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Beyond GDP: Is there a law of one shadow price?

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BEYOND GDP:

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ABSTRACT

This paper builds a welfare measure encompassing household disposable income, unemployment and longevity, while using two different sets of "shadow prices" for non-income variables. The valuations of vital and unemployment risks estimated from life satisfaction data ("subjective shadow prices") and those derived from model-based approaches and calibrated utility functions ("model-based shadow prices") are shown to be broadly consistent once a number of conditions are fulfilled. Subjective shadow prices appear to be inflated by the downward bias on the income variable in life satisfaction regressions conducted at the individual level, while the latter bias is largely removed when running regressions at the country level. On the other hand, model-based shadow prices are typically underestimated as: i) the valuation of the unemployment risk is assumed to take place under the veil of ignorance (i.e. for a representative agent that has no information on her current or future unemployment situation); ii) the standard model relies on a Constant Relative Risk Aversion (CRRA) utility function, which has no specific relative risk aversion parameter for unemployment and vital risks; iii) the Value of Statistical Life that is used in standard calibration pertains to the adult lifespan while life expectancy at birth covers the entire lifetime.

RÉSUMÉ

Les auteurs proposent une mesure du bien-être fondée sur le revenu disponible des ménages, le chômage et la longévité ainsi que sur deux ensembles de « prix implicites » de composantes non monétaires. Ils montrent que les valeurs attribuées au risque pour la vie et au risque de chômage, qui sont calculées à partir de données relatives à la satisfaction à l'égard de la vie (« prix implicites subjectifs ») ou découlent de l'application d'approches par modélisation et de fonctions d'utilité calibrées (« prix implicites obtenus par modélisation »), sont globalement cohérentes dès lors qu'un certain nombre de conditions sont réunies. Il apparaît que les prix implicites subjectifs sont surestimés en raison des erreurs de mesure affectant la variable revenu dans les régressions de la satisfaction à l'égard de la vie effectuées au niveau individuel, tandis que ce même biais est largement réduit dans les régressions effectuées au niveau des pays. À l'inverse, les prix implicites obtenus par modélisation sont généralement sous-estimés quand : i) on suppose que la valeur du risque de chômage est calculée « sous le voile de l'ignorance » (c'est-à-dire pour un agent représentatif qui ne possède aucune information quant à sa situation d'inactivité actuelle ou future) ; ii) le modèle type repose sur une fonction d'utilité à aversion relative au risque constante (CRRA), dans laquelle aucun des paramètres de l'aversion relative au risque ne concerne le risque pour la vie ou le risque de chômage ; iii) on utilise pour le paramétrage la valeur d'une vie statistique, laquelle correspond à la durée de la vie adulte tandis que l'espérance de vie à la naissance couvre toute la durée de la vie.

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1. INTRODUCTION

1. In the past few years the quest for measures of welfare alternative to GDP has become topical in many countries and in many circles (OECD 2011). Many of these approaches put forward dashboards of indicators (e.g. the one used in the OECD report *How's Life?*) that capture various elements of people's well-being (e.g. education, environment, social connections, etc.). Dashboards can be useful from the perspective of evaluating the basic components of welfare evolution but are challenging to read and interpret especially when they include many indicators. In addition, dashboards cannot be readily used for the purpose of evaluating the net impact of policies on overall welfare as they do not make any explicit assumption on the relative importance of their components (or just assume that these components cannot be traded-off with each other). Aggregate measures of welfare can address the latter limitation by setting weights to the welfare dimensions considered. Our paper looks at one approach of the latter kind that the literature sees as promising for its many good theoretical properties: the money-metric approach or income equivalent (Samulson, 1956, 1961, 1974, Fleurbaey 2009, Fleurbaey and Blanchet, 2013).

2. The main challenge of the money-metric approach is to find a credible valuation of non-material goods in a common money metric. Once the "shadow prices" of welfare determinants such as health, access to jobs, environment or personal security have been determined (see OECD, 2013a, for a review of those dimensions), it is then straightforward to construct an aggregate welfare measure. However, assessing credible shadow prices is a major difficulty that has not been overcome yet. In particular, there appears to be a drift between model-based approaches such as Becker et al. (2005) or Gaulier and Fleurbaey (2009) and economic studies that use life satisfaction or happiness data to infer the shadow prices of non-material components. As an example, Gaulier and Fleurbaey find that suppressing the risk of unemployment among OECD countries would be worth about 1% of national GDP per capita (Gaulier and Fleurbaey, 2009, Table 4); in contrast, the subjective cost of being personally unemployed represents an enormous proportion of individual income in life satisfaction studies (e.g. 95% of individual income in Boarini et al., 2012, as derived from Table 3 column 3; see also Clarck and Oswald, 1994, Frey and Stutzer, 2000).[2]

3. This paper aims to reconcile the existing evidence on the shadow prices of two particular risks, namely the mortality and unemployment risks, across the two latter strands of the well-being literature. We compare the "subjective shadow prices" of vital and unemployment risks assessed from life satisfaction data to those derived from a model-based approach, where a calibrated utility function is used to calculate "model-based shadow prices". The two sets of shadow prices are shown to be largely consistent providing that a number of conditions are fulfilled.

