# Incorporating changes in life expectancy into economic growth rates: an application to Belgium, 1867-1997

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**Abstract**
Longevity-adjusted growth rates are computed for Belgium over the period 1867-1997, by using a method based on contributions by Usher (1973a, 1980), Williamson (1984) and Miller (2000). Adjusted growth rates substantially differ from conventional figures, which may have tended to underestimate actual well-being improvements, especially during the second half of the 20th century. The analysis of the size of the adjustments, size which varies across periods, reveals that the post-1974 growth slowdown might have been less severe, in terms of social well-being, than suggested by usual measures. Our results, being robust to the introduction of some degree of endogeneity of longevity, seem to avoid the double-counting criticism. Several shortcomings of our method are discussed and some directions are proposed for future research. It is concluded that, thanks to their richer informational basis, longevity-adjusted growth rates constitute promising indicators to complement usual growth measures in the study of social well-being evolution over time.

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## 1: Introduction: incorporating longevity into growth rates: *why* and *how*?

Developed during the interwar period by distinguished economists such as Kuznets in the United States, Stone and Meade in the United Kingdom and Lindhal in Sweden, national accounts statistics revolutionized economics by improving the design and the assessment of economic policies and also by allowing the empirical testing of models. National income is often regarded not only as a measure of economic activity, but also as a synthetic indicator of social well-being in an economy, whose growth is usually interpreted as reflecting – at least to some extent – economic or social progress. However, it is widely acknowledged that national income constitutes an imperfect measure of the final output contributing to well-being and an incomplete indicator of social well-being itself. For instance, national income includes expenditures affecting social well-being in a negative way ('regrettable necessities') and also ignores or mistreats numerous components of well-being, such as, among other things, the enjoyment of a good health, of an unpolluted natural environment, of natural resources, of leisure time, of freedoms and political rights.[1] Moreover, national income does not tell us anything about the level of inequality, which is problematic, if one considers that social well-being also depends on distributive considerations.[2] Furthermore, while well-being also consists of, besides the (relatively) objective components mentioned above, subjective elements such as happiness, the evolution of social welfare or happiness over time does not seem to be well captured by usual GDP figures, as illustrated by Easterlin's (1974) Paradox.[3]

The present paper is concerned with one particular shortcoming of national income as a social well-being indicator: its neglect of changes in the length of human life. This neglect constitutes an important weakness, because a long life is a central component of human well-being. The achievement of numerous personal goals – whatever these might be – is often conditional on, among other things, a long life, so that information on the length of life should not be neglected by a social well-being indicator. The neglect of longevity may be misleading for cross-country comparisons of well-being, because large differences in longevity may exist between countries regarded as similar in the light of other indicators (see Dreze and Sen, 1989). Ignoring longevity improvements (which vary substantially across periods) may also lead to biased pictures of social well-being evolution over time (see Kakwani, 1993).

However, the need to incorporate information on longevity within national accounts statistics has often been questioned. A usual criticism consists of claiming that longevity is, *by definition*, a demographic – but non-economic – phenomenon, which national accounts statistics should not include. In my view, that argument does not hold, because of two reasons.

Firstly, that argument makes the extent to which longevity is an economic phenomenon depend ultimately on how the term 'economic' is defined. However, there is no unique definition of that term, and, in the light of some definitions, longevity may be regarded as something that belongs to the realm of economics. For instance, Pigou (1928, pp. 10-11) defined economics as the science whose subject-matter is 'economic welfare', 'economic welfare' being defined as 'the part of social welfare that can be brought directly or indirectly into relation with the measuring-rod of money'. While that definition – as Pigou himself acknowledged – provides no rigid separation between economic and non-economic welfare (see Bliss, 1993), it seems to me that, in the light of the voluminous literature on the value of a statistical life, longevity can be brought – although with some difficulties – into relation with money. Hence, according to Pigou's definitions, longevity belongs to economic welfare, so that national accounts statistics, even defined as measuring economic welfare only, should not neglect longevity. Numerous other definitions of economics would also justify the study of longevity by economists. So does the widespread definition of economics as the science studying the ability of economies to overcome the fundamental problems of scarcity (North, 1994). It is undoubtedly true that the lifetime of any human being is limited – because of various economic and non-economic reasons – and, hence, the length of life, being scarce, constitutes a natural topic for economic analysis.

Secondly, as Sen (1994) rightly argued, whatever the narrowness of the definition of 'economic' to which economists adhere, there is no obvious reason why economists should confine themselves to what a particular definition of 'economic' suggests, and neglect, in their assessment of a country's performance, the growth of other variables than GDP (e.g. longevity) that are also influenced by economic policy. Longevity is affected by economic policy and thus it should be included in the informational basis used for the assessment of economic policy. For that assessment purpose, the extra information provided by longevity statistics should have the priority on semantic conflicts on what 'economic' means.

But beyond the issue of whether longevity is an economic phenomenon, the use of longevity statistics as a social well-being indicator, or, more generally, as a part of a wider social well-being indicator, has often been criticized, and it is worth considering here several arguments, discussed by Sen (1973a, 1998), against such a use of longevity statistics. Firstly, it is often argued that using longevity as a social well-being indicator is useless, because there exists a positive relationship between the level of income per head and the length of life, so that mortality rates would tell the same story as the one told by GDP *per capita*. I shall address the double-counting criticism later in this paper, but it should be stressed that the relationship between national income and life expectancy is not as simple as it might appear at first sight, so that constructing an indicator including information on longevity is – at least in principle – justified. Secondly, it might also be argued against the use of longevity statistics that, given that changes in mortality affect the population size, one could capture those changes by using the total GDP instead of the GDP *per capita*. However, as Sen (1973a) underlined, a population might remain constant even if life expectancy at birth changes, provided birth rates evolve in such a way that the population remains unaffected, so that total GDP could not capture the actual social well-being change. Thirdly, it is also argued that life expectancy statistics are too sluggish statistics to assess a country's performance. That criticism does not stand up to empirical evidence showing large fluctuations of life expectancy statistics in situations of social instability (civil wars, famines, diseases, etc.). Moreover, as Sen (1998) rightly argued, the extent to which one considers an indicator to be sluggish depends on the normalisation that is used.[4] Fourthly, it might also be argued against the use of life expectancy in particular (and not against mortality rates) that there might be some kind of incompatibility between national accounts statistics and life expectancy statistics: while the former deals with present well-being, the latter is concerned with future well-being. However, national accounts statistics, which evaluate the part of current production that is saved and invested in order to increase future wealth, are not concerned with present well-being only. Sen (1973a) underlined – not without irony – that, while a rise in the 'expectation of life' of a piece of machinery leads to a higher national income, a rise in human life expectancy does not have the same effect. Therefore the incompatibility argument does not hold. Fifthly, the incorporation of longevity statistics is often accused of being 'arbitrary'. Nevertheless, any act of description – and thus of measurement – necessarily involves some choices (see Sen, 1980b). Excluding longevity statistics is not less arbitrary than including these.

It follows from those discussions that there seems to be, on close examination, no strong argument against the incorporation of longevity information within social well-being indicators. However, even if the necessity to use longevity statistics as a (part of a) social well-being indicator is acknowledged, there might still remain disagreements on *how* the incorporation of longevity statistics ought to be made. There exist two possible ways to proceed.[5] On the one hand, one might adjust the conventional statistics by incorporating within these the element that was neglected. On the other hand, one might introduce longevity into an index including various indicators of well-being (e.g. United Nations' Human Development Index, HDI, UNDP, 1990). Throughout this paper, I shall confine myself to the first approach.

Since the early 1960s, various methods have been developed in order to adjust national accounts statistics for changes in life expectancy. In a pioneer article, Weisbrod (1962) proposed to complement conventional income by a wider indicator, the capitalized value of expected future income *per capita*, which takes into account not only current income conditions, but also expected future income (earnings and non-earnings), current and expected employment opportunities and current and expected survival probabilities at each age (expectations being equal to current conditions). In a related way, Sen (1973a) suggested to take changes in longevity into account by estimating the lifetime expected income of a typical person, that is, by aggregating incomes over the expected human life span rather than over one year, as it is usually done. Expected lifetime income could be approximated here by multiplying current income per head by current life expectancy at birth, which could be divided by some assumed standard level of longevity in order to make interpretations more convenient. Other techniques have also been developed, for instance by Usher (1973a, 1980) and Nordhaus (1998). Those methods, which consist of adding the income or consumption-equivalent of the utility of a longer life (i.e. 'health income') to conventional income, and then computing the growth in the resulting 'adjusted' income, differ fundamentally from Weisbrod and Sen's approaches regarding their treatment of people's preferences with respect to the length of their life. Unlike Weisbrod and Sen's approaches, which do not take people's own valuations into account, Usher and Nordhaus' frameworks assign to longevity changes weights derived from empirical estimates of the value of a statistical life (VSL), which corresponds to the amount of money a group of people would be willing to pay to reduce risks of death in the expectation of saving one life (see Schelling, 1968). One might criticize the (more) 'democratic' nature of Usher and Nordhaus's VSL-based weights, on the grounds that one should not base social evaluations on the 'anarchy of individual preferences' (see Fromm, 1968). However, despite the weaknesses of VSL-based weights, it might be worth constructing a social well-being indicator using these as a complement to indicators using more arbitrary weights (e.g. HDI).

Throughout this paper, the method I shall follow, to which I shall refer as the 'Usher-Williamson-Miller' approach, is a version of Usher's (1973a, 1980) framework that was slightly modified by Williamson (1984) in order to take the double-counting criticism into account, and where the values of key parameters are selected by means of Miller's (2000) empirical rules of thumb, which express the VSL as a multiple of real GDP *per capita*.

It should be stressed here that longevity-adjusted growth rates neglect many dimensions of well-being, and thus are – as *any* well-being indicator – incomplete and imperfect. This point requires some comments. According to Sen (1973a), no perfect social well-being indicator could be ever constructed, because (1) social well-being contains subjective components on which disagreements might subsist forever; (2) well-being is a complex multi-faceted concept that could be hardly captured by a single – though composite – indicator; (3) there is a strong constraint on the availability of the data necessary for measuring the chosen concept. Moreover, besides Sen's remarks, the inquiry into a perfect indicator of social well-being *changes* over time is made even more difficult by the existence of changing preferences. If one wants an indicator to reflect people's preferences and to be meaningful (i.e. to assess the evolution of well-being in the light of some preferences taken as a reference), an impossibility might occur if preferences change over time. However, the difficulties to derive a perfect social well-being indicator – in a static and, *a fortiori*, in a dynamic context – constitute arguments for a plurality of indicators. Hence longevity-adjusted growth rates should be regarded as complements rather than substitutes to already existing social well-being indicators.

This paper is organized as follows. Theoretical foundations of the Usher-Williamson-Miller method are presented in Section 2. Growth rates adjusted for changes in longevity are then computed for Belgium over the period 1867-1997 (Section 3). Section 4 is concerned with methodological issues, and aims at assessing not only our estimates, but also adjusted figures in general, which become increasingly popular in the economic history literature.[6] Some directions are also suggested for future research. Conclusions are drawn in Section 5.

## 2: Theoretical foundations of the Usher-Williamson-Miller framework

The first part of this Section deals with the main assumptions of Usher's (1973a, 1980) model. Then, I shall present the modifications introduced by Williamson (1984) and, finally, Miller's (2000) empirical work, which plays an important role in the calibration exercise.

### *Usher's (1973a, 1980) model*

Usher's (1973a, 1980) pioneer model consists of a framework in which a representative consumer faces a complete uncertainty regarding the length of his (remaining) future life.[7] It is assumed that the representative individual's utility is a function of the utility associated to each possible *scenario* (corresponding to a different length of remaining life), and of the probabilities of occurrence of each *scenario*:

$$(1)\ U(t) = U(U_0, P_0, U_1, P_1, \ldots, U_n, P_n)$$

where $U(t)$ is the representative agent's welfare at time $t$, $U_j$ is the utility of a remaining future life of exactly $j$ years (from now), and $P_j$ is the probability of occurrence of a remaining life of exactly $j$ years. Usher assumes $n$ to be the maximum length of the representative consumer's (remaining) future life. One should notice that $U_j$, $P_j$ and $n$ depend on the representative consumer's age.

Usher's adjustment method is based on the assumption that consumers cannot affect their probabilities of survival, and thus cannot influence the probabilities of having lives of various lengths.[8] That perfect exogeneity assumption is strong, because people do actually affect their life expectancy by their consumption choices (e.g. by their decisions to drive a car). However, the opposite assumption (treating life as a good that could be purchased) would be even stronger.

Implicit in expression (1) is the exclusion of the experienced past welfare: the representative agent is assumed to be a forward-looking, but not backward-looking agent. While the exclusion of the past is a strong postulate, it can nevertheless be defended on paternalistic grounds: one may actually consider that the measurement of the welfare change between two periods should not depend on the welfare experienced in a past, distant period (e.g. the measurement of welfare change between 2002 and 2003 should be independent of the welfare during World War Two).[9]

While the assumption of a forward-looking representative agent is compatible with various functional forms for his utility function, and with various ways to form expectations regarding future consumption and future survival probabilities, the next two assumptions are more restrictive.

First, the representative agent is assumed to form his expectations regarding future consumption flows and future survival probabilities on the basis of the current consumptions flows and the current survival probabilities. In other words, it is supposed that the representative agent believes that the current age-specific consumption and age-specific survival probabilities will hold in the future. Those assumptions are strong, because there exist numerous other ways to form expectations regarding the future (e.g. one may expect some progress in longevity or some economic growth). However, those assumptions can be justified on the grounds that a measure of social welfare change over time should depend on current, actual achievements – rather than on predicted achievements – so that it makes sense to rely on current consumption and current survival probabilities.

Second, it is assumed that the representative agent, facing a situation of uncertainty regarding the length of his remaining life, behaves as an expected utility maximizer. In other words, the representative agent's welfare is supposed to be equal to the sum of the utilities associated to each possible length of (remaining) life, weighted by the probability of occurrence of each length:[10]

$$(2) \quad U(t)=\sum_{j=0}^{n} P_j(t)U_j[C_0(t),C_1(t),\ldots,C_{j-1}(t)]$$

where $U_j$, the consumer's welfare if he lives exactly $j$ (remaining) years, depends on all the consumption flows $C_i$ during the (remaining) $j$ years of life, which are all estimated by their current levels (i.e. at time $t$).[11] Expression (2) corresponds to the consumer's expected utility, where the possible lengths of (remaining) life are supposed to be mutually exclusive states of the world, and the probabilities $P_j$'s, which are also estimated at time $t$, correspond to their occurrences. One should note here that expression (2) incorporates the – somewhat restrictive – above assumption according to which expected future consumption flows and survival probabilities are assumed to be equal to their current values at $t$.

It might be worth discussing briefly the adequacy of the expected utility hypothesis in the present context. As stated in the Expected Utility Theorem, if a decision maker's preference ordering (i.e. complete and transitive) over lotteries satisfies the continuity axiom and the independence axiom, then his preferences can be represented by a function with the expected utility form.[12] While the ordinality axiom and the continuity axiom are most often accepted, the same cannot be said of the independence axiom. Since the Allais Paradox (1953), it is well-known that the independence postulate can be violated in actual behaviour, which casts some doubts on the adequacy of the independence axiom.

However, the fact that the independence axiom may not be satisfied in actual behaviour does not necessarily question the use of the expected utility hypothesis in the present context. Actually, it can be argued that adjusted growth rates should *not* measure changes in standards of living as these are valued by people in facts, but, rather, these should measure changes in standards of living as these *should* be valued by 'rational' people whose preferences satisfy the independence axiom, or can be represented by a utility function having the expected utility form. In other words, the expected utility hypothesis can be here defended on 'paternalistic' grounds. It is clear that such a defence could be attacked in the light of Hume's claim that rationality is only about means for a given end, but does not concern ends, so that preferences over lotteries violating the independence axiom cannot be regarded as 'irrational'. Whereas Humean thinkers will prefer relying on other theories of choice under uncertainty, which are more satisfactory from a descriptive point of view, such as the disappointment theory (see Mas-Colell *et al*, 1995), it does not seem to me that the measurement of social welfare changes over time can remain meaningful if made in the light of valuations governed by feelings such as disappointment. Hence, throughout this study, we shall rely on the expected utility hypothesis. But it should be stressed here that such an adherence is rooted on 'paternalistic' considerations, i.e. on an idea of how people should make their valuations.

Usher also assumes that the utility function for a given length of life is additively-separable over time. More precisely, the utility of a (remaining) life of exactly *j* years, $U_j$, is:

$$(3)\quad U_j(t)=\sum_{i=0}^{j-1}\frac{C_i^{\beta}(t)}{(1+r)^i}$$

where *r* is the subjective discount rate and *β* is the elasticity of annual utility with respect to annual consumption. Like Usher, we shall assume that the marginal utility of consumption is positive (i.e. *β* is strictly positive), but decreasing (i.e. $0 < \beta < 1$).

