifetime welfare. If the social planner maximizes the average realized welfare, the planning problem is

$$\max_{c,d} \pi[u(c) + u(d)] + (1 - \pi)(u(c)) \text{ s.t. } c + \pi d \leq W. \tag{14}$$

That objective function is the same as the previous one. This yields the same optimum allocation: $c = d = W/(1 + \pi)$. The reason why the *ex ante* and *ex post* approaches lead here identical results lies in the fact that the social planner is concerned, in the latter case, with the average realized lifetime welfare, which coincides, under the 'law of large number', to the expected lifetime welfare. Hence, there is a formal similarity between being an *ex ante* utilitarian and an average *ex post* utilitarian (see Hammond 1981).

However, that similarity is not really useful for the issue at stake, since, in the context of risky lifetime, the welfare inequalities are so large that being an average *ex post* utilitarian is questionable. Remind that, as we show in Section 2, even if all individuals within a group face, *ex ante*, the same life expectancy, those individuals may, *ex post*, turn out to have quite different longevities. For instance, all UK females had, in 2009, a life expectancy at birth equal to 82.27 years, but only 86% of these will reach the age 70 years, whereas 14% of these will die before that age. Obviously, for women who enjoy a life of the average duration, or for those who die before having reached 70 years, the consequences in terms of lifetime welfare are very different.

In that context, there is a strong case for being more sensitive to inequalities that turn out to emerge from longevity differentials. The problem is that, in the present context, being egalitarian breaks the equivalence between the *ex ante* and the *ex post* approach to normative economics. To see this, let us now turn back to the above allocation problem, but let us replace the objective functions by egalitarian objective functions, of the maximin type.

The *ex ante* problem consists of allocating the resources W in such a way as to maximize the minimum expected lifetime welfare. Given that all agents are identical *ex ante*, the problem is the same as the one studied above and has the same solution: $c = d = W/(1 + \pi)$. However, the *ex post* social planning problem, studied by Fleurbaey et al. (2011) is

$$\max_{c,d} \min[(u(c) + u(d)), u(c)] \text{ s.t. } c + \pi d \leq W \tag{15}$$

and yields a quite different solution:

$$c > d = \tilde{c}, \tag{16}$$

where $\tilde{c}$ is such that $u(\tilde{c}) = 0$. Thus, under the *ex post* egalitarian approach, the social optimum consists of providing to the old the minimum consumption that makes these indifferent between, on the one hand, further life with that consumption, and, on the other hand, death. The remaining resources should be dedicated to the young age. The rationale is the following: from an *ex post* perspective, the worst-off agent is, in general, the short-lived. Hence, the egalitarian objective recommends to transfer as many resources as possible toward the short-lived. In the real world, no one knows who will be short-lived or long-lived, and this is the reason why the social planner has to transfer resources toward the young, because, by doing so, he must be compensating those who will turn out to be short-lived.[21]

In the light of that simple allocation problem, it appears that adopting an *ex ante* or an *ex post* perspective has strong effects on the social optimum in the context of risky longevity. Therefore, a choice is to be made between the two approaches. Let us further discuss arguments for or against those approaches.

The standard *ex ante* perspective can be defended on the ground that such an approach tends to better 'respect' individual *ex ante* preferences. More precisely, agents will tend, under general preferences, to save resources for the old age, even though they may well turn out to be dead at the next period. Therefore, there is a strong dissonance between what individuals actually do, and what the *ex post* social optimum is. Under the latter, old-age consumption is much lower than what would emerge at the laissez-faire. One can thus regard the *ex post* approach as 'paternalistic', since it prevents agents from saving sufficiently for their old days. That argument supports the *ex ante* view.