4. In calculations of both model-based and subjective shadow prices (in what follows referred as "model-based and subjective approaches") the valuation of non-material goods is defined as the variation in income that compensates for the change in those goods (see Fleurbaey and Blanchet, 2013, Gaulier and Fleurbaey, 2009). However, the model-based and subjective approaches differ in the way they calculate compensating differentials in practice. The model-based approach postulates a particular utility function and then estimates some of its parameters on existing empirical evidence. For instance, Becker et al. (2005) select the Constant Relative Risk Aversion (henceforth CRRA) utility function with intercept also used in Murphy and Topel (2005) and Hall and Jones (2007), and calibrate its intercept using estimates of the

[2] From Boarini et al. (2012) Table 9 Column 1, one similarly finds that setting the country unemployment rate to zero is equivalent to a 90% cut in individual income. Di Tella et al. (2001), Stutzer and Lalive (2004) analyse the effect of general unemployment on life satisfaction and also find a considerable loss, but they do not include individual income in their micro-level regressions.

Value of a Statistical Life (Viscusi and Aldy, 2003). We label this procedure as the "*model-based approach*",[3] in the sense that it is based on a particular model of people's utility.

5. In the second approach, indirect utility is proxied by self-reported life satisfaction (or any other measure of happiness), as available from surveys. In practice, an econometric model of life satisfaction is estimated, and the subjective shadow prices of unemployment and longevity are computed as the ratio between their elasticity and the income elasticity. In other words, subjective shadow prices are the monetary amount that would increase life satisfaction as much as one percentage point reduction in unemployment or a one-year increase in longevity would do. The use of life satisfaction data to value non-material goods is common in numerous studies on housing conditions, environmental quality, employment or health (see Fujiwara, 2013, Fujiwara and Campbell, 2011, for surveys), or several of the latter dimensions (Boarini et al., 2012). As this methodology is relying on subjective data, it is labelled as the "*subjective approach*".

6. None of these two approaches are immune from criticisms and empirical flaws. The main contribution of this study is to show that subjective shadow prices are probably too large due to inference issues, whereas their model-based counterparts are probably too low due to limitations of the CRRA utility function to adequately reflect preferences, among other issues. The paper shows that it is possible to obtain a broadly consistent sets of shadow prices across the two sets of studies, when a number of conditions are fulfilled.

7. On the one hand, life satisfaction regressions conducted at the individual level yields implausibly large subjective shadow prices. This happens because the resulting income coefficient is biased downwards due to measurement errors or unobserved heterogeneity that stem from the dataset at hand (non-official data and cross-sectional). It is possible to remove these effects by carrying out regressions with the dependent variable expressed as country average life satisfaction and the independent variables are measured as country-level income (based on official data) unemployment and longevity and also include country fixed effects.On the other hand, the model-based approaches that rely on ex-ante evaluation of unemployment risks (namely "under a veil of ignorance") underestimate unemployment risk to the extent that they do not take into account individual's information about one's own labour market history. In reality, unemployed workers value unemployment risk their materialization much more than employed workers, a feature that that can be accounted for by allowing state contingent valuations. In addition, the model-based valuation of vital risk also appears to be underestimated when using simple CRRA utility functions because CRRA assumes a) that people are indifferent on the time at which they will know that the mortality risk materialises and b) that the marginal utility of survival is constant. A well-known recursive utility function, that relax these two assumptions, is the one proposed by Epstein-Zin and Weil (Epstein and Zin, 1989, 1991, Weil, 1990The latter utility function is also the most relevant one for estimating longevity shadow prices in a sample that includes also low-income countries, as shown by Cordoba and Ripoll (2013), because it predicts that the shadow price of longevity is decreasing in income, consistently with research in this field.

8. Next section describes the data. Section three presents the subjective approach, while section four presents the theoretical framework used for model-based valuation. Section five displays the calculated equivalent incomes for mortality and unemployment risks among OECD countries. Last section concludes.

3 This label may be slightly misleading, as the parameters of the utility function are calibrated on figures that sometimes reflect *preferences* (such as the willingness-to-pay for lowering vital risk). Therefore this approach should not be viewed as a purely model-based assessment of individuals' welfare.

2. THE DATA

This section describes the data that has been collected for a sample of 31 OECD countries plus one "key partner", namely the Russian Federation.