As it was stressed by Cowen (1989) and Broome (1991a), the assumption of additive-separability over time is a very strong one, because it neglects the possibility of welfare interconnections between different periods of someone's life. Usher justifies that restrictive assumption on the grounds of its convenience. But, alternatively, one may justify that assumption on paternalistic grounds, that is, on the grounds that welfare interconnections between different periods of life may constitute a kind of 'irrational' valuations that should not affect the measurement of social welfare changes over time. More precisely, welfare interconnections between different periods of life might lead to the 'sacrifice' of some periods for the sake of others, or for the sake of 'higher', lifetime objectives. Such 'sacrifices' might be regarded as resulting from some kind of irrationality, which should not affect the measurement of social welfare changes over time.[13]

Expression (3)'s 'paternalistic' neglect of all kinds of welfare interconnections between periods of life also rules out the particular case of habit formation, that is, the existence of preferences such that what matters is not the absolute achievement in the components of individual welfare, but the *relative* size of the achievement compared with a past reference (e.g. the best past experience). While the neglect of habit formation might be regarded as problematic in the light of empirical evidence supporting the existence of that phenomenon (see Helson, 1964; Brickman *et al*, 1978), two remarks should be made here. Firstly, there exist also substantial empirical evidence showing the *limits* of the habit formation mechanisms (see Veenhoven, 1991; Diener *et al*, 1993). Those studies underlined that *absolute* achievements also matter, whatever the achievements reached by your neighbour or the ones reached in the past.[14] Secondly, the 'paternalistic' argument mentioned above can still be used here: even if it was shown that people assess their welfare in the light of a particular standard, it would not be obvious that a measure of social welfare change should necessarily adopt the same standard as the absolute reference.

It should be stressed that expression (3) defines individual welfare in a very narrow way. For instance, it does not assign any intrinsic value to the length of life.[15] Moreover, it makes the utility of life depend on consumption only, so that non-market activities are supposed to have no effect on welfare. Furthermore, it follows from expressions (2) and (3) that Usher also assumes that the representative consumer's welfare does not depend, in any way, on the existence of other people (family, friends, etc).

Those highly debatable assumptions will be discussed in Section 4. Substituting expression (3) into expression (2) gives us the following expression:[16]

$$(4)\quad U(t)=\sum_{j=0}^{n}P_j(t)\left(\sum_{i=0}^{j-1}\frac{C_i^{\beta}(t)}{(1+r)^i}\right)=\sum_{j=0}^{n-1}\frac{C_j^{\beta}(t)S_{j+1}(t)}{(1+r)^j}$$

where $S_j(t)$ is the probability, estimated at *t*, of surviving up to year *j* in the future, defined as $S_j(t)=\prod_{i=0}^{j-1}(1-D_i(t))$, where $D_i(t)$ is the mortality rate *i* years hence (conditional on survival to the beginning of the period), estimated at time $t$.[17] Equation (4) implies that, provided $\beta$ is positive, the representative consumer is happier if his consumption in any year is increased, or if his probability of dying in any year is reduced.

Usher also supposes that consumption is constant across ages and equal to current real income:

$$(5)\quad C_0(t) = C_1(t) = \ldots = C_n(t) = Y(t)$$

Expression (5), which implies that the measurement of lifetime welfare can be made in terms of current real income, is based on Usher's assumption that real income is the maximum consumption that can be sustained indefinitely with present technology and resources. When combined with the assumption that the representative individual forms his expectations regarding the future on the basis of what currently holds, expression (5) implies that the representative agent assumes, at time $t$, that he will consume, at any future period of life, the same consumption as the one that is currently enjoyed.[18]

Substituting expression (5) within (4) allows us to rewrite the latter as:

$$(6)\quad U(t) = Y(t)^{\beta}\, L(t)$$

where $L(t) = \sum_{j=0}^{n-1} \frac{S_{j+1}(t)}{(1+r)^j}$ is the discounted life expectancy.

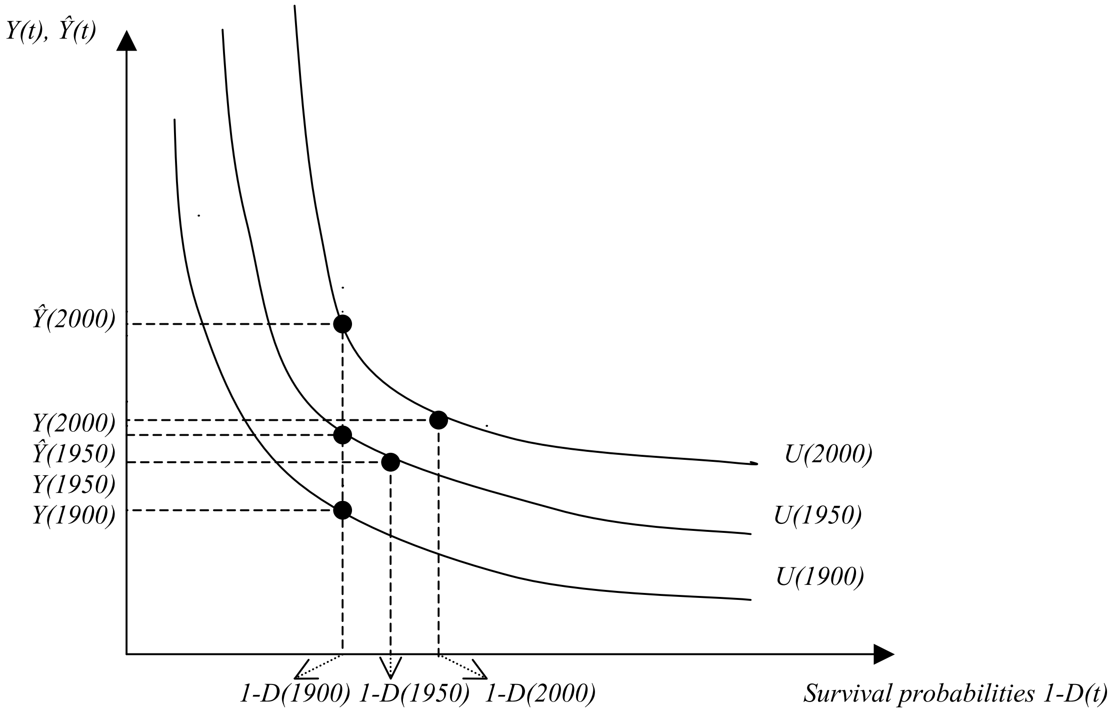
Usher defines the real income inclusive of an imputation for change in life expectancy, denoted by $\hat{Y}(t)$, as the amount such that if a representative consumer had that income in year $t$ and every year after while being subject to the mortality rates of a base year $t^*$, he would be as well off as he is currently with the consumption and mortality rates prevailing at $t$:

$$(7)\quad U(\hat{Y}(t), D(t^*)) = U(Y(t), D(t))$$

where $D(t)$ is a vector of mortality rates in year $t$, $Y(t)$ is the real income in year $t$ without the imputation for changes in longevity and $t^*$ is the base year. In order to illustrate that the longevity-adjusted income $\hat{Y}(t)$ incorporates an imputation for the variation in life expectancy between periods $t^*$ and $t$, let us consider Figure 1, which represents the indifference curves of three representative agents, living respectively in 1900, 1950 and 2000.[19] For convenience, let us suppose that each agent can only live 2 periods (i.e. $n = 2$). It is assumed that they all face probabilities $D(t)$ of dying at the beginning of the second period. Their utility functions are assumed to be the same, and their consumption is assumed to be the same in each period (so that real income $Y(t)$ and real consumption are equal). Figure 1 clearly illustrates that, for constant preferences across time, the representative individual has a higher welfare in 2000, because he enjoys at that time a much larger (unadjusted) income and a lower mortality rate (i.e. a higher survival probability) than his predecessors.

If the survival conditions of 1900 are taken as a reference (i.e. $t^* = 1900$), then the adjusted income $\hat{Y}(1950)$ corresponds to the income such that, if the representative agent living in 1950 had that adjusted income while enjoying the mortality conditions of year 1900, then he would be as well off (i.e. on the same indifference curve) as with the (unadjusted) income and the survival conditions of year 1950. In other words, $\hat{Y}(1950)$ is such that, given the assumptions made on individual welfare, it would exactly 'compensate' the representative individual of 1950 for facing the worse mortality conditions of 1900. In that sense, $\hat{Y}(1950)$ is inclusive of an imputation for changes in mortality conditions. Similarly, $\hat{Y}(2000)$ is such that the representative agent of year 2000 would be indifferent between having $\hat{Y}(2000)$ and the survival probability of year 1900 and having $Y(2000)$ and benefiting from the mortality conditions of year 2000. Figure 1 also illustrates that the adjusted growth rate differs significantly from the conventional growth rate.

Figure 1: Real income inclusive of an imputation for the change in the mortality rate



Substituting (6) in (7) and isolating $\hat{Y}(t)$ gives:

$$(8)\quad \hat{Y}(t) = Y(t)\,[L(t)/L(t^*)]^{1/\beta}$$

It is important to stress here that, *ceteris paribus*, the smaller the $\beta$ is, the larger $\hat{Y}(t)$ is. The rationale behind this statement goes as follows. The larger the $\beta$, the more 'materialistic' the representative agent is, so that a small increase in his income is sufficient to compensate the worse survival conditions faced in $t^*$. Hence, under a large $\beta$, the adjusted income $\hat{Y}(t)$ is very close to the unadjusted income $Y(t)$. Alternatively, if $\beta$ is low, the contribution of consumption to welfare is little, so that a large monetary compensation is required to make the representative agent indifferent between the two states, so that $\hat{Y}(t)$ is much larger than $Y(t)$.

In the light of expression (8), one can then derive the longevity-adjusted growth rate, denoted by $G_{\hat{Y}}$, equal to the sum of the real income growth rate $G_Y$ and the growth in discounted life expectancy $G_L$, the latter being weighted by the inverse of the elasticity of annual utility with respect to consumption:[20]

$$(9)\quad G_{\hat{Y}} = G_Y + G_L/\beta$$

It follows from expression (9) that, if $\beta$ is strictly positive, the effect of the imputation for lower mortality rates is necessarily to increase the growth rate. Provided $\beta$ is also lower than 1, the size of the correction exceeds the growth in discounted life expectancy. Moreover, a higher (lower) $\beta$ corresponds to a lower (higher) weight assigned to improvements in the expected length of life, and thus leads, *ceteris paribus*, to a smaller (larger) adjustment. Furthermore, one should note that the growth rate of the longevity-adjusted national income proposed by Sen (1973a) corresponds to a particular case of Usher's $G_{\hat{Y}}$ for which $\beta$ is assumed to be equal to unity, independently of people's preferences.

Regarding the computation of $G_L$, two important points should be stressed. Firstly, it follows from the present assumptions that people of different ages, who have different $L$, do not necessarily have the same $\hat{Y}$. If we compare the adjusted incomes of a young man of age $i$ with the one of an old man of age $j$, expression (8) tells us that, *ceteris paribus*, this is only in the case in which $L_i(t)/L_i(t^*)$ is equal to $L_j(t)/L_j(t^*)$ that the two adjusted incomes will be the same.[21] Hence, in order to derive a 'social' adjusted growth rate, Usher suggests to compute the value of $L$ of each year by weighting the discounted life expectancy of the different age groups with weights reflecting the proportions of those age groups in the population. Secondly, the fact that older people have generally a shorter (residual) life expectancy $L$ suggests that, within the present approach, an economy could become better off by the mere increase in the proportion of young people in its population. In order to avoid the influence of changes in the age distribution of the population, we shall follow Usher's intuition and compute population-weighted discounted life expectancies of each year by means of weights reflecting the age distribution of the population at a base year. Hence it follows from those two remarks that the computed $G_L$ will correspond to the growth in the population-weighted discounted life expectancy with population-weights from a base year.

### *Williamson's (1984) extension*

Turning now to Williamson's (1984) refinement of Usher's framework, it should be stressed that one of Usher's main assumptions concerns the exogeneity of longevity: changes in mortality rates are assumed to be purely exogenous and thus independent of variations in income. That assumption was criticized by Williamson, who proposed to introduce, within Usher's initial framework, the possibility of endogeneity of mortality conditions. According to Williamson, it is likely that life expectancy is significantly influenced by income growth. But, besides that empirically supported claim, Williamson also makes the stronger claim that longevity-adjusted growth rates should not reflect the total change in life expectancy, but only the change in life expectancy that is not caused by income growth (otherwise, according to Williamson, some 'double-counting' mistake would occur). It is far from straightforward to determine how relevant the *cause* of changes in survival conditions is as far as the adjustment of economic growth rates for changes in mortality conditions is concerned. But before discussing that question, let us firstly present Williamson's refinement of Usher's framework.

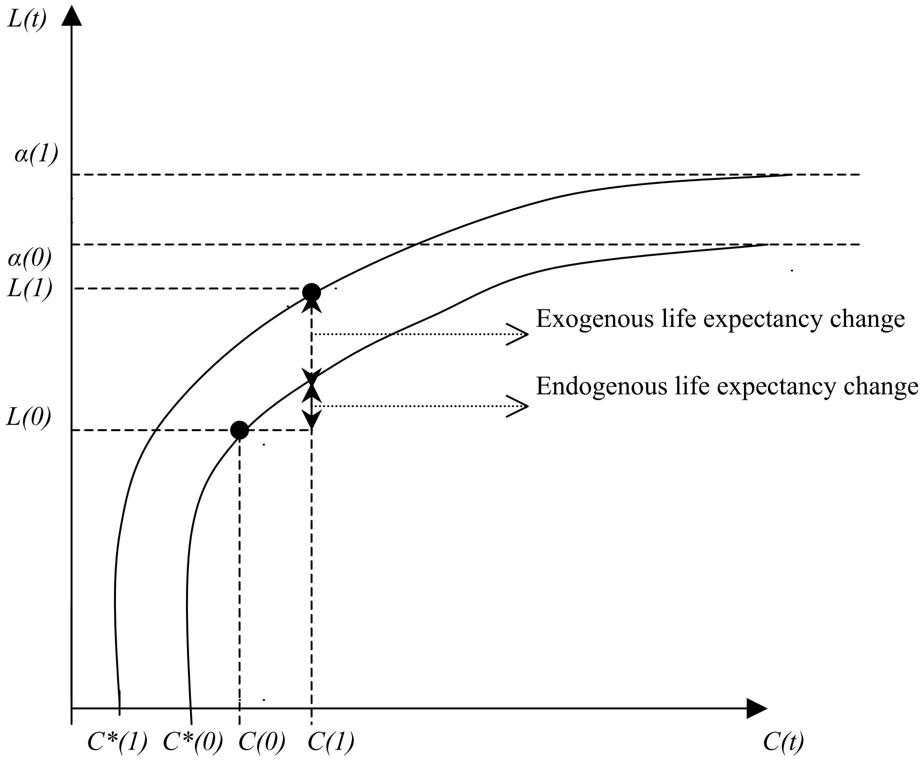
In the light of Preston's (1975) empirical work on the relationship between income growth and life expectancy, Williamson suggests to relax the perfect exogeneity assumption present in Usher's model by assuming that the discounted life expectancy is related to consumption in the following way:[22]

$$(10)\quad L(t) = \alpha(t) - \gamma / C(t)$$

where the (unobservable) variable $\alpha(t)$ corresponds to $L(t)$ in the case where life expectancy is not affected by consumption, while the constant $\gamma$ is such that $\gamma/\alpha(t)$ corresponds to the 'subsistence' consumption level $C^*(t)$ (for which $L(t) = 0$). Expression (10) suggests that the impact of consumption on longevity is positive but decreasing. In order to clarify the assumption made by Williamson, let us consider Figure 2, which shows the growth in consumption and life expectancy between periods 0 and 1. Figure 2 illustrates the distinction between, on the one hand, a change in life expectancy that is caused by consumption (or income) growth, and, on the other hand, a change in life expectancy that is caused by exogenous factors.[23] In the first case, there is a movement along the past life expectancy ‘production function’, while, in the latter case, the ‘technological’ relationship between consumption and life expectancy is affected, in the sense that there is a shift upward of the life expectancy ‘production function’.

The consumption level $C^*(0)$ corresponds to the initial subsistence level: if consumption is lower than that level, then there is no survival and thus life expectancy is zero. For consumption slightly higher than the subsistence level, the impact of a slight increase in consumption on life expectancy is substantial. Then, when consumption becomes larger, the effect of additional consumption on life expectancy diminishes, up to zero, as illustrated by the diminishing slope of the life expectancy ‘production function’. Actually, when life expectancy has reached the level $\alpha(0)$, increases in consumption can no longer affect it.