However, as argued by Fleurbaey (2010), risky situations can be interpreted as situations of 'incomplete information'. Indeed, in our case, agents make their savings decisions while considering that they have a chance π to survive, but, at the end of the day, those agents will be 'either' alive (which is equivalent to $\pi = 1$) 'or' dead (which is equivalent to $\pi = 0$), but in any case their past decision, based on 'a false' π, will be wrong. Once the state of nature will have been revealed, agents will suffer either from over or under savings. Hence, the advantage of the *ex post* approach over the *ex ante* approach is that, at the social planner's level, there is no doubt that a fraction π of agents will turn out to be short-lived, while a fraction $1 - \pi$ will turn out to be long-lived. The social planner can thus make decisions on the basis of the 'correct' information, unlike

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21 Implementing such an allocation is not straightforward as it implies an odd scheme of negative pensions: the surviving retirees pay for the consumption of the young generation.

individuals, who inevitably turn out to be wrong *ex post*. Thus, interpreting risky situations as situations of incomplete information supports the *ex post* approach.

But when facing that ethical dilemma, another view consists of claiming that the *ex ante/ex post* tension becomes benign when the social planner is not very sensitive to inequalities, as under average utilitarianism (see above). This leads us to another central aspect of the discussion: why should the social planner be concerned with welfare inequalities due to longevity differentials? In order to answer that question, it is worth going back to the theoretical foundations of egalitarianism. As advocated by Fleurbaey and Maniquet (2004) and Fleurbaey (2008), one cannot treat all inequalities in the same way. An adequate ethical point of view on inequalities must take the origins of inequalities into account. Some inequalities are due to individual characteristics on which individuals have no control at all. Those characteristics can be called 'circumstances'. Surely, welfare inequalities due to such circumstances are ethically unacceptable, and, as such, invite some correction or compensation by the government. On the contrary, some inequalities are due to other characteristics, on which individuals have an influence. Such factors can be called 'responsibility' characteristics. In that case, governmental intervention is not needed, since individuals can be held responsible for what happens. We are thus in presence of two different kinds of inequalities, which invite two different policies. Inequalities due to luck are ethically unacceptable, and, as such, invite some compensation. This motivates the compensation principle (same responsibility characteristics, same welfare). On the contrary, inequalities due to responsibility characteristics should be left unchanged. This is the intuition behind the natural reward principle (same luck characteristics, no interferences).

That discussion has immediate corollaries for the issue at stake here—the selection of a social objective under risky longevity. As mentioned above, longevity inequalities arise because of various factors, some of which being purely external to individuals, whereas other factors are chosen by individuals. Indeed, the genetic background ε, which is not chosen by individuals, explains one-fourth to one-third of longevity inequalities (see Christensen et al. 2006). But at the same time, lifestyles e explain one-fourth of longevity inequalities (see Balia and Jones 2008). We are thus in a situation where the two kinds of characteristics discussed above are present. The problem is then that it becomes very difficult, if not impossible, to follow the compensation principle, and to try to intervene in such a way as to satisfy the 'same responsibility characteristics, same welfare' goal, without, at the same time, interfering with inequalities that are due to responsibility characteristics, and which are, as such, acceptable. We thus fall under a situation where the compensation principle and the

natural reward principle are incompatible. Some choice will have to be done, and the mere presence of inequalities does not suffice to support compensation over natural reward.

It follows from all this that the selection of an adequate social objective raises serious difficulties in the context of risky lifetime. The difficulty lies in the very different inputs present in the survival process. If all inputs were exogenous to the individual, then the situation would belong to the realm of the compensation principle, and adopting an egalitarian *ex post* social objective would make sense. On the contrary, if all inputs in the survival process were chosen by the individual, then the principle of natural reward would be more appealing, which would support a standard average utilitarian (or *ex ante*) social objective. We are thus in an intermediate situation: adopting one social welfare criterion may be adequate under a particular modeling of survival conditions, but less adequate in another context. Hence, the selection of an adequate social criterion must rely on a case-by-case approach.