2.1. Life satisfaction, income and life expectancy

9. Life satisfaction data is extracted from the Gallup World Poll that has been conducted in more than 150 countries since 2005. Life satisfaction is measured on a 0-10 scale and reflects the cognitive judgement by a person about life as a whole. As shown on Table 1, average life satisfaction varies between 4.8 in Hungary and 7.7 in Denmark, with a sample average of 6.6.

10. The Gallup survey also contains a household total income variable that is used in individual-level regressions. In country-level regressions, an equivalised household disposable income variable borrowed from the OECD (2013b) is preferred, as it also includes in-kind transfers from the state. It is available over the 2005-2010 period. Life expectancy at birth is taken from World Development Indicators database (World Bank, 2013).

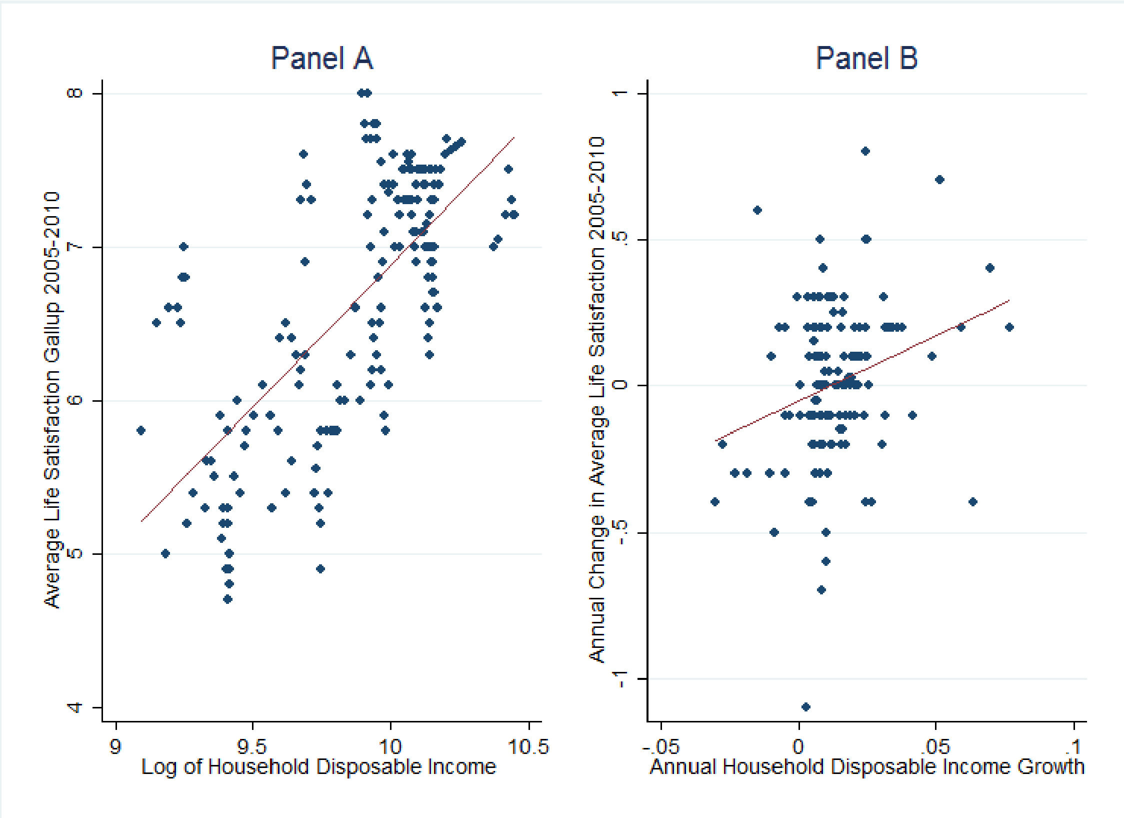
Table 1 – Descriptive Statistics - 2009

	Average life satisfaction	Average disposable household income	Life expectancy at birth	Unemployment rate	Effective replacement rate	Average duration of unemployment spell
	0-10 scale	*USD*	*years*	*per cent*	*per cent*	*years*
AUS	7.4	25581	81.5	5.7	40.9	0.31
AUT	7.3	25817	80.1	4.8	61.1	0.59
BEL	7.0	24519	79.7	8.0	56.0	1.10
CAN	7.5	26351	80.7	8.4	45.4	0.21
CHE	7.5	24850	82.0	4.2	63.2	1.20
CHL	6.5	9443	78.8	10.0	14.2	*na*
CZE	6.3	15825	77.1	6.8	51.1	1.36
DEU	6.7	25590	79.8	7.8	67.1	1.00
DNK	7.7	20281	78.6	6.1	62.2	0.48
ESP	6.2	21345	81.5	18.1	50.1	0.83
EST	5.1	12130	74.8	14.0	37.7	1.19
FIN	7.6	21287	79.7	8.4	57.1	0.46
FRA	6.3	25451	81.1	9.2	55.0	0.79
GBR	6.9	25599	80.1	7.8	40.0	0.68
GRC	6.0	19963	80.2	9.6	34.6	1.24
HUN	4.8	11920	73.9	10.1	45.4	2.01
IRL	7.0	23179	80.0	12.2	53.8	1.18
ITA	6.3	20647	81.4	7.9	38.1	1.44
JPN	5.8	21582	82.9	5.3	33.3	0.48
KOR	5.6	15179	80.3	3.8	29.1	*na*
LUX	7.1	32382	80.1	5.2	59.5	0.75
MEX	7.0	9913	76.5	5.4	13.4	0.84
NLD	7.6	23590	80.5	3.7	59.7	0.76
NOR	7.6	27376	80.8	3.2	57.8	0.42
NZL	7.3	16311	80.7	6.3	38.0	0.30
POL	6.0	12894	75.7	8.3	35.0	0.91
PRT	5.3	17202	78.7	10.0	42.2	1.41
RUS	5.2	11618	68.6	8.5	40.0	*na*
SVK	5.9	13653	74.9	12.1	37.4	1.97
SVN	5.8	17980	79.0	6.0	45.1	2.50
SWE	7.3	23450	81.4	8.5	52.3	0.51
USA	7.2	33746	78.1	9.4	31.0	0.38
Average	6.6	20520	79.0	8.0	45.2	0.94

11. As shown on Figure 1 (Panel A), there is a large cross-country correlation of 0.69 between average life satisfaction and average household disposable income. Over the 2005-2010, there also appears

to be a significant correlation, albeit weaker, of 0.26 between the annual change in average life satisfaction and annual disposable income growth (Panel B). This finding is consistent with the view that life satisfaction and income are less correlated with each other in the time dimension than in the cross-section (Easterlin, 1974), although many countries do exhibit significant correlations between growth in life satisfaction and in income even over relatively long periods (Stevenson and Wolfers, 2013).

Figure 1 – Average Life Satisfaction and Household Disposable Income Across Countries and Time



2.2. Unemployment variables