Figure 2: Endogenous and exogenous changes in life expectancy



Let us now consider an exogenous change in life expectancy. As Williamson argued, exogenous changes in life expectancy could be captured either by a change in $\alpha$ or in $\gamma$. We shall focus here only on changes in $\alpha$. Figure 2 illustrates an exogenous improvement in the ‘production’ of life expectancy, which takes the form of a shift in the curve, with an increase in $\alpha$, which becomes $\alpha(1)$. Such an increase in $\alpha$ can be regarded as the outcome of some exogenous factors. It corresponds to something like a ‘technological progress’ in the production of life expectancy by means of consumption, in the sense that, for any given level of consumption above $C^*(0)$, it is now possible to reach a higher level of life expectancy than before the shift. The shift of the curve has also the effect to reduce the consumption subsistence level from $C^*(0)$ to $C^*(1)$. The interpretation of that reduction goes as follows: the more ‘efficient’ technology allows us to be maintained alive at a lower consumption level than what was allowed under the past technology. Figure 2 allows us to decompose the growth in $L$ between periods 0 and 1 in two effects: the change in $L$ that is due to the increase of consumption for the *given* past production function corresponds to the endogenous change in $L$ (i.e. the one caused by consumption growth only, that is, by consumption growth *ceteris paribus*), while the change in $L$ that is represented by the upward shift of the curve corresponds to the exogenous change in $L$. This corresponds to the difference between the actual current life expectancy and the life expectancy that would have been achieved at the current consumption level *under* the past ‘production function’.

Having discussed the assumed relationship between consumption and life expectancy, it is now possible to highlight the difference between Usher and Williamson’s frameworks. First of all, it is important to stress that, although consumption affects life expectancy within Williamson’s model – and not in Usher’s model –, the representative agent remains in a situation of uncertainty regarding the length of his (remaining) life, except in the case in which the consumption flow is lower than the subsistence level (i.e. the case in which $P_0 = 1$). However, in most cases, future life remains a (non-trivial) ‘lottery’ with different lengths of (remaining) life, the only difference being that for any consumption level, there is a particular life expectancy determined by the consumption level, and thus particular mortality conditions. In other words, the representative agent within Williamson’s model keeps generally the most important feature of the representative agent in Usher’s model: he does not know, nor choose, the length of his future life, because only the *expected* length of his life (i.e. his life expectancy) is determined by consumption, but not his actual length of life. Hence Williamson’s additional assumption is not incompatible with the assumption of uncertainty regarding the length of remaining life, nor with the expected utility assumption made above.

According to Williamson, the adjusted income should only reflect the exogenous change in life expectancy. Hence, expression (8) becomes:

(11) $\hat{Y}(t) = Y(t)\,[\alpha(t)/\alpha(t^*)]^{1/\beta}$

Unlike $G_L$, $G_\alpha$ is not observable, but it can be rewritten, from (10), as:[24]

(12) $G_\alpha = G_L - [Y^*(0)/Y(0)]\,(G_L+G_Y)$

where $Y^*(0)$ corresponds to the income subsistence level. Hence, the longevity-adjusted growth rate, equal to $G_{\hat{Y}} = G_Y + (1/\beta)G_\alpha$, can be rewritten as:

(13) $G_{\hat{Y}} = G_Y + (1/\beta)\,G_L - [(1/\beta)\,(Y^*(t)/Y(t))\,(G_L+G_Y))]$

Expression (13) corresponds to the Usher-Williamson adjusted growth rates, where, for given values of $\beta$, $G_Y$ and $G_L$, the third term (the correction in order to avoid the double-counting) tends to decline over time, because $[Y^*(t)/Y(t)]$ usually tends to fall when $t$ increases. This suggests that the size of Usher’s overestimation of $G_{\hat{Y}}$ is larger when the development process is at its earliest stages (that is, when $Y^*(t)/Y(t)$ is higher). Expression (13) can be rewritten as:

(14) $G_{\hat{Y}} = G_Y + (1/\beta)\,z\,G_L$

where the exogeneity parameter $z$, equal to $G_\alpha / G_L$, is the (unobservable) share of (observed) changes in population-weighted discounted life expectancy that is not caused by income growth. Usher’s adjusted growth rate (9) corresponds to the special case of Williamson’s growth rate, where $z$ is assumed to be equal to one (i.e. complete exogeneity of longevity).

Let us now consider the implications from valuing, like Williamson, exogenous changes in life expectancy only. For that purpose, let us focus on two special cases. Firstly, the case in which there is a positive consumption growth between periods 0 and 1 [i.e. $C(0) < C(1)$], but no growth in life expectancy [i.e. $L(0) = L(1)$]. In such a case, Usher’s adjusted growth rate is simply equal to the consumption growth rate. However, according to Williamson, the consumption growth rate over-estimates the progress in living conditions between periods 0 and 1. Actually, under expression (10), a constant $L$ despite a positive consumption growth can only be achieved provided the life expectancy 'production function' has shifted downwards, that is, provided there has been some 'technological regression' between periods 0 and 1 as far as the production of life expectancy is concerned. Williamson regards such a regression as a negative achievement, so that the 'true' adjusted consumption growth rate should be lower than the one based on Usher's framework. In the alternative case in which there is a constant life expectancy but a negative consumption growth between periods 0 and 1, Usher's adjusted growth rate would still be equal to the consumption growth rate, while Williamson's correction, based not on the observed life expectancy, but on the maximum $L$ that can be potentially achieved for a given technological relation between consumption and life expectancy, would lead to a slightly larger (i.e. less negative) measure, because, according to Williamson, there must have been a kind of longevity 'technological' progress between periods 0 and 1 if life expectancy has remained constant despite the fall in consumption. Hence, the adjusted growth rate must take that progress into account.

It follows from those examples that Williamson's approach consists of valuing life expectancy changes not as such, but *relative* to what could have been achieved given the (assumed) past technology and the observed consumption growth. Is such a relative valuation of life expectancy changes justifiable, and, if yes, on which grounds? While one may argue that, if one is concerned with human well-being, the source of well-being should not affect the valuations (i.e. only the results count), it is nevertheless possible to argue that it may be the case that some consumption expenditures do not affect individual instantaneous utility, but only the length of life. Under that assumption, one can provide some justification to Williamson's approach in the light of the two previous examples. In the first one, in which there is some growth in consumption but not in longevity, it is possible to justify Williamson's correction on the grounds that it is true that Usher's adjusted growth rate over-estimates the 'true' growth in standards of living, because some part of the consumption growth is purely 'nominal', and does not affect welfare. In the second case, it can be argued that Usher's measure over-estimates the regression, because it forgets that some part of the consumption is not welfare-producing, but only longevity-producing.

Although intuitively attractive, that argument cannot justify Williamson's correction on *theoretical* grounds, because it suffers from the fact that it presupposes a decomposition of consumption expenditures, instead of the homogeneous consumption good postulated throughout this study. However, the above argument suggests that Williamson's correction has some intuitive appeal on *pragmatic* grounds. More precisely, Williamson's approach can be regarded, in the light if the above argument, as a pragmatic – and somewhat approximate – solution to the double-counting problem. Actually, although it is clear that some consumption goods (e.g. medical operations) bring very little (instantaneous) utility directly, but only indirectly through an increase in longevity, it is nevertheless hard to select precisely the expenditures that have that property: many medical expenditures influence not only the length of life, but also the quality of life, so that there is, in their cases, a double output (and thus Usher's imputation brings no double-counting). Hence a pragmatic solution to that problem consists of defining, at the aggregate level, a relationship between aggregate consumption and life expectancy, and then of making the adjustment only for the part of the observed change in life expectancy that is not caused by the aggregate consumption growth given the past life expectancy 'production function'. One can thus regard Williamson's correction as a 'second-best' way of solving the complex double-counting problem.

### *The calibration of preference parameters and Miller's (2000) 'rules of thumb'*

The most difficult part of the adjustment exercise consists of the choice of a value for the parameter $\beta$. For that purpose, we shall follow Usher (1973a, 1980), and derive plausible values for $\beta$ from the empirical estimates of the value of a statistical life (VSL).[25] Although we shall, throughout this study, use values of $\beta$ extrapolated from how people seem to value changes in the risk of death, it should be stressed here that there exist several other ways to extrapolate plausible values for $\beta$.

Instead of using estimates of $\beta$ from the VSL literature, one may, for instance, derive values for $\beta$ from empirical estimates of the inter-temporal elasticity of substitution, equal here to $1/(1-\beta)$. As it is shown in Browning *et al* (1999), there is no consensus among empirical studies on the estimation of that elasticity. According to Browning *et al*, it is likely that the inter-temporal elasticity of substitution is slightly above 1 for non-durable goods, so that $\beta$ should have a positive but low value. Alternatively, it is possible to extrapolate a value for $\beta$ from empirical estimates of the coefficient of relative risk aversion (CRRA), which corresponds here to $(1-\beta)$. However, as Kaplow (2003) noticed, the different empirical estimates of the CRRA are far from unanimous. In the light of that literature, it is unlikely that CRRA is lower than 1, so that $\beta$ should be close to zero.

It is crucial to emphasize, at this stage, that not only do the values of $\beta$ differ substantially among studies of the same kind, but also, and more importantly, across studies of different kinds. As Kaplow (2003) underlined, there may exist an incompatibility between the estimates of the CRRA from financial economics and the estimates of the income-elasticity of VSL, which suggest that individuals do not behave in a consistent way across markets. Such an inconsistency implies that a choice has to be made regarding the empirical source from which values of $\beta$ will be extrapolated.

Hence, in front of such incompatibilities between different empirical sources, it is worth discussing the reason why VSL estimates seem to be the most appropriate source for the present purpose. In my view, the voluminous literature on VSL empirical estimates constitutes definitely the 'best' source for the extrapolation of plausible values for the parameter $\beta$, because that literature concentrates precisely on the trade-off between longevity and consumption, which corresponds exactly to the central issue that governs the weighting exercise in the construction of longevity-adjusted income. It makes more sense, in the present context, to derive $\beta$ from the VSL revealed by people's decisions, than from how people behave on financial markets. Therefore the empirical literature on the VSL, despite its weaknesses (see *infra*), seems to be the most appropriate for the present purpose.

Let us now consider how plausible values of $\beta$ can be extrapolated from the VSL literature. As Usher argued, differentiating (4) with respect to $C_0$ and $D_t$ allows us to derive the marginal rate of substitution between a mortality rate $D_t$ and current consumption $C_0$:[26]

$$(15) \quad \frac{\partial C_0}{\partial D_t} = \frac{C_0}{\beta}\left(\sum_{j=t}^{n-1}\frac{\left(C_j/C_0\right)^{\beta}S_{j+1}}{\left(1+r\right)^{j}}\right)\frac{1}{(1-D_0)(1-D_t)}$$

where $\frac{1}{(1-D_0)(1-D_t)}$, as Usher argued, can be eliminated from expression (15) by shortening the time periods enough that the probability of dying in any period is effectively zero. Expression (15), being the MRS between a mortality rate and current consumption, also corresponds to the price ratio between these two goods. Provided the price of current consumption is fixed to unity, one might interpret expression (15) as the value or shadow price of a reduction in the mortality rate $D_t$. If we impose (5) on (15), and if we ignore $1/(1-D_0)(1-D_t)$ in (15), we obtain the shadow price of a reduction in the current mortality rates:

$$(16)\quad \frac{\partial C_0}{\partial D_0} = \frac{1}{\beta} YL$$

Expression (16), which corresponds to the MRS between mortality risk and consumption, tells us how much consumption an individual would be willing to give up, at the margin, in order to benefit from a slight reduction in the probability of death (while keeping the same welfare as before). Alternatively, (16) can be regarded as giving the minimum (maximum) amount of consumption the representative agent would be willing to accept (pay) to suffer (benefit) from a rise (reduction) in the risk of death. As such, expression (16) will serve as a basis for the derivation of appropriate values for $\beta$.

Expression (16) invites several comments. It tells us that the fall in consumption that would make the representative agent as well off as before while benefiting from a reduction in mortality depends negatively on $\beta$, and positively on $Y$ and $L$. The negative influence of $\beta$ on the representative agent's willingness-to-pay for a reduction in the risk of death is hardly surprising: if $\beta$ is high, then consumption is highly valued, so that the individual is not willing to pay a lot to benefit from a reduction in the risk of death. Alternatively, the lower the $\beta$, the less 'materialistic' the individual is, and thus the larger is the consumption the individual would accept to give up for a slight reduction in the risk of death. In a related way, the representative individual's willingness-to-accept a higher risk of death decreases with $\beta$: if consumption is highly valued, then a small increase in consumption is sufficient in itself to compensate the individual for the increase in risk of death. If $\beta$ is low, then a much larger compensation will be required for the deterioration of safety. Expression (16) also tells us that, *ceteris paribus*, a higher income leads to a higher shadow price of a reduction in mortality. Such a positive relation is actually supported by large empirical evidence, which is not surprising: as Broome (1983) underlined, a richer person would always be willing to pay more to reduce risks, because money is simply less valuable for richer people.[27] Another corollary of expression (16) is that the shadow price of lower mortality would be increasing with (discounted) life expectancy, that is, decreasing with the age. The relation between VSL and age is a complex one. As Usher (1985) argued, there are, intuitively, two effects playing in opposite directions. On the one hand, the life expectancy of a younger person is higher, so that the young has 'more to lose' than the old, and would thus be willing to pay more. This effect is captured by (16).[28] However, on the other hand, older people actually face the highest mortality rates in the society, and these high mortality rates may make them value changes in mortality to a larger extent. As shown in the models of Jones-Lee (1976), and Weinstein *et al* (1980), the willingness-to-pay for a mortality reduction increases with the initial level of risk.[29] That second effect has also some intuitive support: as Broome (1983) underlined, an older person would be willing to pay more to reduce the risk of death, because his greater nearness to death makes money less valuable for him. But given the existence of two conflicting effects, what is suggested by empirical evidence? Actually, although empirical evidence supports the general hypothesis of age-dependency of VSL, it is inconclusive regarding the sign of the dependence: while Thaler and Rosen (1976), Maclean (1979), Viscusi (1979), Smith and Desvousges (1987), Corso *et al* (2001) and Hammitt and Liu (2003) estimated a negative effect of age on VSL over the whole lifespan (i.e. a decreasing VSL with the age at all ages, which supports expression (16)), Jones-Lee *et al* (1985), Johannesson *et al* (1997), Persson *et al* (2001), Aldy and Viscusi (2003) and Kniesner *et al* (2004) estimated an inverted-U relationship between age and VSL. Hence, although all studies agree on the fact that VSL diminishes during the second period of life (roughly speaking after 40 years), whether it is slightly increasing or already decreasing in the first half of life remains unknown.[30] While it might constitute an interesting extension of the present framework to account for a change in tastes with the age (i.e. a non-constant $\beta$ over the lifetime), I tend to think that the assumption of decreasing VSL with the age, expressed in (16), seems to be, at the present day, the most plausible one. The reason for my scepticism regarding the estimated inverted-U relationships is that such estimates may reflect other effects, such as the fact that the young is less rich or is more subject to unemployment. If so, then it is not clear that adjusted growth rates should reflect such considerations. Hence we shall rely on the assumption of decreasing VSL with the age over the whole lifetime.

In the light of expression (16), it is possible, for a given shadow price of lower mortality, and for given $Y$ and $L$, to derive a plausible value for the parameter $\beta$. Expression (16) does not guarantee a positive imputation for a decrease in mortality risks. If people are risk-lovers (i.e. provided they could, people would require a positive compensation for a decrease in risk of death), then the left side of (16) becomes negative, implying a negative value for $\beta$ and a negative adjustment for an increased longevity. It would make no sense to lower growth rates for a decrease in mortality, so that I shall regard risk-loving behaviour as something irrational that should not affect longevity-adjusted growth rates.[31] This exclusion of risk-loving behaviour underlines that the weights in adjusted growth rates are not completely democratic, because some structure (here, $\beta$ strictly positive) has to be imposed on people's preferences. The general question of the adequacy of the imposed structure is a major source of criticisms against the present framework (see Section 4).