4 Implications for social policy

In this section, which closely corresponds to the title of this survey, we consider a number of problems in which changing longevity, whether it is endogenous or not, impacts on the design of public policy. The policy we have in mind concerns taxing or subsidizing health investment and also saving and labor; it may furthermore include the design of pension systems. In each subsection, we start by using the traditional utilitarian approach, and, then, we indicate to what extent departing from it can affect our results. We first analyze three situations with endogenous longevity, and then look at three problems with exogenous longevity.

4.1 Free-riding on longevity-enhancing effort

As soon as longevity becomes endogenous, one expects that rational individuals will make decisions that include some arbitrage between the cost of investing in longevity and the benefits of living additional years in good health. Note that so doing individual do not generally consider that keeping the population alive longer may have some effects, positive or negative, on public concerns such as public debt, the environment, the return of annuities, or the cost of pay-as-you go (PAYG) social security.[22] Typically, regarding these different issues individuals tend to 'free ride'.

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[22]   See Becker and Philipson (1998), Davies and Kuhn (1992). See also Pestieau et al. (2008) for a dynamic setting.

To illustrate this point, we consider a society made of identical individuals, who can increase their survival probability by some health investment, e. In the first period of their life, this costs them e, but in return it increases their probability π of surviving the first period and enjoying a consumption d. Assume that this second period consumption d is financed some annuity return for their saving and some PAYG pension for which they contribute in their active period for an amount θ. One can expect some negative effect that longevity-enhancing spending can have on the returns of annuities, either public or private. The return of private annuity saving is indeed $(1 + r)/\pi(e)$, and that the PAYG pension scheme $(1 + n)/\pi(e)$. We can write the expected lifetime utility of our representative individual as:

$$U = u(w - \theta - s^* - e) + \pi(e)u\left(\frac{s^*(1 + r)}{\pi(e)} + \frac{\theta(1 + n)}{\pi(e)}\right). \qquad (17)$$

The optimal saving s^* is given by

$$u'(c) = u'(d)(1 + r). \qquad (18)$$

As to the level of health expenditure, it is given by

$$\pi'(e)u(d) = u'(d)(1 + r) + \pi'(e)u'(d)d. \qquad (19)$$

In a market economy, it is likely that the individual will ignore the externality $\pi'(e)u'(d)d$, that is, the depressive effect that an increase in longevity has on the return of either saving or social security contribution. This calls for a corrective Pigovian tax.

Up to here, the externality associated with endogenous longevity pertained to the returns of annuities. Note that one has a similar issue when dealing with endogenous fertility. Fertility choices have an impact on the return of PAYG pensions. Another externality arises when dealing with environmental questions and particularly with the idea that earth is like a spaceship; it has a limited number of seats.[23] This externality is known as the 'Tragedy of the Commons:' a dilemma arising from the situation in which individuals, acting independently and rationally, will ultimately deplete a shared limited resource, even when it is clear that it is not in anyone's long-term interest for this to happen.

4.2 Productivity and longevity genes are non-observable

As previously mentioned, longevity inequalities are due to a variety of individual characteristics, some of these being hardly observable, such as the genetic background. As a consequence, the design of optimal

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[23] See Jouvet et al. (2010).

tax/transfer policy in such a context requires to consider a second best setting, where individual longevity-affecting characteristics are not observable by governments.

In order to illustrate that second best approach, let us consider an economy composed of individuals differing in two characteristics: their productivity w_i and their genetic endowment ε_i, both characteristics affecting, either directly or indirectly, their life expectancy.[24] Individual expected lifetime utility can be expressed as follows:

$$U_i = u(h_i w_i - s_i^* - e_i) - v(h_i) + \pi(e_i, \varepsilon_i) u\left(\frac{s_i^*}{\pi(e_i)}\right), \qquad (20)$$

where h is labor supply and $v(h)$ the disutility of labor. We assume a perfect annuity market with a zero rate of interest. The utilitarian first best optimum is obtained by maximizing:

$$\sum n_i \left[u(c_i) - v\left(\frac{y_i}{w_i}\right) + \pi(\varepsilon_i, e_i) u(d_i) \right] \qquad (21)$$

subject to

$$\sum n_i(c_i + e_i + \pi(\varepsilon_i, e_i) d_i - y_i) = 0, \qquad (22)$$

where $y_i = h_i w_i$.