12. The stock of unemployment UN is extracted from OECD database (OECD, 2013c), while unemployment turnover variables are constructed from a collection of sources (Murtin and Robin, 2013, Murtin et al., 2013, OECD, 2010).[4] Two series can conveniently describe unemployment turnover in a two-states (i.e. employment versus unemployment) model: the monthly unemployment inflow rate S that captures job destruction, and the monthly unemployment outflow rate f that is driven by both job vacancy creation and the efficiency of the matching process between employers and employees. These two series provide an adequate description of unemployment dynamics, as there is a very high correlation between the actual rate of unemployment and the steady-state unemployment rate equal to $s/(s+f)$.

13. The outflow series f is less noisy than the inflow series (as it is of larger magnitude and hence relatively less sensitive to business cycle fluctuations), which is recalculated implicitly from the unemployment rate and its outflow, so that the following equation holds by construction:

4 These measures of unemployment considered here are based on formal employment only. Informality cannot be dealt with due to the lack of comparable data across the countries covered in this study.

$$UN = \frac{s}{s+f}.$$

14. The average duration of the unemployment spell can be easily calculated (in years) from the outflow rate, as it equals $D = 1/(12.f)$. Unemployment spells are particularly short in some English-speaking countries such as the Australia, Canada and the United States, and particularly long in Southern and Eastern European countries.

15. The replacement rate of unemployment benefits has a large influence on the valuation of the unemployment risk, and must therefore be constructed in a very careful way. When workers are laid-off and fall into unemployment, they receive unemployment benefits if they are covered by unemployment insurance (henceforth UI). According to ILO (2009), only a fraction of unemployed workers are covered by such a scheme as shown on Table 1. This proportion is larger among high-income countries, but with the exception of Germany, OECD countries are far from providing full coverage.

16. When the unemployed is covered by UI, she/he receives benefits at a rate τ^C that is proxied by the average of four replacement rates corresponding to respectively a single person with average wage, a person living in a household with one wage-earner, with two wage earners, and to a lone parent. Moreover, these four replacement rates decrease with time and eventually fall quickly to zero for some categories of workers, as it is the case for instance in Italy. To account for this fact, we calculate τ^C as the weighted average of the initial and long-term replacement rates, with a weight equal to unemployment spell's average duration and a maximum spell of 5 years. More precisely, one has:

$$\tau^C = \frac{5-D}{5}\bar{\tau}^{i,c} + \frac{D}{5}\bar{\tau}^{lt,c},$$

where $\bar{\tau}^{i,c}$ is the average initial replacement rate calculated across the latter four groups and $\bar{\tau}^{lt,c}$ its long-term counterpart. All these rates are extracted from OECD (2013c).