It should be stressed that the approach used in the present paper slightly differs from what Usher and Williamson suggested, on the grounds that an *interval* of plausible values for $\beta$ will be selected by means of Miller's (2000) rules of thumb, which express the VSL in an economy as a multiple of the level of real GDP *per capita* prevailing in that economy. Miller used data from 68 empirical studies (risk-wage studies, surveys and consumer behaviour studies) measuring the VSL across 13 countries in order to derive an interval of plausible values for VSL as multiples of real GDP per head. This method is especially interesting for extrapolating values of $\beta$ when no VSL empirical estimate exists, as it seems to be the case for Belgium, as far as I know. Replacing the VSL by its notation in Usher's framework (expression (16)), Miller's rules of thumb are written:

$$(17)\quad k_L Y \leq \frac{\partial C_0}{\partial D_0} \leq k_H Y$$

where $k_H$ and $k_L$ correspond to the upper bound and lower bound parameters linking the VSL to real GDP per head $Y$. Expression (17) means that plausible values for VSL belong to the interval $[k_L Y,\ k_H Y]$. Expressions (16) and (17) provide us a range of plausible values for $\beta$:

$$(18)\quad \beta_L \leq \beta \leq \beta_H \quad \text{or} \quad L/k_H \leq \beta \leq L/k_L$$

Expression (18) suggests that the choice of a value of reference for the population-weighted discounted life expectancy $L$ is crucial for choosing values of $\beta_L$ and $\beta_H$.[32] The value of $L$ that seems the most adequate is the one prevailing at the time of the empirical estimates of VSL, and for the population structure prevailing at the time of the estimation. Then, for that year, and provided some discount rate is chosen, the values of $k_H$ and $k_L$ allow us to determine the preferences parameters $\beta_L$ and $\beta_H$ prevailing at the year of the estimation of VSL (by means of (18)). Throughout this paper, I shall assume that the values of $\beta_L$ and $\beta_H$ are constant over time. That assumption might seem strong, because this neglects empirically observed adaptive preferences (see Elster, 1985). However, two points should be stressed. Firstly, making the alternative assumption of changing preferences might not be adequate when measuring welfare changes over time, because variations of preferences due to changes in economical constraints can be regarded as some kind of irrationality, which should not influence the measurement of social well-being. Secondly, assuming the constancy of the preference parameters $\beta_L$ and $\beta_H$ over time is definitely not the same as assuming constant VSL over time: our assumption, which allows some conjoint growth of VSL and income over time, is not incompatible with empirical evidence of changing VSL over time, such as Costa and Kahn's (2002) evidence of growing VSL over the second half of the 20th century in the U.S.

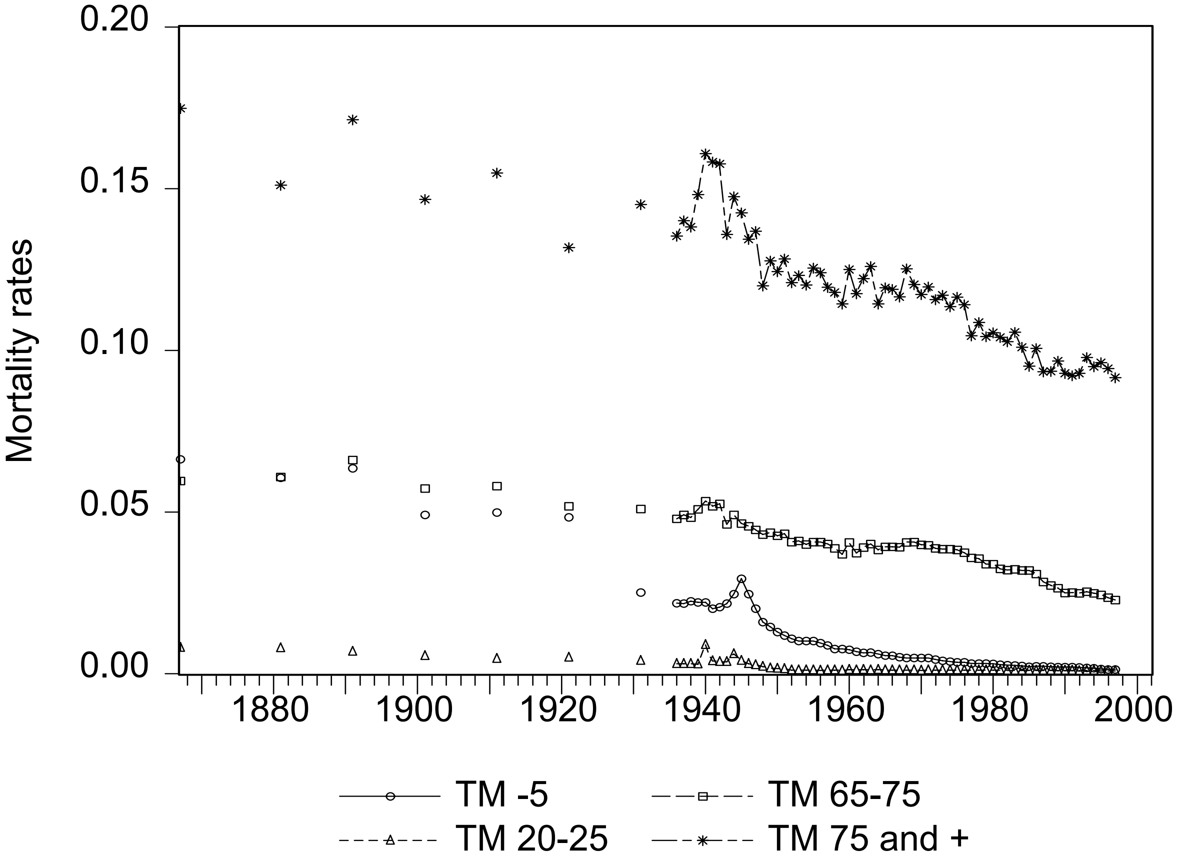
The choice of a discount rate also involves the imposition, *a priori*, of some structure on people's 'raw' preferences, and hence raises the general issue of the optimal degree of paternalism (see Broome, 1994). Although a large literature has been dedicated to the empirical study of time preferences, this is far from clear whether people's own subjective discount rates should be used in the construction of adjusted growth rates. In order to address that issue, it is important to identify firstly the channels through which the discount rate affects the Usher-Williamson-Miller framework. The discount rate has two distinct influences: (1) it enters the informational basis $L$ (population-weighted discounted life expectancy); (2) for a given VSL, $r$ determines the value of $\beta_L$ and $\beta_H$. Hence, a higher $r$ will, *ceteris paribus*, imply a lower $G_L$, but also a lower $\beta$ leading to higher weights assigned to $G_L$. Generally, the effect (2) slightly dominates (1), so that a higher discount rate usually leads to a slightly higher $G_{\hat{Y}}$. The fact that (2) dominates (1) suggests that, within our framework, the discount rate should be better interpreted not as a rate of 'pure' time preferences (like in Usher), but rather as the expression of some myopia, for which a correction is introduced.[33] Imposing that correction may appear paternalistic, so that I shall introduce a range of discount rates, each of these leading to some $\beta_L$ and $\beta_H$ derived by means of Miller's rules of thumb.

## 3: An application to Belgium: 1867-1997

This section applies the Usher-Williamson-Miller method to Belgium over the period 1867-1997. The sources of data and methodological remarks regarding the construction of the statistics are provided in the Appendix. As shown on Figure 3, mortality rates in Belgium have tended to fall over time since 1867, but with absolute changes varying across age groups. There seems to have been some convergence process working between mortality rates of extreme age groups (the highest mortality rates) and mortality rates of intermediate age groups (the lowest). For instance, while the mortality rate of people below 5 year-old was 8 times higher than the mortality rate of people between 20 and 25 year-old in 1867, that ratio, in 1997, was only a 2:1 ratio, and thus it has been divided by 4 in a period of 130 years.

As it was stressed in Section 2, the adjustment exercise requires several stages. The first stage consists of computing population-weighted discounted life expectancies for various discount rates and population structures. Discount rates are fixed to 0, 1 and 3 per cent. Reference population structures are from years 1866, 1890, 1930, 1961, 1970 and 1981.

Figure 3: Age group mortality rates (-5 years, 20-25, 65-75, 75 and +): 1867-1997



Sources: Institut National de Statistiques (Belgium).

Plausible values for $\beta$ are derived from the Miller's (2000) values of $k_L$ and $k_H$, which are respectively equal to 127 and 180 for Belgium. The value of $L$ chosen for the computation of the $\beta$'s should ideally be the value of $L$ at the year of the estimation exercise and for the discount rate $r$ assumed. As far as I know, there is no direct estimation of VSL for Belgium. Nevertheless, Miller's rules of thumb allow us to derive an interval of plausible values for VSL from empirical studies in other industrialized countries. VSL estimates from which Miller derived his rules of thumb were carried out over the period 1974-1999, so that it seems adequate to choose as a reference the average $L$ over that period. Average population-weighted discounted life expectancy (with 1981 age-structure) over the period 1974-1997 in Belgium was, for discount rates of 0, 1 and 3 per cent: 38.1, 30.1 and 20.6 years respectively. Dividing these by 180 and 127 gives the values of $\beta_L$ and $\beta_H$ in Table 1.

Table 1: Values of $r$, $\beta_L$ and $\beta_H$

| | Discount rate $r$ | | |
|---|---|---|---|
| | $r = 0.00$ | $r = 0.01$ | $r = 0.03$ |
| $\beta_L$ | 0.21 | 0.17 | 0.11 |
| $\beta_H$ | 0.30 | 0.24 | 0.16 |

Regarding the choice of the parameter *z*, Williamson (1984) argued that *z* tends to increase with the level of development. Williamson's argument is based on expression (13), where the correction for double-counting falls when *Y*(t)/Y(t)* falls. Given that the relative importance of the subsistence income is likely to fall with the level of development, it seems reasonable to deduce that *z* increases with the level of development. As far as the choice of a precise *z* is concerned, the voluminous empirical literature on the sources of longevity produced no consensus – neither for developed nor for developing countries – on the effects of income growth on longevity, so that no obvious value for *z* seems to emerge.[34] In the light of Preston's (1975) conclusion that income growth accounts for 10 to 25 per cent of growth in life expectancy, I shall choose 0.7 as the lower bound value for *z*. I shall fix *z* to 1, 0.8 and 0.7 for the 1867-1945 period and the immediate post-war period, and to slightly higher values (1.0, 0.9 and 0.8) for the post-1960 period, corresponding to a later stage of Belgium's economic expansion.

Having selected age-distributions at some base years and values for parameters *r*, *β* and *z*, it is now possible to compute Usher-Williamson-Miller adjusted growth rates. Table 2 presents adjusted growth rates over the period 1867-1945 by sub-periods, for population structures in 1866, 1890 and 1930, and for *z* equal to 1.0, 0.8 and 0.7. $G_Y$ refers to the annual average compound growth rate of real GDP per head. $G_{\hat{Y}}$ refers to the annual average compound growth rate adjusted for changes in population-weighted discounted life expectancy. For each period and for each value of the exogeneity parameter *z*, annual average compound growth rates inclusive of an imputation for changes in longevity are computed for various combinations of *r* (0, 1 and 3 per cent) and *β* (lower bound and upper bound values from Table 1). Table 2 provides for each period the minimum and the maximum adjusted growth rate and its average value (denoted by *Av* $G_{\hat{Y}}$). The bottom of Table 2 also shows the average of $G_{\hat{Y}}$ over population structures (denoted by *TAv* $G_{\hat{Y}}$) and the two bounds of the adjustment interval. However, when making interpretations, more emphasis should be laid on the adjusted figures (in bold in the table) under the population structure prevailing over the sub-period considered.

Table 2: Economic growth rates adjusted for changes in longevity (%), 1867-1945

| Periods | 1867-1881 | | | 1881-1911 | | | 1911-1921 | | | 1921-1939 | | | 1939-1945 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | z=1.0 | z=0.8 | z=0.7 | z=1.0 | z=0.8 | z=0.7 | z=1.0 | z=0.8 | z=0.7 | z=1.0 | z=0.8 | z=0.7 | z=1.0 | z=0.8 | z=0.7 |
| *Av* $G_Y$ | 1.200 | 1.200 | 1.200 | 1.008 | 1.008 | 1.008 | -0.230 | -0.230 | -0.230 | 1.315 | 1.315 | 1.315 | -2.840 | -2.840 | -2.840 |
| W1866 | | | | | | | | | | | | | | | |
| *min* $G_{\hat{Y}}$ | 1.309 | 1.287 | 1.276 | 1.831 | 1.666 | 1.584 | 1.123 | 0.852 | 0.717 | 1.872 | 1.761 | 1.705 | -3.527 | -3.389 | -3.321 |
| *max* $G_{\hat{Y}}$ | 1.421 | 1.377 | 1.354 | 2.505 | 2.206 | 2.056 | 2.021 | 1.571 | 1.346 | 2.430 | 2.207 | 2.095 | -3.095 | -3.044 | -3.019 |
| *Av* $G_{\hat{Y}}$ | **1.356** | **1.325** | **1.309** | 2.135 | 1.910 | 1.797 | 1.542 | 1.188 | 1.011 | 2.115 | 1.955 | 1.875 | -3.273 | -3.187 | -3.144 |
| W1890 | | | | | | | | | | | | | | | |
| *min* $G_{\hat{Y}}$ | 1.301 | 1.281 | 1.271 | 1.837 | 1.671 | 1.588 | 1.108 | 0.840 | 0.707 | 1.866 | 1.756 | 1.701 | -3.573 | -3.426 | -3.353 |
| *max* $G_{\hat{Y}}$ | 1.408 | 1.366 | 1.345 | 2.517 | 2.215 | 2.064 | 1.972 | 1.532 | 1.311 | 2.422 | 2.201 | 2.090 | -3.107 | -3.054 | -3.027 |
| *Av* $G_{\hat{Y}}$ | 1.346 | 1.316 | 1.302 | **2.144** | **1.917** | **1.803** | **1.514** | **1.165** | **0.991** | 2.108 | 1.950 | 1.870 | -3.299 | -3.207 | -3.161 |
| W1930 | | | | | | | | | | | | | | | |
| *min* $G_{\hat{Y}}$ | 1.283 | 1.266 | 1.258 | 1.778 | 1.624 | 1.547 | 1.169 | 0.889 | 0.749 | 1.761 | 1.671 | 1.627 | -3.146 | -3.085 | -3.054 |
| *max* $G_{\hat{Y}}$ | 1.357 | 1.325 | 1.310 | 2.421 | 2.138 | 1.997 | 2.179 | 1.697 | 1.456 | 2.192 | 2.017 | 1.929 | -2.924 | -2.907 | -2.899 |
| *Av* $G_{\hat{Y}}$ | 1.314 | 1.291 | 1.280 | 2.067 | 1.855 | 1.749 | 1.633 | 1.260 | 1.074 | **1.950** | **1.823** | **1.759** | **-3.013** | **-2.979** | **-2.961** |
| *Av* $G_Y$ | 1.200 | 1.200 | 1.200 | 1.008 | 1.008 | 1.008 | -0.230 | -0.230 | -0.230 | 1.315 | 1.315 | 1.315 | -2.840 | -2.840 | -2.840 |
| *TAv* $G_{\hat{Y}}$ | 1.339 | 1.311 | 1.297 | 2.115 | 1.894 | 1.783 | 1.563 | 1.204 | 1.025 | 2.058 | 1.909 | 1.835 | -3.195 | -3.124 | -3.089 |
| *Adjust Interval (VAbs.)* | [0.083, 0.221] | [0.066, 0.177] | [0.058, 0.154] | [0.770, 1.509] | [0.616, 1.207] | [0.539, 1.056] | [1.338, 2.409] | [1.070, 1.927] | [0.937, 1.686] | [0.446, 1.115] | [0.356, 0.892] | [0.312, 0.780] | [0.084, 0.733] | [0.07, 0.586] | [0.06, 0.513] |

Several observations can be made in the light of Table 2. Firstly, the size of the adjustments does not seem to vary a lot according to the population structure chosen for computing population-weighted discounted life expectancies, so that our results seem robust regarding the choice of population structures. Another, general remark is that, except for the period 1939-1945, adjustments are positive. Hence conventional economic growth rates may have tended to underestimate the increase in social well-being that occurred in Belgium over the period considered. Moreover, the underestimation of well-being changes seems to be non-negligible. In particular, the size of the adjustments remains significant, even when the exogeneity parameter $z$ takes its lowest value, so that the double-counting criticism is not sufficient, *per se*, to justify the absence of adjustment for changes in longevity. Furthermore, the sensitivity to the chosen VSL seems non-negligible. Another observation is that the size of the adjustments is not identical over time. Exactly as there are phases of fast or slow GDP growth, there exist periods of rapid improvements in longevity and periods of relative slowdown. Hence it is worth looking at the size of the adjustments for each sub-period.