This yields the following first best optimality conditions:

- $w_2 > w_1$ implies $h_2 > h_1$.
- $c_i = d_i = \bar{c} \; \forall i$.
- $\varepsilon_i > \varepsilon_j$ implies $e_i > e_j$ if $\pi_{\varepsilon e} > 0$, that is if both arguments are complements.

These results are standard. We now turn to the second best case, that is, a setting in which the social planner does not observe the two individual characteristics ε and w. To keep things simple, we consider the case in which type 2 is tempted to mimic type 1. To avoid such an outcome, we add to the planner's problem the following self-selection constraint:

$$u(c_2) + \pi(\varepsilon_2, e_2) \, u\,(d_2) - v(h_2) \geq u(c_1) + \pi(\varepsilon_2, e_1) \, u\,(d_1) - v\left(\frac{y_1}{w_2}\right). \quad (23)$$

The outcome can be shown to depend on the relative values of both w_i and ε_i, and of the substitutability of effort e_i and genes ε_i in the longevity function. Table 2 yields the solution in terms of the rates of taxation on

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[24] See Leroux et al. (2011a,b).

Table 2 Signs of taxes in the second best

Second best	Tax	Ext	SSC	Total effect
$\pi_{\varepsilon e} > 0$	σ_1	0	+	+
$w_2 \geq w_1$	σ_2	0	0	0
$\varepsilon_1 < \varepsilon_2$	θ_1	+	+	+
	θ_2	+	0	+
	τ_1	0	+	+
	τ_2	0	0	0

labor, τ_i, saving, σ_i, health investment, θ_i, for particular values of the parameters.[25]

The column Ext corresponds to the external effect mentioned above and the column SSC gives the effect of the self-selection constraint. We clearly see that there can be a case for taxing health and also savings and earnings.[26]

4.3 Myopia or ignorance as to the effect of prevention

As we stressed in Section 3, there is no obvious reason why economic agents would, in the context of varying longevity, necessarily act in a perfectly rational manner. Various misperception or behavioral mistakes are likely to occur, and it is important to explore their consequences for optimal policy.[27]

For that purpose, let us now consider an economy where individuals are either myopic or ignorant as to the consequence of sinful behavior on their longevity. Alternatively, they do not perceive the positive effect of prevention on longevity.[28] In the model we have in mind, identical individuals consume two goods in the first period of their life, a composite good, c, and a sin good, x. The second period of life is of length ℓ that depends on x and on some curative health spending, e. They then consume d, which is financed by saving 'minus' curative health spending. The *ex ante* longevity function varies with degree of rationality of individuals: $\ell = \ell(\alpha x, e)$, where α equals 1 for a rational individual and 0 for a myopic one. By assumption, we have $\ell_x < 0$, $\ell_e > 0$.

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[25] The results presented in Table 2 come from Leroux et al. (2011a).
[26] Atkinson and Stiglitz (1976), Banks and Diamond (2010), and Cremer et al. (2010).
[27] In particular, optimal taxation of sin goods under time-inconsistency was studied by Gruber and Koszegi (2001, 2004) as well as by O'Donoghe and Rabin (2003, 2006).
[28] See Cremer et al. (2012) and Pestieau and Ponthiere (2012).

The social planner—or any rational individual—maximizes:

$$U = u(c) + u(x) + \ell(x, e)\, u\,(d) \qquad (24)$$

subject to the resource constraint:

$$c + x + e + \ell(x, e)\, d = w. \qquad (25)$$

This yields the conditions:

$$u(c) = u(d) = u(x) + \ell_x[u(d) - u'(d)d] = \ell_e[u(d) - u'(d)d], \qquad (26)$$

where $u(d) - u'(d)d > 0$ by assumption.