17. When the unemployed is not covered by UI, we assume that she/he receives income transfers from family, which equal the income earned by the bottom decile of the income distribution as measured by OECD (2013c). Typically, the latter income equals 15% of the average income in high-inequality emerging countries such as Russia or Mexico, and between 20% and 40% of the average income among developed economies. The implicit replacement rate arising from those transfers to non-covered unemployed workers is denoted τ^{nc}. In the data, it is of course never larger than the replacement rate of covered unemployed workers, but among some high-income countries providing small benefits, such as the United States or the United Kingdom, the discrepancy between the two rates is not very large.

18. As a result, our measure of the effective replacement rate τ is simply the weighted average of the two latter rates, with a weight equal to the degree of coverage of UI:

$$\tau = c.\tau^c + (1-c).\tau^{nc}.$$

19. Table 1 shows that the effective replacement rate is on average equal to 45.2%, and ranges between 13.4% in Mexico and 67.1% in Germany. Interestingly, unemployment rates and turnover are not very different across the two latter countries. This suggests that similar unemployment rates and turnover may hide very different income risks across OECD countries, depending on the magnitude of the effective replacement rate.

3. THE SUBJECTIVE VALUATION OF VITAL AND UNEMPLOYMENT RISKS

20. Subjective well-being data are increasingly used to study people's preferences (OECD 2013; UK Green Book). Underlying these approaches is the recognition that what matters to a good life is the impact of a specific set of circumstances (individual and country's ones) on how people feel about their life, as well as the view that people are the best judges of how their life is going. Because of this, questions on life satisfaction are often used to evaluate how people trade-off different aspects of their life (e.g. work versus leisure) and to express these trade-offs in monetary terms, with the implicit assumption that life satisfaction is a good proxy of individual's utility. This assumption is corroborated by the empirical literature in this field that shows that life satisfaction reflects a cognitive assessment of one's own life and is indeed found to capture decisional utility (Kahneman et al., 1999; Heliwell and Barrington-Leigh, 2010) as opposed to experienced utility (Kahneman and Krueger, 2006).

21. Subjective well-being measures are not only theoretically relevant but also relatively easier and cheaper to collect than, for instance, measures elicited through stated-preferences or contingent evaluation methods (OECD 2013). Differently from the latter, life satisfaction measures also have the immense advantage of being available on a comparable basis for a large number of countries, a real asset for our research.

22. This section first describes life satisfaction regressions conducted at the individual level, and then at the country level. Life satisfaction is regressed on (log) income, unemployment and longevity, and the shadow prices of the two latter variables is calculated from their life satisfaction elasticity relative to the life satisfaction elasticity of income.

3.1. Econometric issues in micro-level life satisfaction regressions

23. Economic studies relying on micro-level life satisfaction data often select self-assessed health as a proxy for health. This morbidity-related variable is therefore disconnected from the mortality risk that is considered in this paper. Similarly, unemployment is often included inside life satisfaction micro-level regressions as a dummy taking value one for the currently unemployed and zero otherwise. This variable captures the ex-post effect of unemployment upon the life satisfaction of a specific fraction of the population, namely the unemployed, while employed workers are by construction not subject to any welfare loss. We aim to complement the pure ex-post perspective by also valuing the ex-ante unemployment risk, which affects all workers, employed and unemployed ones (although not in an identical ways, see below). This paper therefore departs from the two proxies (morbidity and materialized unemployment) commonly used in microeconomic studies. However, there exist economic studies running micro-level life satisfaction regressions with aggregate indicators such as the country unemployment rate (e.g. Boarini et al., 2012) or life expectancy (Deaton, 2008). Those regressions are typically of the form:

$$LS_{i,j,t} = a_j + b_t + \gamma X_{i,j,t} + \alpha \log y_{i,j,t} + \beta^T T_{j,t} + \beta^U UN_{j,t} + \varepsilon_{i,j,t}, \quad (1)$$

where *LS* stands for life satisfaction of individual *i* in country *j* at time *t*, *X* for personal characteristics, *y* for individual (household) income, *T* for country-level life expectancy[5], *UN* for the rate of unemployment and ε for some residual. From the above regression, the "subjective" compensating income δ^S corresponding to one additional year of life satisfaction or one additional percentage point of unemployment is given by :

5 Life expectancy and the rate of unemployment are extracted from the World Development Indicators database (World Bank, 2013).

$$\delta_{i,j,t}^{S} = y_{i,j,t}\left[1 - \exp\left(-\frac{\beta^{k}}{\alpha}\right)\right] \text{ with } k \in \{T, U\}. \quad (2)$$

24. In this framework, compensating differentials are a share of personal income that is common to all individuals and countries (see Decancq *et al.*, 2015, for a model specification where elasticities (α, β^{k}) depend also on individual characteristics).