Regarding period 1867-1881, Table 2 suggests that, if we take the age-distribution of population in 1866 as a reference, the adjusted growth rate lies between 1.3 and 1.4 per cent, according to the assumed value of $z$.[35] The unadjusted growth rate over that period being 1.2 per cent, our computations suggest that adjusted and unadjusted GDP growth rates provide relatively similar pictures of the changes in social well-being over that period. Our diagnosis differs regarding the period 1881-1911, for which the size of the adjustments lies between 0.8 and 1.2 per cent of annual growth (on average), according to the value chosen for $z$ (with 1890 weights). Hence the conventional GDP growth rate, equal to 1.0 per cent, may have underestimated the actual changes in social well-being that took place during that period. However, it should be stressed that the Usher-Williamson-Miller adjusted growth rates, as the unadjusted ones, are average measures, and thus do not tell us anything about the distribution of welfare in general – and about the distribution of improvements in longevity in particular – among the population. As I shall argue in Section 4, the ignorance of distributive aspects constitutes a serious shortcoming of longevity-adjusted growth rates. Over the period 1881-1911, although the sensitivity of the adjustments to the value of $z$ is non-negligible, there is still a non-negligible annual adjustment of 0.8 per cent when $z$ is equal to 0.7. The period 1911-1921 is a singular period, and the unavailability of annual data does not allow us to have a precise measure of the annual adjusted growth rates. I will not pay too much attention to those average figures, which certainly hide the large annual variations that took place in the middle of the decade because of World War One (1914-1918). For periods with such volatility in longevity, average figures are definitely unsatisfactory. Adjusted growth rates for the period 1921-1939 lie between 1.8 and 2 per cent (with 1930 population structure), depending on the parameter $z$. The adjustment amounts here to at least 0.5 per cent of annual growth, which is non-negligible. Hence conventional GDP growth rates may have tended to underestimate the increase in social well-being that took place during the interwar period. However, the comment I made above regarding the neglect of the distributive aspects holds here as well. The last three columns of Table 2 present annual average compound adjusted growth rates during the World War Two period. As for World War One, annual data would be definitely more adequate for such a period of high volatility in mortality.

The adjustment exercise for the second half of the 20th century (Table 3) is based on population weights from years 1930, 1961, 1970 and 1981. Parameters $\beta_L$ and $\beta_H$ keep the same values as above.[36]

Conventional economic growth rates seem to have underestimated the increase in social well-being during the period 1945-1997: while average unadjusted growth rates lie approximately between 1.8 and 4.4 per cent according to the sub-period considered, average adjusted growth rates lie approximately between 2.8 and 5.8 per cent. This implies that the average annual size of adjustment, over the entire post-war period, lies between 1 and 1.5 per cent. Those figures suggest an average annual adjustment of a substantial size, and, on average, of a much larger size than over the period 1867-1945, for which the size of the average adjustment rarely exceeded 1 per cent. Therefore the underestimation of well-being changes by usual growth rates seems to have been more serious during the second half of the 20th century. Moreover, adjustments remain substantial even for low values of $z$. Furthermore, although the sensitivity of adjusted figures to the chosen population structures is also low, the dependence on the assumed VSL remains non-negligible. It should also be stressed that, as in Table 2, the adjustment sizes largely differ across periods: these are large over the period 1945-1960, smaller over 1960-1974, and significant over 1974-1997.

Table 3: Economic growth rates adjusted for changes in longevity (%): 1945-1997

| Periods | 1945-1960 | | | 1960-1974 | | | 1974-1997 | | |
|---|---|---|---|---|---|---|---|---|---|
| | z=1.0 | z=0.8 | z=0.7 | z=1.0 | z=0.9 | z=0.8 | z=1.0 | z=0.9 | z=0.8 |
| $G_Y$ | 3.163 | 3.163 | 3.163 | 4.397 | 4.397 | 4.397 | 1.816 | 1.816 | 1.816 |
| W1930 | | | | | | | | | |
| *min* $G_{\hat{Y}}$ | 5.166 | 4.773 | 4.575 | 4.873 | 4.828 | 4.781 | 2.803 | 2.705 | 2.606 |
| *max* $G_{\hat{Y}}$ | 6.681 | 6.000 | 5.655 | 5.182 | 5.109 | 5.034 | 3.450 | 3.288 | 3.126 |
| *Av* $G_{\hat{Y}}$ | **5.856** | **5.331** | **4.986** | 5.017 | 4.958 | 4.899 | 3.106 | 2.978 | 2.850 |
| W1961 | | | | | | | | | |
| *min* $G_{\hat{Y}}$ | 5.164 | 4.771 | 4.574 | 4.878 | 4.832 | 4.785 | 2.819 | 2.719 | 2.619 |
| *max* $G_{\hat{Y}}$ | 6.665 | 5.988 | 5.646 | 5.208 | 5.132 | 5.055 | 3.536 | 3.366 | 3.195 |
| *Av* $G_{\hat{Y}}$ | 5.848 | 5.326 | 5.062 | **5.030** | **4.970** | **4.909** | 3.148 | 3.016 | 2.884 |
| W1970 | | | | | | | | | |
| *min* $G_{\hat{Y}}$ | 5.138 | 4.751 | 4.556 | 4.875 | 4.829 | 4.783 | 2.820 | 2.720 | 2.620 |
| *max* $G_{\hat{Y}}$ | 6.621 | 5.953 | 5.615 | 5.204 | 5.129 | 5.053 | 3.546 | 3.374 | 3.203 |
| *Av* $G_{\hat{Y}}$ | 5.814 | 5.299 | 5.038 | 4.932 | 4.967 | 4.907 | **3.152** | **3.020** | **2.887** |
| W1981 | | | | | | | | | |
| *min* $G_{\hat{Y}}$ | 5.109 | 4.728 | 4.536 | 4.877 | 4.831 | 4.785 | 2.827 | 2.726 | 2.625 |
| *max* $G_{\hat{Y}}$ | 6.587 | 5.927 | 5.592 | 5.209 | 5.134 | 5.057 | 3.556 | 3.384 | 3.211 |
| *Av* $G_{\hat{Y}}$ | 5.782 | 5.273 | 5.016 | 5.030 | 4.970 | 4.910 | **3.161** | **3.028** | **2.894** |
| $G_Y$ | 3.163 | 3.163 | 3.163 | 4.397 | 4.397 | 4.397 | 1.816 | 1.816 | 1.816 |
| *TAv* $G_{\hat{Y}}$ | 5.825 | 5.307 | 5.025 | 5.002 | 4.966 | 4.906 | 3.142 | 3.010 | 2.879 |
| *Adjust. Inter.* | [1.946, 3.518] | [1.565, 2.837] | [1.373, 2.492] | [0.476, 0.812] | [0.431, 0.737] | [0.384, 0.660] | [0.987, 1.740] | [0.889, 1.568] | [0.790, 1.395] |

Adjusted growth rates during the period 1945-1960 lie between 5 and 5.8 per cent (with 1930 population structure), according to the value of $z$. Although the usual growth rate is high (3.2 per cent), this leaves us with a substantial adjustment of between 1.8 and 2.6 per cent of annual growth. Longevity-adjusted growth rates suggest that the well-being changes that actually took place during that period would have been almost twice higher than measured by conventional GDP growth rates. Whatever the value of $z$, the immediate post-war recovery may have been seriously underestimated by usual measures of growth. Adjustments seem to be much smaller over the period 1960-1974: while the average annual GDP growth is 4.4 per cent, adjusted growth rates do not exceed 5.1 per cent. This constitutes a surprise, because one might expect significant improvements in longevity during that period. However, this simply reflects that progress in population-weighted discounted life expectancy was less strong during that period than over the other sub-periods. Table 3 also suggests an important qualification regarding Belgium's recent economic history. Historical studies of Belgium's post-war economic development usually emphasize that the post-war growth was especially high during the Golden Sixties period, with a strong acceleration of productivity growth, but then declined after 1974. The post-1974 period is thus often regarded as a period of relative growth crisis or economic slowdown, even though, as Cassiers, De Villé and Solar (1996) underlined, the slowdown was definitely more serious for some of Belgium's neighbours. Although Table 3 does not contradict the usual view of Belgium's economic history, adjusted growth rates tend to qualify it. These suggest that, once changes in the length of life are taken into account, the post-1974 growth slowdown seems to have been less severe, so that the growth gap between periods 1960-1974 and 1974-1997 might be less sizeable than usually measured (whatever the precise division between sub-periods). As a consequence of non-negligible adjustments over the latter period (between 1 to 1.3 per cent of annual growth, according to the value of $z$), the growth gap between periods 1960-1974 and 1974-1997, equal to 2.5 per cent in unadjusted terms, is reduced to approximately 1.9 per cent in terms of adjusted growth rates. Therefore, it seems that conventional growth measures may have led to an overestimation of the growth gap between the Golden Sixties and the post-1974 period.

## 4: Criticisms against the Usher-Williamson-Miller framework

Do adjusted figures constitute underestimates or overestimates of real changes in social well-being? As I shall discuss in this Section, there exist several good reasons to think in both directions. But before considering specific criticisms against the Usher-Williamson-Miller framework, some preliminary remarks should be made regarding the use of the – very controversial – value of a statistical life (VSL) in the present work.

### *General criticisms against the value of a statistical life (VSL)*

As it was stressed above, the size of the adjustment for longevity improvement is significantly dependent on whether the lower bound or the upper bound estimate is used for the value of a statistical life. In other words, longevity-adjusted growth rates are – not surprisingly – sensitive to the 'pricing' aspect of the adjustment exercise. The dependence of longevity-adjusted growth rates on the VSL chosen for the correction is a source of criticisms, because the concept of VSL, introduced by Schelling (1968), is controversial.[37] While the main advantage of the VSL is to allow economists to replace the compensation for death (infinite) by the compensation for an increased risk of death (finite), Broome (1978a, 1985) argued that such an indirect procedure does not make the issue of valuing a whole life disappear: if it is worth spending $x$ pounds to save a person from a chance $p$ of dying, then it is also worth spending $x/p$ pounds to save that person from a certain death. Moreover, Broome underlined that considering a statistical death – instead of the certain death of a particular person – does not make a big difference from a moral point of view. Independently of estimation issues (see *infra*), the use of VSL has also been widely criticized on other grounds. As Usher (1980) underlined, the use of a *single* VSL estimate in a normative context might be problematic, because mortality rates are private commodities, whose 'prices' may vary substantially across people according to factors such as the age, income, unionisation, culture, initial level of risk and kind of risk (see Jones-Lee, 1989; Viscusi, 2003).[38] But what is true for normative analysis also holds in the context of measurement of social welfare changes over time. Hence the present approach, which relies on the assumption of a unique 'price', may simplify the picture. Moreover, as Bailey (1968) and Viscusi (1993) underlined, the willingness-to-pay approach is a marginalist approach, so that estimated trade-off values between risks and money are pertinent only in a local range (i.e. these are 'in the neighbourhood' kind of calculations'). Hence VSL estimates should be regarded as valid 'prices' for marginal changes in longevity, but only as approximations of the true 'prices' for the valuation of larger changes in mortality conditions (e.g. the immediate post-war period).

But besides those criticisms, the empirical estimation of VSL has also been criticized on numerous grounds. I shall distinguish here between, on the one hand, general criticisms, which hold for all kinds of estimates, whatever these are derived by means of labour market studies (i.e. risk-wages trade-offs), consumer behaviour studies (i.e. purchase of safety-goods), or from the contingent valuation method (i.e. surveys), and, on the other hand, criticisms that are specific to a particular method.

A first general criticism against all VSL empirical studies is that these are (most often) based on the assumption of perfect rationality (see Viscusi, 1993). Such an assumption is very strong, especially in the context of decision-making under uncertainty, as it was shown by Jones-Lee *et al* (1995). Another problem is the one raised by the assumption of perfect knowledge and/or perfect perception of the risks. Regarding the latter assumption, it is a well-known fact that people exhibit a tendency to overestimate the occurrence of small risks and to underestimate the occurrence of large risks (see Fischoff *et al*, 1981; Jones-Lee, 1989). Individuals have also generally some difficulties to deal with small numbers, and with changes in small numbers (see Fromm, 1968; Viscusi, 1993). A main source of troubles concerns the observed gap between the willingness-to-accept (WTA) – i.e. the minimum compensation people would accept – and the willingness-to-pay (WTP) – i.e. the maximum price people would be willing to pay – for a change in risk of death of *equal* size (see Shogren *et al*, 1994). While such a gap is not specific to the good under study, the fact that people require more compensation for a slight increase in the risk of death than they would be willing to pay to benefit from an equal reduction in the mortality rate is problematic, because these should be identical in principle.[39] Another problem concerns the definition of the relevant VSL estimate: should it be the VSL estimated *ex ante* (before the determination of the risk status) or *ex post* (after that determination)? Actually, as stressed by Weinstein *et al* (1980) and Rosen (1981), the *ex ante* and *ex post* VSL estimates might vary substantially.[40]

But each method has also its own shortcomings. Labour market and consumer behaviour studies, being revealed preferences techniques, face the problem that an observed choice might result from various motivations and sets of preferences, so that the inference of preferences from observed behaviour is problematic (Sen, 1973b). For instance, the identification of the risk premium on labour market constitutes a difficult task (see Viscusi, 1992, 1993, 2003). What we face here is the general possibility of an omitted variable bias affecting the validity of the estimated VSL. For instance, several jobs have non-monetary advantages, which, if omitted, may lead to an underestimation of the 'true' 'price' of higher risks of death. Another source of difficulty lies in the fact that workers exhibit some heterogeneity in front of risks. Moreover, the assumptions of perfect knowledge and perfect perception of the risks is also questionable. Compared to risk-wage studies, for which the two components of the trade-off (wages and risks levels) can be observed, consumer behaviour studies exhibit the additional drawback that most often either the risk level or the value of the monetary component cannot be observed. The contingent valuation method also exhibits several weaknesses.[41] Firstly, there is a non-negligible sensitivity of the answers to the precise way in which the questions are asked. 'Framing effects' of various kinds exist, such as the 'starting point bias'(see Mitchell and Carson, 1989).[42] There also exist non-negligible 'embedding effects': when the WTP for a good is inferred from the WTP for a more inclusive good, then the WTP for the good in question is lower than if its WTP is estimated separately (see Kahneman and Knetsch, 1992a,b). Secondly, respondents may have incentives to misrepresent their WTP, that is, to provide deliberately false answers, leading to 'strategic bias' (i.e. attempt to influence the provision of the good or the level of individual payment for it), or 'compliance bias' (i.e. false answers to satisfy the sponsor or the interviewer). Thirdly, respondents might misunderstand the question and answer another one (see Johansson, 1995).

It follows from this that VSL empirical estimates – whatever the precise estimation procedure – are imperfect, so that these should be generally treated with extreme caution.

However, despite the numerous criticisms against the VSL, one should not exaggerate the fragility of the Usher-Williamson-Miller growth rates. Five points should be stressed here.

Firstly, one should keep in mind that the VSL is nothing else than a shadow price, whose significance, as the one of any price, is quite limited. As Usher (1980) pointed out:[43]

> '[…] by value of life, I mean nothing more than the amount one would pay per unit for a decrease in one's mortality rate in the current year. The statement that the price of life is \$200,000 in this sense does not mean that a man would sacrifice his life for \$200,000, any more than the statement that the price of butter is \$0,25 per pound means that a man would pay \$200,000 for the pleasure of consuming 400 tons of butter.'

Although it does not make Broome's critiques irrelevant, Usher's remark emphasizes that one should not regard the VSL as more than what it is, that is, as more than a price for a transaction that never takes place, no person being willing to sell his life, whatever the price.

Secondly, it seems to me that an indirect measure of the value of longevity – even if that measure is imperfect – is better than no measure at all. Hence, what criticisms suggest is not that Usher-Williamson-Miller measures should be rejected, but rather that these would definitely benefit from future progress made in the empirical estimations of VSL.

Thirdly, it should be kept in mind that the use of VSL in this paper differs from its use in the context of cost-benefit analysis, where VSL estimates have direct (future) policy implications. For our measurement purpose, a finite value has to be assigned to the length of life. Otherwise, any increase in life expectancy would have an infinite value, so that adjusted growth rates would always be infinite, making imputations for changes in life expectancy meaningless. Hence the present measurement purpose requires a finite value to be given to a change in mortality rates.

Fourthly, the relative fragility of the present framework is inherent to the use of weights that are more 'democratic' than the ones used in indicators such as the HDI, which may be regarded as somewhat arbitrary (see Dasgupta, 1993). Taking people's preferences into account raises numerous difficulties, because preferences cannot be observed easily and might be irrational. As the difficult choice of values for parameters $\beta$ and $r$ suggest, people's raw preferences cannot be taken as such as a basis for the imputation exercise, so that weights are only relatively democratic, but not absolutely democratic. This is hard to know to what extent some account should be taken of people's myopia or misinformation. However, those difficulties do not justify the rejection of preferences-based weights, but, rather, raise the complex issue of what kind of structure should be imposed *a priori* on people's raw preferences (see Broome, 1994).