Clearly, if all individuals are rational, there is no need for public action. Consider now the case of myopia or ignorance. A myopic individual maximizes in the first period:

$$U = u(w - s - x) + u(x) + \ell(0, e)\, u\left[\frac{(s - e)}{\ell(0, e)}\right]. \qquad (27)$$

He will clearly overconsume the sin good. It is not clear that he will not save enough. In the second period, given x, he allocates his saving between d and e so as to maximize:

$$\ell(x, e)\, u\left(\frac{(s - e)}{\ell(x, e)}\right). \qquad (28)$$

To recoup the first best allocation, one needs to subsidize (or tax) saving and to tax the sin good (alternatively to subsidize the preventive effort).

In the above three subsections, we have seen the incidence of endogenous longevity using an *ex ante* utilitarian approach. How would the conclusions reached change if we were to adopt a Rawlsian approach or an *ex post* approach?[29] As long as we keep an *ex ante* approach, the tax policy would be kept unchanged. In the case of genetic differences, to control for responsibility, we could have given more weights to the individuals with a lower genetic endowment without consequence on the outcome. In contrast, it is clear that with an *ex post* approach priority would be given to the short-lived individuals; this would push for a tax on saving and preventive health care.[30]

4.4 Retirement and social security

Special pension provisions such as early retirement for workers in hazardous or arduous jobs are the subject of a great deal of debate.

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[29] See Rawls (1971). The *ex post* approach is discussed in Section 3.
[30] On the treatment of prevention under the *ex post* approach, see Fleubaey and Ponthiere (2012).

Such provisions are historically rooted in the idea that people who work in hazardous jobs—say, underground mining—merit special treatment: such type of work increases mortality and reduces life expectancy, thus reducing the time during which retirement benefits can be enjoyed.[31] This results in such workers being made eligible for earlier access to pension benefits than otherwise available for the majority of workers.

In a recent paper, Pestieau and Racionero (2012) discuss the design of these special pension schemes. In a world of perfect information, earlier retirement could be targeted toward workers with lower longevity. If there were a perfect correlation between occupation and longevity, it would suffice to have specific pension provisions for each occupation. Unfortunately, things are less simple as the correlation is far from being perfect. Granting early retirement to an array of hazardous occupations can be very costly. Government thus prefers to rely on disability tests before allowing a worker to retire early. Another argument for not having pension provisions linked to particular occupations is the political impossibility of reversing it if these occupations become less hazardous.

To analyze this issue, they adopt a simple setting with two occupations and two levels of longevity. All individuals have the same productivity but those with a hazardous occupation face a much higher probability of a short life than those who have a secure occupation. The health status that leads to high or low longevity is private information and is known to the worker at the end of the first period. Before the end of the first period everyone is healthy.

Individuals are characterized by their health status that leads to either long or short longevity (indexed L or S) and by their occupation (one for the harsh one and two for the safe one). Individuals retire after z years of work in the second period. At that time, they know their health status. The disutility of working z years in the second period is inversely related to longevity. This disutility is represented by the function $v(z, \ell)$. We assume that $v(\cdot, \cdot)$ is strictly convex in z, and that the marginal disutility of prolonging activity decreases with longevity.

The individual utility is given by

$$U = u(c) + \ell u(d) - v(z, \ell), \tag{29}$$

with a budget constraint equal to

$$c + \ell d = w(1 + z), \tag{30}$$

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[31] Note, however, that the impact of employment on mortality remains a hot research topic for a broad class of activities, and not only for jobs that are usually regarded as risky. See Ruhm (2000, 2003).

where we implicitly assume a zero rate of interest.