25. Taking stock of the Gallup survey, we estimate regression (1) on the sample described in section 2 and over the 2005-2010 period. We consider both equivalised and total household income, and include several individual controls such as a dummy for females and a quartic in age to account for non-monotonic variation in life satisfaction with age (Wunder *et al.*, 2013). In addition, we include country-level life expectancy (lagged one year[6]) and the unemployment rate. Time dummies are always included while countries effects are introduced in most of the regressions (columns 3 to 6). Sampling weights have been tested and do not yield plausible results as they drive the shadow prices of health and unemployment at unconventionally high levels.

26. Table 2 describes the results. Log income is always highly significant, so as the unemployment rate and life expectancy (except on column 4). The elasticity of log income varies little across the various specifications.

27. As reported at the bottom of Table 2, we derive from (2) the compensating differential (as a share of income) corresponding to one additional year of life expectancy and minus one percentage point of unemployment. These “subjective shadow prices” are very large as compared with the model-based prices, with an average of 9% of income per percentage point of unemployment, and around 11% per year of life expectancy (ignoring the non-significant estimate in column 4). Given that the average unemployment rate in the sample is 7.1%, this suggests that households would be willing to give up as much as *half of their income* to eliminate the risk of unemployment. Moreover, these results imply that American households would be willing to give up about 40% of their total income to reach the same level of life expectancy as in Japan.

28. On columns 5 and 6, we decompose the shadow price of unemployment by interacting the country-level unemployment rate with an individual-level dummy taking value one if the worker is currently employed.

6 Assuming that progress in life expectancy are observed with one year of delay.

Table 2 – Micro-level Life Satisfaction Regressions – 32 Countries 2005-2010

	No country effects		With country effects		With country effects and interactions	
	OLS	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable is individual life satisfaction					
Log of total household income	0.619***		0.553***		0.524***	0.524***
	(0.007)		(0.007)		(0.007)	(0.007)
Log of household equivalised income		0.551***		0.480***		
		(0.007)		(0.007)		
Unemployment rate	-0.038***	-0.037***	-0.055***	-0.062***	-0.055***	
	(0.002)	(0.002)	(0.004)	(0.005)	(0.005)	
Not employed					-0.267***	-0.050*
					(0.013)	(0.030)
Unemployment rate x not employed						-0.071***
						(0.005)
Unemployment rate x employed						-0.041***
						(0.005)
Lagged life expectancy	0.071***	0.071***	0.079***	-0.020	0.053**	0.054**
	(0.002)	(0.002)	(0.022)	(0.030)	(0.023)	(0.023)
Female dummy	0.153***	0.152***	0.136***	0.132***	0.165***	0.165***
	(0.011)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)
Age	-11.161***	-17.322***	-5.896***	-10.714***	-7.638***	-7.842***
	(1.693)	(1.790)	(1.628)	(1.721)	(1.667)	(1.666)
Age^2	21.579***	43.672***	3.062	20.670***	3.319	3.977
	(5.656)	(5.984)	(5.439)	(5.751)	(5.553)	(5.552)
Age^3	-17.735**	-50.484***	8.430	-18.190**	14.405*	13.558*
	(7.799)	(8.249)	(7.499)	(7.926)	(7.652)	(7.650)
Age^4	5.499	21.760***	-7.421**	5.961	-12.331***	-11.961***
	(3.797)	(4.014)	(3.650)	(3.856)	(3.726)	(3.725)
Subjective price of one unemployment percentage point (% income): *average*	**6.0**	**6.5**	**9.5**	**12.1**	**10.0**	**7.9**
for the unemployed						**12.7**
for the employed						**7.5**
Subjective price of not being employed (% income)					**40.0**	**9.1**
Subjective price of one year of life expectancy (% income)	**10.8**	**12.1**	**13.3**	**-0.04**	**9.6**	**9.8**
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes
Country dummies	No	No	Yes	Yes	Yes	Yes
R^2	0.15	0.13	0.22	0.2	0.21	0.22
N	1.2e+05	1.1e+05	1.2e+05	1.1e+05	1.1e+05	1.1e+05

note: *** (respectively **/*) denotes significance at a 1% (resp. 5%/10%) confidence level.

29. We also include an individual no-employment dummy to capture the direct "ex-post" cost of non-employment. The latter is found to be very large on column 5 as in other studies, but it is much smaller on column 6 when the interacted unemployment rate (that tests the fact that unemployed people are more unappy the larger is the country-level unemployment rate) is included. Interestingly, the aggregate unemployment rate has indeed a larger negative association with life satisfaction of the non-employed than with life satisfaction of employed workers (i.e. the coefficients are -0.071 and -0.041 respectively). But as before, we find implausibly large shadow prices for both unemployment and health.