Fifthly, VSL estimates might well be controversial, but the use, in the Usher-Williamson-Miller method, of a relatively large interval of VSL estimates provides – at least to some extent – some immunization against practical criticisms.

In the light of those arguments, one should not overestimate the consequences of the imperfections of VSL on the validity of VSL-based adjusted measures. However, it remains true that the concept and measurement of VSL could be improved.

### *The narrow conception of individual well-being in the Usher-Williamson-Miller framework*

A first criticism against the Usher-Williamson-Miller method is that it completely ignores the intrinsic value of longevity, i.e. the value of longevity in itself, independently of the value of any activity or consumption that is allowed by longevity. In the theoretical model, the length of life has an instrumental value only: an additional life-year is only valued to the extent that it allows the representative individual to consume more goods and services. The question raised here is whether or not that assumption is plausible.[44] But for our measurement purposes, what we need to know is the exact measure of the intrinsic value of longevity. From the answer to that question depends the size of the downward bias in the adjusted growth rates. The bias in our estimates might be non-negligible, depending on the extent to which VSL estimates already account for the intrinsic value of longevity.

Secondly, the Usher-Williamson-Miller model is based on a very restrictive conception of life, in the sense that it focuses only on the ‘materialistic’ side of life: individual’s lifetime utility is assumed to be derived from consumption only (see Linnerooth, 1979). However, a life cannot be reduced to a period of consumption: utility can be derived from non-market activities, such as, for instance, sleeping in a park or looking at a setting sun. Although (free) leisure time is an important component of welfare, the Usher-Williamson-Miller framework neglects it. For instance, adjusted growth rates cannot discriminate between having one additional year of working life or one additional year of retired life (provided consumption is identical in each case).[45] It is difficult to know the precise size of the downward bias in the estimates, bias which depends on the extent to which VSL estimates are themselves biased.[46] It might be possible to broaden the definition of individual welfare by introducing other arguments in the utility function (e.g. leisure time). However, as Mishan (1982) argued, some problems would arise when one would try to extrapolate the shadow price of lower mortality rates, because one can only estimate the non-materialistic side of life by firstly estimating the value of life by conventional methods, and then by subtracting from it the value of lifetime consumption.[47] More generally, as Nordhaus (2000) underlined, the valuation of non-market activities is one of the main challenges for future improvements of national accounts. That challenge, which involves the quality of life dimension and not the mere length aspect, goes beyond the scope of the present paper.[48]

Thirdly, as it was stressed above, a potential source of upward bias lies in the possibility of overestimating the effect of consumption and longevity on individual welfare. Actually, some empirical evidence supports the fact that welfare may be more ‘relative’, in the sense that individuals value their consumption and longevity in the light of some standards, which may correspond to what other people enjoy, or to what they enjoyed themselves in the past.[49] If this is true, then adjusted growth rates may overestimate the actual size of the welfare change. However, empirical evidence also shows that absolute achievements matter (see *supra*), so that the size of the upward bias might not be so large. Moreover, the relevancy of ‘relative’ standards for the measurement of social welfare changes over time can also be questioned: does it really matter if people are ‘stuck’ to a particular standard of reference? Although the answer to that question is not obvious, it might be worth developing an alternative, general framework accounting for habits formation, in which individual welfare would not only depend on absolute current achievements, but also on the comparison of those achievements with what was achieved in the past. There is no place here to develop such a framework, but it should be stressed that the extent to which the derived adjusted measures differ from the present one definitely depends on the precise specification of the ‘relativity’ of welfare, and on the assumptions on individual expectations (see the Appendix).

Fourthly, while the expected utility hypothesis can be defended on ‘paternalistic’ grounds (see *supra*), the Usher-Williamson-Miller framework also relies on strong assumptions regarding the precise ways in which the representative agent forms his expectations regarding future consumption flows and future survival probabilities. In particular, the present framework is based on the implicit assumption of a complete independence of valuations from the past experienced welfare. While the independence from the past can be justified on paternalistic grounds (i.e. the measurement of welfare change between two periods should be independent of the welfare associated to a period that is very distant in the past), the inclusion of expected future consumption flows and survival probabilities is more problematic, on two distinct grounds. First, those consumption flows and survival probabilities are future, that is, not yet experienced by individuals, so that one may be reluctant to make an indicator of social well-being changes dependent on non-experienced things, even in the hypothetical case in which the future would be perfectly known. Second, the future is unknown, so that one might also argue that a measure of social welfare changes should not be dependent on expectations, which might be of bad quality: should a rise in optimism be counted as a welfare gain? The previous remarks suggest that the Usher-Williamson-Miller framework might exhibit some upward bias, in the sense that the actual welfare gain might be lower than measured. However, here again, one might defend the assumptions made on paternalistic grounds: even if people do not feel better off to that extent, because, for instance, these people are myopic or risk-lovers, the adjusted growth rate suggests that people *should* value the passage from one period to the other in the precise way in which these measures value it.

Fifthly, adjusted growth rates neglect the external effects of longevity. As Fromm (1968) underlined, there exist external effects of an individual's continued existence on the lives of his familial contemporaries. However, those are neglected by the Usher-Williamson-Miller framework, which assumes that the representative consumer's welfare does not depend on the existence of other people. Such a strong assumption might have led to an underestimation of the value of lower mortality. According to Needleman (1976) and Jones-Lee (1976), one can avoid the downward bias by using in the evaluation not only a person's own willingness-to-pay for an increased safety, but also what other people (family and friends) would be willing to pay for an increased safety of that person. However, as Linnerooth (1982) underlined, adding the values assigned by others as a correction might lead to some double-counting, because in his valuation of his own life, the individual may already take others' feelings and values into account.[50] Moreover, as Bergstrom (1982) and Jones-Lee (1991, 1992) pointed out, the adequate correction depends ultimately on the precise nature of the welfare interdependencies, which can be of different kinds ('pure altruism', 'pure paternalistic altruism', 'safety-focused altruism', etc.). Furthermore, this is not clear that the downward bias is so large. For instance, Needleman (1976) concluded from his estimations of a range of 'coefficients of concern' (i.e. the ratio of the amount of money that an individual A would be willing to pay to reduce the risk of death of an individual B, over the amount he would be willing to pay for himself in the same situation) that these coefficients were equal to 1/10, in the case of parents with respect to their children, and even less in the reverse case (1/30). However, Jones-Lee (1992) suggested that accounting for the values assigned by other people would make the VSL larger of 10 to 40 %, which implies the existence of a non-negligible downward bias in our estimates due to the neglect of welfare interdependencies.[51]

### *The narrow conceptions of social well-being within the Usher-Williamson-Miller framework*

Beyond the restrictive assumptions on individual well-being, the Usher-Williamson-Miller framework also relies on strong assumptions on social well-being.

Firstly, adjusted growth rates neglect the external effects of survival not only on individual welfare, but also on the whole society and on future generations. Strictly speaking, those effects are infinite: when a young person's life is saved, the lives of his or her potential future children and grand-children are also saved (see Parfit, 1984). As Fromm (1968) and Broome (1992) underlined, prolonging a person's life and adding a new life are alternative ways of doing the same thing, so that the problems of valuing a longer life and a larger population cannot be treated separately. Broome's (1985) rejection of the willingness-to-pay approach is deduced from the conjunction of three statements: (1) current changes in mortality affect future population, (2) there is no objective reason for neglecting future people and (3) there exists no satisfactory theoretical bases for valuing population changes. Although Broome's criticism is well-founded, it should be stressed that neither the difficulties faced by population ethics nor the fact that population effects are unknown do necessarily imply a rejection of the valuation of longer lives. Moreover, the time horizon restriction, although ethically unjustified, cannot be avoided here, because of our measurement purposes.

Secondly, another important point should be stressed regarding demographic effects: the existence of interdependencies between generations. According to Arthur (1981), the effects of a decrease in age-specific mortality rates on social welfare are most often overestimated by the willingness-to-pay approach, which ignores that the prolongation of life is not costless: longer lives mean larger lifetime consumptions, and this must be financed by younger workers. Actually, the cost of ageing is ignored by the Usher-Williamson-Miller framework, which is a representative agent model that hides the social heterogeneity between workers and non-workers. More precisely, longevity-adjusted growth rates are based on the assumption that consumption will remain at its current level in the future, despite the potential ageing of the population. Such a separation between longevity conditions and the 'material' conditions is actually very strong because, in the long run, it might be the case that consumption could not remain constant without a longer working time for the members of the ageing society. Hence ignoring intergenerational interdependencies might have led to a non-negligible upward bias.

Thirdly, a strong criticism against Usher-Williamson-Miller adjusted growth rates is that these are national average measures that might hide large inequalities in income and longevity among the population. Actually, the figures presented in Section 3, being in *per capita* terms, tell us nothing about the distribution of income and longevity at the different points in time. For instance, these figures do not tell us anything about the distribution of longevity gains between different categories of workers (blue collars and white collars). Those disparities might have been substantial, so that adjusted growth rates may hide large inequalities in longevity between groups (defined by categories such as gender, location, race, socio-economic class, etc). Neglecting information on the distribution of income and longevity among the population is not desirable if one considers, like Morris (1979), that a good social well-being indicator should take into account inequalities on the spaces considered. Therefore an extension of the Usher-Williamson-Miller indicator, accounting also for changes in intra-country inequalities in income and life expectancy, is desirable. However, incorporating inequalities in longevity would raise several difficulties. Firstly, as Sen (1993) underlined, inequalities in longevity differ from inequalities in income, and thus require particular treatments: life expectancy is, by definition, an 'average' figure: no individual can have a life expectancy in the same way as that individual has some income. Moreover, intra-country and inter-country income inequalities are larger than the corresponding inequalities in life expectancy.[52] Secondly, some difficulties might arise regarding the theoretical foundations of such an inequality-sensitive measure. For instance, as Sen (1993) pointed out, this is not clear that the efficiency argument for equality could be easily transposed in the longevity space. Thirdly, data on longevity inequalities at the individual level may be unavailable. Although that difficulty may be overcome by making adequate assumptions on the relation between inequalities in income and inequalities in health (see Deaton, 1999), the relation between those inequalities is not well-known, so that serious difficulties remain regarding the availability of the data.

Fourthly, one might argue that Williamson's (1984) treatment of the double-counting issue is imperfect, and that some double-counting remains. For instance, one could argue that we should add the adjustment term for growth in life expectancy not to the real GDP per head growth, but rather to the growth in the real GDP per head *net* of inputs used in the production of longevity, because expenditures on health and education, which are already counted within national accounts, have contributed to a large extent to the growth in longevity. Nevertheless, two points should be stressed. Firstly, to the extent that the amounts of expenditures on health and education depend on income, the Williamson correction for double-counting is sufficient, because expenditures on health and education might be regarded as the channels by which income affects longevity, so an income-based correction for double-counting is roughly the same as correcting for double-counting by means of direct inputs (it might be even better if many other income-dependent inputs affect longevity). Moreover, in the realistic case where expenditures on health and education depend on income, subtracting these from the real GDP and then adding the adjustment term to the growth in the net real GDP per head would lead us to an under-counting. Secondly, a treatment of the double-counting issue based on inputs would raise many difficulties, because, as Nordhaus (1998) argued, a substantial part of inputs generate several outputs (e.g. comfort). Furthermore, as Usher (1973a) emphasized, a large number of expenditures may potentially influence life expectancy, so that trying to avoid double-counting by subtracting those expenditures would be endless. Hence the Williamson correction for double-counting remains appealing on pragmatic grounds.

### *Underestimates or overestimates?*

To summarize, it is hard to know whether the computed adjusted growth rates constitute underestimates or overestimates. Nevertheless, it seems clear that the neglects of non-market activities, welfare interdependencies, intergenerational transfers and inequalities seem to be more important than the others. Moreover, the sources of bias play in opposite directions, so that, if there is some error of estimation, as it is probably the case, then this should be of relatively limited size, because of the cancellation of the different bias. Furthermore, the relative importance of the different bias may have varied over time. For instance, inequalities in income and longevity might have risen to a larger extent in the 19th century than after World War Two (see Bourguignon and Morrisson, 2002). It follows from all this that the sign of the total bias and its net size may vary over time, because several neglected effects may dominate the others over some periods but not over other periods.

## 5: Conclusions

In conclusion, the following points should be stressed.

Firstly, the relevancy of a social well-being indicator accounting for changes in longevity cannot be overemphasized. The length of life is a central component of human well-being, which a good indicator should not ignore. Usual criticisms do not stand up to close scrutiny and thus cannot justify the neglect of longevity. Moreover, there is a need to complement existing indicators accounting for changes in life expectancy, but which are based on somewhat arbitrary weights (e.g. United Nations’ HDI).

Secondly, the Usher-Williamson-Miller method is based on strong assumptions on both individual and social welfares. Those assumptions (e.g. additive-separability at the individual level, ‘average person’ at the social level, constancy of preferences over time) should be kept in mind when looking at the computed adjusted figures. One should also notice that several postulates, such as the expected utility hypothesis, the neglect of habituation mechanisms, and the assumption of ‘neutral’ expectations (i.e. reflecting achieved progress), are not justified on empirical, descriptive grounds, but, rather, those assumptions draw their legitimacy from ‘paternalistic’ considerations, regarding how people *should* make their valuations. This suggests that Usher-Williamson-Miller adjusted growth rates correspond more to measures of how a – specifically defined – ‘rational’ representative agent should have valued changes in basic standards of living, rather than measures of how a hypothetical individual would have valued those changes.

Thirdly, the computation of adjusted growth rates for Belgium over the period 1867-1997 leads us to the following findings. (1) Growth rates adjusted for changes in longevity generally differ – at least to a non-negligible extent – from conventional real GDP growth rates. (2) The sign of the adjustment is, generally, positive, suggesting that usual growth figures might have underestimated the increase in social well-being. (3) The size of the adjustments remains substantial even when some endogeneity of longevity is allowed. (4) The size of the adjustments differs across periods. (5) Adjusted growth rates also allow us to qualify the usual version of Belgium’s post-war economic history, by suggesting that the growth gap between the Golden Sixties and the post-1974 period may have been much smaller than usually measured. (6) Our results are robust with respect to the population structures chosen as references. (7) The size of the adjustments depends to a non-negligible extent on the VSL used, justifying the use of an interval of VSL rather than a unique estimate.

Fourthly, several criticisms can be made against the Usher-Williamson-Miller approach. (1) The concept of VSL, which is used in order to determine the weights assigned to changes in longevity, can be severely criticized on theoretical and practical grounds. However, for our measurement purposes, those difficulties can be regarded as the price to pay for having a social well-being indicator based on (more) democratic weights. Moreover, its practical shortcomings can be partly overcome by using an interval of VSL. (2) The Usher-Williamson-Miller framework neglects the intrinsic value of longevity. (3) It can be accused of relying on a narrow, ‘materialistic’ conception of life. (4) It neglects the relativity of welfare judgements. (5) It relies on strong assumptions on people’s expectations. (6) It neglects the value assigned to someone’s life by other people. (7) It neglects population effects. (8) It ignores intergenerational transfers. (9) Adjusted growth rates, being average measures, may hide large inequalities on the aspects of well-being considered. In the light of those criticisms, this is hard to know whether adjusted figures constitute under- or overestimates of actual social well-being changes.

Fifthly, it seems to me that, thanks to their richer informational basis, longevity-adjusted growth rates constitute promising indicators to complement usual growth measures in the study of social well-being evolution over time. The widening of the informational basis in order to account for changes in longevity, by providing an original and more complete picture of social welfare changes, definitely generates some extra-value. However, it is undeniably true that the incorporation of longevity changes into national accounts statistics raises numerous difficult issues, so that much work remains to be done.