In the laissez-faire, the individual chooses saving, s, and retirement, z, that are given by

$$u'(c) = u'(d) = v' \frac{(z, \ell)}{w}. \tag{31}$$

In the laissez-faire, $c = d$. Agents with the higher longevity will retire later than the other and will consume more. We have thus four types of individuals denoted by kj with $k = L,S$ and $j = 1,2$. By definition, the probability of having a long life is higher in occupation 2 than in occupation 1, namely $p_2 > p_1$.

In a world where $p_1 = 0$ and $p_2 = 1$, the central planner's problem would be easy. In the reality, however, we do not have those extreme cases: some workers can experience health problems even in a rather safe occupation and workers can have a long life even holding a hazardous job. If health status were common knowledge, the first best optimum would still be achievable. If it is private information, one has to resort to second best schemes. Tagging is a possibility.

Assume that $p_1 > 0$ and $p_2 = 1$. Then, it may be desirable to provide a better treatment to type $L1$ than to type $L2$ because the former benefit from an informational hedge that the latter does not have. At the same time, we have the standard horizontal inequity outcome that tagging generates. An alternative (or a supplement) to tagging might be disability tests. If these were error-proof and free, they could lead to the first best. Otherwise, a second best outcome is unavoidable.

In the Pestieau and Racionero approach, the focus is on *ex ante* utilitarian welfare. Note that if we adopt a Rawlsian criterion, implying that we maximize the welfare of type $S1$, the above result would not change much. Things would change, if we would adopt an *ex post* view, implying that we maximize the welfare of the short-lived individuals. In that case, saving is nil and the first-period consumption is just equal to w. Individuals who survive the first period will work longer as shown by Fleurbaey et al. (2012).

4.5 Long-term care social insurance

Most lifecycle risks (unemployment and disability) tend to be negatively related to income. This makes a good case for social insurance when income taxation is distortionary. Given that low-income individuals will benefit from distortionless social insurance more than high-income individuals, social insurance dominates income taxation. In that reasoning, moral hazard is assumed away but the argument remains valid with some moral hazard. This result does not apply to risks whose probability is

positively correlated to earnings, typically LTC. Dependency is known to increase with longevity and longevity with income. Consequently, the need for LTC is positively correlated with income, and the above argument implies that a LTC social insurance would not be desirable with optimal income taxation.[32]

In spite of that, one can argue in favor of social insurance for LTC for a number of reasons. First, we do not live in world where income taxation is optimal. Second, even if we had an optimal tax policy, it is not clear that everyone would purchase LTC insurance. There is quite a lot of evidence that most people understate the probability and the severity of far distanced dependence. This type of myopia or neglect calls for public action. Finally, private LTC insurance is far from being actuarially fair; loading costs are high and lead even farsighted agents to keep away from private insurance: low income individuals will rely on family solidarity or social assistance and high income individuals on self-insurance.

Cremer and Pestieau (2011) study the role of social LTC insurance in a setting, which accounts for the imperfection of income taxation and private insurance markets. Policy instruments include public provision of LTC as well as a subsidy on private insurance. The subsidy scheme may be linear or nonlinear. In the case of linearity, the lifetime utility of an individual is given by

$$\max_{s,\theta} u((1-\tau)hw - v(h) - s - \theta + a) + \pi(1-\varphi)u\left(\frac{s}{\pi}\right) + \varphi\pi H\left(\frac{s}{\pi} + g + \frac{\theta\gamma_p}{\varphi\pi}\right),$$
(32)

where θ is insurance premium; γ_p, loading factor; φ, probability of dependence; a, demogrant; g, social LTC benefit; and τ, the payroll tax rate. Individuals differ in both w and π that are assumed to be positively correlated. If φ is taken as rather constant, we have indeed that w and φ are positively correlated. Maximizing the sum of those individual utilities, it appears that without tax distortion (h inelastic) and with no loading factor, $g = 0$ and $\tau = 1$. However, as soon as there are tax distortions and loading factor and if $a = 0$, it can be shown that there will be no subsidy on θ and that there is a need for social insurance ($g > 0$). One obtains the same results with nonlinear schemes.