30. Among the various empirical problems contaminating life satisfaction regressions, those affecting the individual income variable are of major importance as they directly affect the magnitude of compensating differentials through the income elasticity α. In particular, Powdthavee (2010) highlights the role of large measurement errors on income and of unobserved heterogeneity, which yield a sizeable attenuation bias on income.[7] He finds an effect of income on life satisfaction twice as large as the estimate in his basic specification.

31. Similarly, Fujiwara (2013) argues that the "Wellbeing Valuation" provides biased estimates of the value of non-market goods unless the income variable is instrumented. Strikingly, he finds in his case-study that the coefficient on log income jumps from 0.16 (non-instrumented income variable) to 1.10 (instrumented variable).

32. In absence of any relevant instrument for individual income and any panel data covering all 32 countries, one can reduce the influence of measurement errors and unobserved heterogeneity by averaging out the data by country, namely by running macro-level regressions of country average life satisfaction on national log household disposable income, life expectancy, the unemployment rate, country and time dummies. In this way, any measurement error affecting individual variables is presumably washed away, so as unobserved heterogeneity affecting the level of life satisfaction.[8]

33. We also examine to which extent business cycle shocks affect the shadow prices of mortality and unemployment, as life satisfaction, disposable income and unemployment are plausibly subject to cyclical effects. Business cycle shocks can conveniently be removed by applying a Hoddrick-Prescott filter with smoothing parameter 50 to the latter variables.

34. Table 3 reports the results. Across all specifications, log income, life expectancy and unemployment turn out to be significant. Most importantly, the coefficient on income appears to be larger than in micro-level regressions, about twice larger on columns (1, 2, 4 and 5) and five to seven times larger on column (3 and 6). We interpret this finding as the sign that measurement errors and unobserved factors at the individual level have been largely removed by averaging the data at the country level. Moreover, an R2 of 0.99 leaves little room for unobserved variables to bias the estimates.

[7] Powdthavee underlines the role of omitted factors such as working hours and relatives' income, which are positively related to personal income and negatively linked with life satisfaction.

[8] However, this procedure is unable to adequately treat the unobserved heterogeneity affecting the coefficient on log income, which could only be accounted for in a panel data model with random coefficients ("Generalized Latent Mixed Models").

Table 3 – Macro-level Life Satisfaction Regressions – 32 Countries 2006-2010

	Actual series			Smoothed series		
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent variable is average life satisfaction					
Log household disposable income	1.286***	1.286***	3.538***	1.290***	1.291***	2.465***
	(0.213)	(0.216)	(0.933)	(0.202)	(0.205)	(0.355)
Unemployment rate	-0.067***	-0.068***	-0.063***	-0.067***	-0.066***	-0.041***
	(0.014)	(0.015)	(0.012)	(0.014)	(0.015)	(0.008)
Lagged life expectancy	0.058***	0.058**	0.192**	0.059***	0.060***	0.200***
	(0.022)	(0.023)	(0.087)	(0.021)	(0.022)	(0.036)
Subjective price of one unemployment percentage point (% income)	**5.1**	**5.2**	**1.8**	**5.1**	**5.0**	**1.6**
Subjective price of one year of life expectancy (% income)	**4.4**	**4.4**	**5.3**	**4.5**	**4.5**	**7.8**
Time dummies	No	Yes	Yes	No	Yes	Yes
Country dummies	No	No	Yes	No	No	Yes
R^2	0.51	0.52	0.96	0.59	0.59	0.99
N	144	144	144	144	144	144

note : annual series smoothed with Hodrick-Prescott filter with smoothing parameter 50

35. As a consequence, the shadow subjective prices of one additional year of life expectancy and of a cut in the unemployment rate by one percentage point appear to be much lower than those described in Table 2. The subjective price of one year of longevity appears to be in the vicinity of 5% of disposable income, with a range comprised between 4.4% and 7.8%. The subjective price of a cut by one percentage point of unemployment is worth about 4% of disposable income and ranges from 1.6% to 5.2%.

36. Importantly, the valuation of one year of life expectancy at 5% of income is in line with traditional estimates of the Value of one Statistical Life-Year (VSLY), as shown by the following back-of-the-envelope calculation. In Murphy-Topel (2006), the VSLY is displayed by age (see Figure 2), and it turns out that the average VSLY, weighted by cohort size in the United States 2005, would equal 213 000 US dollars. This is the amount that each cohort is willing to pay once in a lifetime to gain one year of life. As the average size of a cohort is equal to 0.9% of total population, the amount to be paid by each individual every year is equal to 0.09 x 213 000 = 1942 US dollars, or 5.8% of household disposable income. It is striking that two completely different methods, one based on stated preferences (i.e. life satisfaction) the other one on revealed preferences (i.e. VSL studies) yield almost the same valuation of life.