## 6: Appendix 1: The Usher-Williamson-Miller model

### *Derivation of expression (4)*

In order to see how expression (4) is derived, it suffices to spread the whole sum.

$$(1^*)\quad U=\sum_{j=0}^{n} P_j \left( \sum_{i=0}^{j-1} \frac{C_i^\beta}{(1+r)^i} \right)$$

$$=D_1 S_1 C_0^\beta + D_2 S_2\left(C_0^\beta + \frac{C_1^\beta}{1+r}\right) + D_3 S_3\left(C_0^\beta + \frac{C_1^\beta}{1+r} + \frac{C_2^\beta}{(1+r)^2}\right) +...+ D_n S_n\left(C_0^\beta + \frac{C_1^\beta}{1+r} +...+ \frac{C_{n-1}^\beta}{(1+r)^{n-1}}\right)$$

Expression (1*) can be rewritten as:

(2*)

$$U=C_0^\beta(D_1 S_1 + D_2 S_2 +...+ D_n S_n) + \frac{C_1^\beta}{1+r}(D_2 S_2 + D_3 S_3 +...+ D_n S_n) +...+ \frac{C_{n-2}^\beta}{(1+r)^{n-2}}(D_{n-1} S_{n-1} + D_n S_n) + \frac{C_{n-1}^\beta}{(1+r)^{n-1}}(D_n S_n)$$

The first term is equal to $C_0^\beta(1-D_0S_0)$, where $S_0=1$, so that the first term collapses to $C_0^\beta(1-D_0)$, while the second term is the product of $(C_1^\beta/1+r)$ by $(1-D_0-D_1S_1)$, which is equal to $(C_1^\beta/1+r)$ . $(1-D_0-D_1S_0(1-D_0))$, whose second factor is equal to $(1-D_0)(1-D_1S_0)$, and thus to $(1-D_0)(1-D_1)$. Moreover, given that $D_n$ is assumed to be equal to 1, the last term is multiplied by $S_n$. Hence (2*) can be rewritten as:

(3*)

$$U=C_0^\beta(1-D_0) + \frac{C_1^\beta}{1+r}(1-D_0)(1-D_1) + \frac{C_2^\beta}{(1+r)^2}(1-D_0-D_1 S_1 - D_2 S_2) +...+ \frac{C_{n-2}^\beta}{(1+r)^{n-2}}(D_{n-1} S_{n-1} + D_n S_n) + \frac{C_{n-1}^\beta}{(1+r)^{n-1}} S_n$$

$$U=C_0^\beta(1-D_0) + \frac{C_1^\beta}{1+r}(1-D_0)(1-D_1) + \frac{C_2^\beta}{(1+r)^2}(1-D_0-D_1 S_1 - D_2 S_1(1-D_1)) +...+ \frac{C_{n-2}^\beta}{(1+r)^{n-2}}(D_{n-1} S_{n-1} + S_{n-1}(1-D_{n-1}))$$

$$+\frac{C_{n-1}^\beta}{(1+r)^{n-1}} S_n$$

$$U=C_0^\beta(1-D_0) + \frac{C_1^\beta}{1+r}(1-D_0)(1-D_1) + \frac{C_2^\beta}{(1+r)^2}(1-D_0)(1-D_1)(1-D_2) +...+ \frac{C_{n-2}^\beta}{(1+r)^{n-2}} S_{n-1} + \frac{C_{n-1}^\beta}{(1+r)^{n-1}} S_n$$

In the light of the definition of a survival probability [i.e. $S_t=\prod_{j=0}^{t-1}(1-D_j)$ ], expression (3*) can be rewritten as:

$$(4^*)\quad U=C_0^\beta S_1 + \frac{C_1^\beta}{1+r} S_2 + \frac{C_2^\beta}{(1+r)^2} S_3 +...+ \frac{C_{n-2}^\beta}{(1+r)^{n-2}} S_{n-1} + \frac{C_{n-1}^\beta}{(1+r)^{n-1}} S_n = \sum_{j=0}^{n-1} \frac{C_j^\beta S_{j+1}}{(1+r)^j}$$

which corresponds to equation (4).

### *Derivation of expression (12)*[53]

Expression (10) is

(10) $\alpha(t)=L(t)+\gamma/C(t)$

Then, by differentiating with respect to time, and dividing by $\alpha$ on each side, one has:

(5*) $G_\alpha = G_L(L(t)/\alpha(t))-G_C(\gamma/\alpha(t)C(t))$.

This implies, for $t=0$,

(6*) $G_\alpha =G_L(L(0)/\alpha(0))-G_C(C^*(0)/C(0))$.

But given that $L(0)/\alpha(0)=1- (\gamma/\alpha(0)C(0))=1-(C^*(0)/C(0))$ [obtained by (10) and $\gamma=C^*(t)\ \alpha(t)$], it follows that

(7*) $G_\alpha=G_L(1-C^*(0)/C(0))-G_C(C^*(0)/C(0))=G_L-(C^*(0)/C(0))(G_L+G_C)$

which, under the assumption (5), is equal to expression (12).

*Derivation of expression (15)*[54]

The MRS between risk of death and consumption is:

$$(8^*)\ \left.\frac{\partial C_0}{\partial D_t}\right|_U=-\frac{\partial U/\partial D_t}{\partial U/\partial C_0}$$

where

$$(9^*)\ \frac{\partial U}{\partial C_0}=\sum_{j=0}^{n}\frac{\partial U}{\partial U_j}\frac{\partial U_j}{\partial C_0}=\sum_{j=0}^{n}P_j\frac{\partial U_j}{\partial C_0}$$

and $\frac{\partial U}{\partial D_t}=\sum_{j=0}^{n}\frac{\partial U}{\partial P_j}\frac{\partial P_j}{\partial D_t}=\sum_{j=t}^{n}U_j\frac{\partial P_j}{\partial D_t}$ (because $\frac{\partial P_j}{\partial D_t}=0$ *for* $j<t$ )[55]

Hence

$$\frac{\partial U}{\partial D_t}=U_t\frac{P_t}{D_t}-\sum_{j=t+1}^{n}\frac{P_j}{1-D_t}U_j$$

Given that $\frac{P_t}{D_t}-\sum_{j=t+1}^{n}\frac{P_j}{1-D_t}=S_t-S_t\left(\sum_{j=t+1}^{n}D_j\prod_{i=t+1}^{j-1}(1-D_i)\right)=0$, it implies that:[56]

$$(10^*)\ \frac{\partial U}{\partial D_t}=\sum_{j=t}^{n}\frac{P_j}{1-D_t}(U_t-U_j)$$

By substituting (9*) and (10*) into (8*), one obtains:

$$(11^*)\ \frac{\partial C_0}{\partial D_t}=\frac{\sum_{j=t}^{n}\left[P_j/(1-D_t)\right](U_j-U_t)}{\sum_{j=1}^{n}P_j(\partial U_j/\partial C_0)}$$

The numerator of (11*) can be rewritten as:

$$(12^*)\ \sum_{j=t}^{n}\frac{P_j}{1-D_t}(U_j-U_t)=\sum_{j=t}^{n}\frac{P_j}{1-D_t}\left(\sum_{i=0}^{j-1}\frac{C_i^{\beta}}{(1+r)^i}-\sum_{i=0}^{t-1}\frac{C_i^{\beta}}{(1+r)^i}\right)$$

which is equal to:[57]

$$(13^*)\ \sum_{j=t}^{n}\frac{P_j}{1-D_t}\left(\sum_{i=t}^{j-1}\frac{C_i^{\beta}}{(1+r)^i}\right)=\frac{1}{1-D_t}\sum_{j=t}^{n-1}\frac{C_i^{\beta}S_{j+1}}{(1+r)^j}$$

The denominator of (11*) becomes:

$$(14^*)\ \sum_{j=0}^{n}P_j\frac{\partial U_j}{\partial C_0}=\sum_{j=1}^{n}\beta P_j C_0^{\beta-1}=(1-D_0)\beta C_0^{\beta-1}$$

Substituting (13*) and (14*) into (11*) gives us:

$$(15^*)\ \frac{\partial C_0}{\partial D_t}=\frac{C_0}{\beta}\left(\sum_{j=t}^{n-1}\frac{(C_j/C_0)^{\beta}S_{j+1}}{(1+r)^j}\right)\frac{1}{(1-D_0)(1-D_t)}$$

which is expression (15).

## 7: Appendix 2: The Usher-Williamson-Miller framework and the relativity of welfare judgements

It is clear that the precise effect of the inclusion of some ‘relativity’ in welfare judgements on the Usher-Williamson-Miller framework depends on the particular assumptions made on individual welfare. In this Appendix, I shall only consider a basic case, in which a simple comparison with respect to the most recent past experience(s) is introduced, so that individual welfare does no longer depend on absolute achievements only, but also on a comparison with some standard taken as a reference.
Let us firstly replace expression (3) by:

$$(16^*)\ U_j = \sum_{i=0}^{j-1} \frac{[C_i(t) - \lambda C_{i-1}(t-1)]^\beta}{(1+r)^i}$$

where $\lambda$ is the parameter that synthesizes the relativity of welfare judgements. According to expression (16*), individual welfare depends not only on the absolute achievement in consumption, but also on the gap between current consumption and the consumption of the previous period. Expression (3) is a special case of (16*) in which $\lambda$ is equal to zero.
Substituting (16*) into expression (2) yields:

$$(17^*)\ U = \sum_{j=0}^{n} P_j \left( \sum_{i=0}^{j-1} \frac{[C_i(t) - \lambda C_{i-1}(t)]^\beta}{(1+r)^i} \right)$$

By decomposition of the sum, one obtains (time is here omitted for convenience):

$$\begin{aligned}(18^*) U &= \sum_{j=0}^{n} P_j \left( \sum_{i=0}^{j-1} \frac{(C_i - \lambda C_{i-1})^\beta}{(1+r)^i} \right) \\ &= D_1 S_1 (C_0 - \lambda C_{-1})^\beta + D_2 S_2 [(C_0 - \lambda C_{-1})^\beta + \frac{(C_1 - \lambda C_0)^\beta}{1+r}] + D_3 S_3 [(C_0 - \lambda C_{-1})^\beta + \frac{(C_1 - \lambda C_0)^\beta}{1+r} + \frac{(C_2 - \lambda C_1)^\beta}{(1+r)^2}] \\ &\quad + \ldots + D_n S_n [(C_0 - \lambda C_{-1})^\beta + \frac{(C_1 - \lambda C_0)^\beta}{1+r} + \ldots + \frac{(C_{n-1} - \lambda C_{n-2})^\beta}{(1+r)^{n-1}})\end{aligned}$$

Expression (18*) can be rewritten as:

(19*)

$$U = (C_0 - \lambda C_{-1})^\beta (D_1 S_1 + D_2 S_2 + \ldots + D_n S_n) + \frac{(C_1 - \lambda C_0)^\beta}{1+r} (D_2 S_2 + D_3 S_3 + \ldots + D_n S_n) + \ldots + \frac{(C_{n-1} - \lambda C_{n-2})^\beta}{(1+r)^{n-1}} (D_n S_n)$$

The second factor of the first term is equal to $(1-D_0S_0)$, where $S_0=1$, while the second factor of the second term is equal to $(1-D_0-D_1S_0(1-D_0)) = (1-D_0)(1-D_1S_0) = (1-D_0)(1-D_1)$. Moreover, given that $D_n$ is assumed to be equal to 1, the last term is multiplied by $S_n$. Hence (19*) can be rewritten as:

$$(20^*)\ U = (C_0 - \lambda C_{-1})^\beta (1 - D_0) + \frac{(C_1 - \lambda C_0)^\beta}{1+r} (1 - D_0)(1 - D_1) + \ldots + \frac{(C_{n-1} - \lambda C_{n-2})^\beta}{(1+r)^{n-1}} S_n$$

In the light of the definition of a survival probability [i.e. $S_t = \prod_{j=0}^{t-1}(1-D_j)$ ], expression (20*) can be rewritten as:

$$(21^*)\quad U=[C_0(t)-\lambda C_{-1}(t)]^{\beta} S_1(t)+\frac{[C_1(t+1)-\lambda C_0(t)]^{\beta}}{1+r} S_2(t)+\ldots+\frac{[C_{n-1}(t+n-1)-\lambda C_{n-2}(t+n-2)]^{\beta}}{(1+r)^{n-1}} S_n(t)$$

$$=\sum_{j=0}^{n-1}\frac{[C_j(t+j)-\lambda C_{j-1}(t+j-1)]^{\beta} S_{j+1}(t)}{(1+r)^j}$$

It is at this precise stage that the importance of the assumptions on how the representative agent forms his expectations appears. If one makes, as in Section 2, the assumption that the representative agent assumes that current consumption will hold forever in the future, and if one also assumes that the future consumption flow is also equal to current real income [expression (5)], then it is easy to see that, under those assumptions, the introduction of some habits formation mechanism does not affect the adjusted income at all.

Actually, under those assumptions, the adjusted income, can be defined as the income such that, if enjoyed in each period of remaining life while facing the survival conditions of a period of reference, it would make the representative agent indifferent with the situation in which he enjoys both the current income and the current survival conditions:

$$(22^*)\quad \sum_{j=0}^{n-1}\frac{[\hat{Y}(t)(1-\lambda)]^{\beta} S_{j+1}(t^*)}{(1+r)^j}=\sum_{j=0}^{n-1}\frac{[Y(t)(1-\lambda)]^{\beta} S_{j+1}(t)}{(1+r)^j}$$

In the light of expression (22*), it is easy to see that, under those assumptions, the adjusted income collapses to its form in Section 2:

$$(23^*)\quad \hat{Y}(t)=\frac{\left[\left(\frac{L(t)}{L(t^*)}\right)(Y(t)(1-\lambda))^{\beta}\right]^{1/\beta}}{(1-\lambda)}=Y(t)\left(\frac{L(t)}{L(t^*)}\right)^{1/\beta}$$

Hence, under the assumptions made in Section 2, the introduction of an habit formation assumptions does not affect the value of the adjusted income, nor its growth rate. The rationale behind that result goes as follows. Once the representative agent expects constant consumption over time, the unique effect of the habit formation mechanism is that a proportion (1- $\lambda$) of his income – instead of the totality of income – will be 'enjoyed'. But, given that the same proportion applies to the adjusted income, the value of $\lambda$ does not affect the level of the adjusted income.

Alternatively, if one relaxes the assumption of constant expected income over time, it can be seen that habituation has an ambiguous effect on the value of the adjusted income. Actually, under the assumption of non-constant expected income, expression (22*) becomes:

$$(24^*)\quad \sum_{j=0}^{n-1}\frac{(\hat{Y}(t)-\lambda\hat{Y}(t))^{\beta} S_{j+1}(t^*)}{(1+r)^j}=\sum_{j=0}^{n-1}\frac{(\hat{Y}(t)(1-\lambda))^{\beta} S_{j+1}(t^*)}{(1+r)^j}=\sum_{j=0}^{n-1}\frac{(Y(t+j)-\lambda Y(t+j-1))^{\beta} S_{j+1}(t)}{(1+r)^j}$$

From expression (24*), the adjusted income can be written as:

$$(25^*)\quad \hat{Y}(t)=\frac{\left[\sum_{j=0}^{n-1}\frac{S_{j+1}(t)(Y(t+j)-\lambda Y(t+j-1))^{\beta}}{(1+r)^{j}}(L(t^*))^{-1}\right]^{1/\beta}}{(1-\lambda)}$$

Naturally, for $\lambda$ equal to zero, expression (25*) corresponds to the definition of the adjusted income in the case of no habits formation (see *supra*).
Let us now consider the influence of the habits formation parameter $\lambda$ on the level of the adjusted income. For that purpose, let us compute the derivative of (25*) with respect to $\lambda$:

$$(26^*)\quad \frac{\partial\hat{Y}}{\partial\lambda}=\frac{\frac{1}{\beta}(\theta)^{(1/\beta)-1}\left(\sum_{j=0}^{n-1}\frac{S_{j+1}(t)\beta(Y(t+j)-\lambda Y(t+j-1))^{\beta-1}(-Y(t+j-1))}{(1+r)^{j}}(L(t^*))^{-1}\right)(1-\lambda)-[(\theta)^{1/\beta}(-1)]}{(1-\lambda)^{2}}$$

where $\theta$ refers to the big expression in brackets at the numerator of expression (25*). While the denominator of (26*) is unambiguously positive, the first term of the numerator is negative, whereas the second term of the numerator is positive, so that the sign of the derivative is unknown. It is worth discussing briefly the two effects at work. The first term of the numerator is negative, and reflects the fact that, once habituation is introduced, the welfare associated to each period is, *ceteris paribus*, lower than without habituation, so that the welfare gain from remaining alive is also lowered by the introduction of habituation. The extent to which the welfare gain from remaining alive is smaller depends not only on $\lambda$, but also on the income prevailing at the anterior period. This negative effect of $\lambda$ on the adjusted income is captured by the first term of the numerator. One should notice that, in the case in which the income at *t-1* is zero, the first, negative, effect disappears. However, there is also another effect, which plays in the opposite direction. Once habituation mechanisms work, the monetary compensation that is required to compensate the fact of facing worse survival conditions is increased, because the habituation somewhere 'weakens' the power of income in terms of welfare. That second effect is captured in the second term of the numerator of (26*). It should be stressed that, when the income at *t-1* is zero, the first effect disappears, but the second effect remains, because, in presence of habituation, a larger adjusted income is, *ceteris paribus*, required to compensate the higher mortality.