In this analysis, we have adopted an *ex ante* viewpoint. If we were to adopt an *ex post* viewpoint, the question is who is the worse off: the individuals who live a short life or those who have a long life but with disability. In the first case, saving for old age including for LTC will not be the priority. In the second case, saving for LTC will be highly desirable.

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[32] See Rochet (1991).

4.6 Poverty and longevity

Besides prevention, retirement and long-term care, unequal longevity has also consequences in domains where this is less expected, such as poverty reduction. The reason is the following. The empirical literature on the income–longevity relationship is unambiguous on the sign of the correlation: richer individuals tend, *ceteris paribus*, to enjoy a longer life.[33] This means also that poorer persons live much shorter lives than non-poor persons. This empirical fact leads to some kind of paradox when measuring poverty.

As shown by Kanbur and Mukherjee (2007), standard poverty measures tend, under income-differentiated mortality, to reflect not only the 'true' poverty but also the interferences or noise due to the selection induced by income-differentiated mortality. A counterintuitive corollary is that, under most poverty indicators, a worsening of the survival conditions faced by the poor would lead to a reduction of the measured poverty. That counterintuitive result is particularly observed when measuring poverty at old ages (see Lefebvre et al. 2012).

Income-differentiated mortality leads to what could be called, following Sen (1998), 'missing poor persons'. Such an observation, which is rather universal, is a bit ironical, as it implies that a government that aims at minimizing poverty in old age and is given the possibility of increasing longevity of poor people at no cost would prefer to reject such an offer. Indeed, it leads to a delicate arbitrage between alleviating poverty and increasing longevity for the poor.

For the sake of the argument, take a society made of four types of individuals: 'poor young', 'rich young', 'poor old', and 'rich old'. Their respective incomes or consumptions are 20, 100, 10, and 100 and their respective numbers are 20, 30, 10, and 30. This implies that half the poor do not survive the first period. Besides *status quo*, two policies are considered both financed by a tax on the young: either increasing the longevity of the poor (so that there would be 15 poor old), or increasing the consumption of the poor old to the level of 15.

A utilitarian prefers the rise in longevity (assuming concave temporal utility); this is consistent with the 'repugnant solution' (Parfit 1984). A Rawlsian planner also chooses this policy, as it maximizes the EU of the poor. A social planner concerned by minimizing the poverty rate is in favor of increasing the consumption of the poor old. Finally, a social planner adopting an *ex post* view would focus on the welfare of the poor who only lives one period, and thus supports the *status quo*, as

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33 See Pamuk (1985), Duleep (1986), Deaton and Paxson (1998), Deaton (2003), Jusot (2003), and Salm (2007).

each reform implies a slight decrease in the consumption of the prematurely dead poor.

5 Conclusions

Thanks to steady advances in medical knowledge and technology and also to collective and individual behavior, people today are living much longer lives than they did as little as a century ago. Overall, they are also enjoying higher standards of living and a better quality of life. However, individuals do not evenly benefit from those appealing longer lifespans. There remains a lot of inequality before death. These differential changes in longevity have been neglected for long by public economists. The purpose of this article was to survey the implications that changing longevity may have on the design of optimal public policy. It showed also how the foundations of individual and social preferences had to be revised to take into account this evolving setting.

As it is clear from this survey, there remain a number of issues for further research. Two of them are quite important. First, most of the work covered above is cast in a 'static' setting. There is a quite insightful research that studies public education and PAYG pensions in dynamic models with endogenous longevity. Second, one has to admit that most surveyed results rest on a particular social objective: the standard utilitarian *ex ante* approach. There is a clear need to extend them to encompass the normative problems mentioned above.

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