To summarize, the introduction of basic habituation mechanisms within the present approach leads various effects, depending on the assumptions made on expected future consumption. If one adheres to the assumptions made in Section 2, then the adjusted income remains unaffected by the inclusion of a standard of reference. However, if one relaxes the assumption of constant expected future income, then habituation has an effect on the adjusted income and on its growth rate, but its sign and magnitude depend on the relative importance of two effects, playing in opposite directions. Hence much work remains to be done to explore the consequences from relaxing the assumptions made in Section 2, even though, from a normative point of view, it is far from clear that the measurement of social welfare changes should be governed by feelings such as habituation, or by the optimism of expectations (see *supra*).

## 8: Appendix 3: Sources of data and methodology

Mortality rates (men and women) cover 8 ages-categories: less than 5 year-old, between 5 and 15 year-old, 15-20, 20-25, 25-45, 45-65, 65-75, and 75 year-old and above. Age group mortality rates are constructed by following the methodology proposed by the United Nations (see United Nations, 1996). It consists of dividing the number of people who died at some age during the year by the number of people of the same age at some moment in that year.[58]

$$(27^*)\ d_g(t) = n_g^{+}(t) \,/\, n_g(t)$$

where $d_g(t)$ is the mortality rate of group $g$ for year $t$; $n_g^{+}(t)$ is the number of people who belong to group $g$ who died during year $t$; $n_g(t)$ is the number of people who belong to group $g$ on the first of January of year $t$.[59]

It should be stressed that the mortality rates constructed by following the usual method constitute only approximations of the true probabilities of dying at particular ages, which are provided by the mortality tables, which unfortunately cover an unsatisfactory period for the present purposes. Annual age-specific mortality rates are constructed on the assumption that the mortality rate for any age group applies equally to all ages that belong to that age-interval. The maximum age is assumed to be 85 years. This assumption, which comes from the insufficient availability of data, is not restrictive (people above 85 year-old represented only 0.20 per cent of the population in 1866, 0.63 per cent in 1961 and 1.32 per cent in 1981).

Within the model, it was assumed that all deaths occurring in a year take place on the first day of that year. Given that it is clearly not the case in real life (i.e. the death during the last life-year can potentially take place at *all* times during that year), it follows that the life expectancy computed on the basis of the theoretical model may underestimate the 'true' life expectancy. Therefore, some correction is required to account for the fact that in real life death does not necessarily occur on the first day of the period. In order to compute the discounted life expectancy at age $j$, the following formula was used, where $d_k$ is an age-specific mortality rate from (27*) (see Usher, 1980, p. 257):

$$(28^*)\ L_j = \sum_{i=j}^{n-1} \frac{\prod_{k=j}^{i-1}(1-d_k)[1-(d_i/2)]}{(1+r)^{i-j}}$$

The numerator of expression (28*) is the sum of the probability of a man of age $j$ completing at least $i$-$j$ years of life [i.e. $\prod_{k=j}^{i}(1-d_k)$ ] and half the probability of his dying $i$-$j$ years from now [i.e. $\prod_{k=j}^{i-1}(1-d_k)d_i/2$ ] . Hence, expression (28*) accounts for the fact that a man who will die $i$ years from now has an expectation of staying alive for half of that year (and not zero year as assumed in the model).

The population-weighted discounted life expectancy is then obtained from computing the weighted sum of the age-specific discounted life expectancies, by means of weights representing the proportion of each age-groups at some base years:[60]

$$(29^*)\ L(t) = \sum_{j=0}^{n-1} \frac{n_j(t^*)}{n(t^*)} L_j(t)$$

where $n_j(t^*)$ is the number of people of age $j$ at the base year $t^*$, while $n(t^*)$ is the total population at that base year.

Regarding the economic growth rates on which our adjustment exercise is based, these are computed from Angus Maddison's historical data sets. Our real GDP per head series was obtained by dividing the real GDP levels in 1990 Geary-Khamis dollars (see Maddison, 1995, table C-16a, pp. 180-181, for the period before 1960, and, for after 1960, the database OECDG03 from Maddison's website at the Groningen Growth and Development Centre (http://www.eco.rug.nl/ggdc)) by our own population figures for Belgium, in order to have a perfect correspondence between the population figures used for the computation of real GDP per head and the population figures used in the computation of mortality rates and population-weighted discounted life expectancies.[61] The post-1960 real GDP levels, which correspond to revised estimates of real GDP satisfying the 1993 SNA (Standardized system of National Accounts), account for substantial expenditures on computer software since the 1980s.[62] Nevertheless, there is no incompatibility between the two resulting sets of growth rates, because there is (almost) no difference between the two series and their growth rates during the 1950s and the 1960s; it is only after 1970 that statistically significant differences appear (even if the differences remain lower than 0.3 per cent of annual growth until 1980).

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**Notes**

[1] On various weaknesses of national accounts statistics, see Beckerman (1968), Nordhaus and Tobin (1972), Sen (1973a), Eisner (1988), Nordhaus (1994, 2000) and Dasgupta (2001).

[2] See Hicks (1940), Beckerman (1980) and Klasen (1994).

[3] On the causes of Easterlin's Paradox, see Abramovitz (1979). For an illustration in the U.S. and the U.K. (during the last 30 years), see Blanchflower and Oswald (2000).

[4] As Sen (1998) pointed out, if one considers the speed of convergence between poor and rich countries, life expectancy shows most often a quicker convergence than GDP per head.

[5] See Beckerman (1968). Under each option, the aggregation may cause a loss of information: keeping separate indicators may provide a more detailed view. Hence, composite indicators should be regarded as complements rather than substitutes to single-variable indicators.

[6] See Costa and Steckel (1997), Sandberg and Steckel (1997), Crafts (1997a, 2002), and Nordhaus (1998).

[7] The next pages are based on Usher (1973a, pp. 197-208) and (1980, pp. 233-243).

[8] See Conley (1976) for a model where survival probabilities are behavioural variables.

[9] For a general framework in which in which both the past, present and future welfare are taken into account, see Ponthiere (2004).

[10] One should notice here that expression (2), having the expected utility form, is unique up to a strictly positive affine transformation.

[11] Usher's (discrete) framework also relies on the assumption that the whole risk of dying is concentrated on the first day of any period, that is, on one's birthday.

[12] See Mas-Colell *et al* (1995) and Hammond (1998) on the expected utility hypothesis.

[13] Let us consider the particular case where the representative individual's preferences are such that what the individual would like to avoid, above everything, is a fall in his consumption profile over time. His utility function, in a two-period model, may be given, for instance, by $U(c_1, c_2) = c_1 + c_2 - \mu(c_1-c_2)$. Let us make the assumption of an extreme 'relativity' of welfare (e.g. $\mu$=100). With such preferences, the representative agent would strictly prefer the consumption vector (50, 50) to the vector (100, 99), which can be regarded as clearly irrational: at any period the consumption under (100, 99) exceeds substantially the consumption under (50, 50). The priority given to the avoidance of a fall in consumption profile seems to be some kind of irrationality that should not affect the measurement of changes in welfare. Hence, even though empirical evidence supports the relativity hypothesis, that is, a strictly positive $\mu$ (see Michalos, 1980), it is questionable, from the point of view of the measurement of social welfare changes over time, that a positive $\mu$ should be taken into account. The present framework can thus be regarded as imposing, in a 'paternalistic' way, the postulate that $\mu$ should be regarded as equal to zero.

[14] Given that the present model is based on the assumption of no inequality in consumption, I shall not investigate here the other 'relativity' assumption, that is, the relativity with respect to what *other* people achieve.

[15] In other words, it is assumed that the utility of a life-year with zero consumption is zero.

[16] See the Appendix for the derivation.

[17] One should notice that it is always possible to replace the probability of survival up to $j$, $S_j$, by $S_{j-1}(1-D_{j-1})$ [i.e. the product of the survival probability up to $j-1$ by the probability of surviving the period $j-1$]. One should also notice that the sum of the $P_j$ for $j$ going from 0 to $n$ is equal to 1. Actually, $\sum_{j=0}^{n} P_j = \sum_{j=0}^{n} D_j S_j = D_n S_n + \sum_{j=0}^{n-1} D_j S_j = S_{n-1} - D_{n-1} S_{n-1} + \sum_{j=0}^{n-1} D_j S_j = S_{n-1} + \sum_{j=0}^{n-2} D_j S_j = S_{n-2} + \sum_{j=0}^{n-3} D_j S_j = S_1 + D_0 S_0 = S_0 = 1$ (see Usher, 1980, footnote 7).

[18] Actually, expression (5) differs from an assumption of habit formation. In the latter case, well-being in $t+1$ would be assessed relatively to what prevailed in the past (e.g. in period $t$), while, in the present framework, well-being in $t+1$ will depend on $C_{i+1}(t+1)$, that is, on the absolute consumption achieved in period $t+1$, independently of what was achieved in $t$, and of what was expected, at $t$, to be achieved in $t+1$. Hence there is no relativity of welfare judgements in the present framework, where the well-being of a period is always assessed in the light of what is currently achieved – and not of what was achieved or previously expected to be achieved.

[19] Figure 1 is based on Usher (1980, Figure 11.4 p. 240).

[20] One should notice here that the adjusted income – and thus its growth rate – is invariant to any strictly positive affine transformation of the representative agent's expected utility function.

[21] For instance, when there is a complete *statu quo*, $L_i(t)/L_i(t^*)=L_j(t)/L_j(t^*)=1$, so that the adjusted incomes for individuals $i$ and $j$ are all equal to $Y(t)$.

[22] The rest of this Section is based on Williamson (1984), pp. 162-163, equations (8) and (9).

[23] See Williamson (1984), Figure 2, p. 164.

[24] See the Appendix for the derivation.

[25] The VSL corresponds, for instance, to the amount of money a group of 10,000 people would be willing to pay to reduce the mortality rate from 0.0010 to 0.0009.

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[26] The reference to time is here omitted for convenience. See the Appendix for the derivation.

[27] For empirical evidence, see Jones-Lee *et al* (1985), Viscusi and Evans (1990), and Miller (2000).

[28] One should notice here that, in the general case in which the assumption (5) of constant consumption across ages is not made, it might be the case, as Kniesner *et al* (2004) showed, that the old has 'more to loose' than the young, because of a life-cycle planning deferring consumption to the old age (e.g. if the old has much larger consumption, his VSL may exceed the one of the young, despite the lower life expectancy of the old).

[29] That hypothesis is supported by empirical evidence: see Marin and Psacharopoulos (1982). However, Smith and Desvousges (1987) found the inverse relationship: willingness-to-pay for a given reduction in risks would tend to fall with the level of base risk.

[30] On the age-dependency of VSL, see also Aldy and Viscusi (2003), and Kniesner *et al* (2004).

[31] It should be stressed that there is no consensus on whether preferences can be irrational. See Broome (1993b) for a discussion on the possibility of irrational preferences.

[32] It should be stressed that what $L$ accounts for is not life expectancy at birth. The VSL is not the value of the life of a newborn person, but the value of a statistical life in the economy considered. Hence the relevant concept is the *population-weighted* life expectancy (i.e. the weighted sum of life expectancies at all ages, with weights reflecting the statistical proportions of all age groups within the economy).

[33] If $r$ is interpreted as representing people's 'pure' time preferences, then a higher $r$ should lead to lower adjustments. In our framework, a higher $r$ leads to larger adjustments, so that the discount rate is better interpreted here as a correction that is introduced against people's myopia (leading to an underestimation of the value of longevity improvements).

[34] See, for instance, Auster, Leveson and Sarachek (1969), Preston (1975, 1980), Anand and Ravallion (1993), Pritchett and Summers (1996) and Easterlin (1999).

[35] Note that average compound GDP growth rate over the period 1870-1881 is used as an approximation of the period 1867-1881.

[36] Unadjusted and adjusted average growth rates in Table 3 are obtained by taking the geometric average of one *plus* the annual growth rate, *minus* one, over the periods considered. The resulting average growth rates correspond to the annual average compound growth rates over the periods considered. See Kakwani (1997) for a general discussion on the computation of average growth rates out of annual growth rates.

[37] See Jones-Lee (1976, 1982) and Broome (1978a, 1985).

[38] On the dependence on income, age and level of risks, see the references above. Regarding unionisation, Olson (1981) found a positive effect, while Marin and Psacharopoulos (1982) and Arabsheibani and Marin (2000) found no effect (see Viscusi, 2003). On the influence of cultural factors on VSL, see Hersch and Viscusi (1990), who showed that, independently of differences in education and unionisation, cigarette smokers and seatbelt non-wearers receive lower compensations for riskier jobs, leading to a lower VSL. On the dependence to the kind of risk, see Johansson (1995).

[39] Actually, Hanemann (1991) argued that the divergence between the willingness-to-pay and the willingness-to-accept can only disappear with full information and repeated exposure to the market if the good in question has a very close substitute, so that the substitution with that good is high. Given that this is not the case for risk of death (see Shogren *et al*, 1994), the divergence between WTA and WTP is likely to persist in the field under study, which raises the question of the right VSL estimate to be chosen.

[40] For instance, the value of a reduction in mortality from 0.2 to 0.1 conditional on a heart attack might be higher than the value of a mortality reduction from 0.02 to 0.01 with a probability of heart attack of 0.1.

[41] See the detailed studies by Mitchell and Carson (1989) and Johansson (1995). For a critical assessment of willingness-to-pay surveys on health issues over the period 1985-1998, see Olsen and Smith (2001).

[42] In particular, as Fuchs and Zeckhauser (1987) underlined, respondents to hypothetical questions on health trade-offs seem to be risk averse with respect to gains but risk preferring with respect to losses.

[43] See Usher (1980), p. 229.

[44] Within the utilitarian tradition, that issue is discussed by Cowen (1989) and Ng (1989b).

[45] As Professor Pestieau pointed out to me, adjusted growth rates regard as equal two countries with the same growth in income and longevity, even if, for instance, people in one country, thanks to an earlier retirement age, benefit to a larger extent from longevity gains.

[46] As Viscusi (1993) underlined, the bias in VSL estimates may be non-negligible, for instance in wage-risks studies ignoring non-materialistic motivations (e.g. social prestige).

[47] For instance, estimating the value of the social prestige associated to a job requires to know the – much higher – extra-wage one would require to accept the same job *without* the social prestige. However, most often the same job without the social prestige does not exist.

[48] On leisure time, see Nordhaus and Tobin (1972), Usher (1973b), Beckerman (1980) and Zolotas (1981).

[49] See Parducci (1968), Michalos (1980), Smith *et al* (1989) and Tversky and Griffin (1991).

[50] Broome (1978b) made a similar remark in a discussion on the choice-preference relation.

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[51] This is also confirmed by the large monetary equivalent to the death of a husband or wife in Blanchflower and Oswald (2000).

[52] It should be stressed that this may or may not be the case if inequalities are measured in terms of the time-distance necessary to reach some level of reference (see Sicherl, 1980).

[53] See Williamson (1984), footnote 15.

[54] See Usher (1980), footnotes 11 and 12.

[55] For instance, the probability of death in 25 years does not affect the probability of a remaining life exactly 10 years.

[56] Actually, the expression in the large brackets is equal to 1. The reason for that is simply that each product corresponds to the probability of survival up to age $j$ while being of age $t+1$. Each of those product is multiplied by the corresponding probability of death at age $j$, so that each term of the sum corresponds to the probability of a remaining life of exactly $j-(t+1)$ years. But the summation takes place over the whole range of potential lengths of remaining life (i.e. from 0 to $n-(t+1)$), so that that sum, which covers all possible remaining lengths of life, must be equal to 1.

[57] By an argument similar to the one underlying the derivation of expression (4) above.

[58] Sources: various publications of the Belgian *Institut National de Statistiques*: *Annuaire Statistique de la Belgique* (1871-1995), *Annuaire Statistique de la Belgique et du Congo Belge* (1912-1959), and *Statistiques Demographiques* (1996-2002).

[59] Sources: $n_g^+(t)$ and $n_g(t)$ are from publications of the Belgian *Institut National de Statistiques*: several volumes of the *Annuaire Statistique de la Belgique* (volume 2 (1871)- volume 113 (1995)) and the *Annuaire Statistique de la Belgique et du Congo Belge* (1912-1959).

[60] Sources: *Annuaire Statistique de la Belgique et du Congo Belge*, volume 44, (1913) and *Annuaire Statistique de la Belgique*, volume 113, (1995).

[61] Sources: *Annuaire Statistique de la Belgique* (volume 2 (1871) – volume 113 (1995)), the *Annuaire Statistique de la Belgique et du Congo Belge* (1912-1959), and the *Statistiques Demographiques* (years 1996-2002). Unlike Maddison (1995), I did not raise the 1820-1924 population figures by 0.8 per cent (in order to include Eupen and Malmedy acquired in 1925), because I wanted the population figures to correspond exactly to the figures used for the computation of mortality rates and population-weighted discounted life expectancies.

[62] In the 1993 SNA, expenditure on mineral exploration and computer software are now treated as investments rather than intermediate inputs (see Maddison 2001, p. 189).