3.2. Accounting for unemployment benefits

37. In the former two Tables, the unemployment rate was used as a pure measure of risk given that the average household disposable income already reflects foregone earnings of the unemployed. In reality, unemployed workers receive unemployment benefits at a given replacement rate and for a given duration, which mitigates monetary losses from being laid-off and hence the magnitude of the unemployment risk. To account for the effect of unemployment benefits on life satisfaction, it is convenient as a starting point to include the effective replacement rate inside the regressions.

38. As shown by Table 4, the replacement rate is neither significant in level (column 2) nor in interaction with unemployment (column 3). One possible interpretation for this lack of significance is that

the replacement rate captures mainly the monetary effect of unemployment, which is already reflected in disposable income, and constitutes as such a poor measure of risk. Said differently, the unemployment risk does not appear to be adequately proxied by an index of the unemployment rate, the replacement rate and their interaction. Let us try to define a proper measure of unemployment risk that reflects both the exposure to the shock (the unemployment rate) and the mitigating influence of the safety net (the replacement rate). Convenient risk measures can be derived theoretically from the specification of individual preferences and their link to life satisfaction. Let us consider the following model,

$$u(y,UN,T) = E(\tilde{y})(1+\lambda CV(\tilde{y}))\exp(\gamma T), \qquad \lambda < 0 \qquad \text{with} \qquad LS = a + \alpha \log(u(y,UN,T)) + \varepsilon,$$

where utility depends positively on the average y of a stochastic disposable income $\tilde{y}$, negatively on its coefficient of variation and positively on "health-related human capital" defined in an exponential way.[9] Life satisfaction is then assumed to be a log-linear transformation of utility in order to reflect the link between life satisfaction and log income. In appendix, we show that the latter assumptions jointly imply the following specifications for life satisfaction regressions:

$$LS = a + \alpha \log(y) + \beta^R.R(UN,\tau) + \beta^T T + \varepsilon,$$
$$R(UN,\tau) = \frac{(1-\tau)(UN - UN^2)^{1/2}}{(1 - UN + \tau.UN)}.$$

39. The measure R can be viewed with a good degree of approximation as the coefficient of variation in income. Table 4 column (4) report the results. All explanatory variables turn out to be strongly significant. It is then straightforward to calculate the compensating differential for one additional year of life expectancy and for a cut in one percentage point of unemployment at various replacement rates for both unemployment risk measures. For the unemployment risk, non-linearities of the risk measure imply that the valuation of the risk depends on the level of the unemployment rate. To obtain an average valuation, one calculates the compensating income differential for the elimination of the risk of unemployment and one divides the obtained value by the unemployment rate.

40. Strikingly, the subjective shadow prices of vital and unemployment risks are fully consistent with those derived from a regression with no replacement rate (e.g. column 1). This finding suggests an overall consistency of the Wellbeing Valuation conducted at the country-level.

41. As a preliminary conclusion to this section, it is clear that the assessment of vital and unemployment risks can be misleading if the data is not treated appropriately for measurement errors and unobserved heterogeneity, two issues that arise primarily at the micro-economic level, and to a much lower extent at the country-level. We now turn to the discussion of "objective" valuations.

[9] This is justified by the linear relationship between log income (i.e. monetized human capital) and life expectancy at the cross-country level once some standard of economic development has been reached (i.e. when the Preston curve becomes fully linear).

Table 4 – Macro-level Life Satisfaction Regressions with Measures of Unemployment Risk

	(1)	(2)	(3)	(4)
	Dependent variable is smoothed life satisfaction			
Log household disposable income *smoothed with Hodrick-Prescott filter*	2.465*** (0.355)	1.532*** (0.439)	1.839*** (0.478)	1.785*** (0.487)
Unemployment rate *smoothed with Hodrick-Prescott filter*	-0.041*** (0.008)	-0.043*** (0.011)	-0.039*** (0.012)	
Lagged life expectancy	0.200*** (0.036)	0.137*** (0.043)	0.120*** (0.043)	0.143*** (0.046)
Unemployment effective replacement rate		-1.242 (0.981)	-0.455 (1.095)	
Unemployment rate x centered replacement rate			-0.125 (0.080)	
Unemployment risk measure *coefficient of variation in income*				-2.159** (1.071)
Subjective price of one unemployment percentage point (% income)	**1.6**	**2.8**	**2.1**	**2.1**
Subjective price of one year of life expectancy (% income)	**7.8**	**8.6**	**6.3**	**7.7**
Time dummies	Yes	Yes	Yes	Yes
Country dummies	Yes	Yes	Yes	Yes
R^2	0.99	0.99	0.99	0.99
N	144	107	107	107

4. MODEL-BASED VALUATION OF VITAL AND UNEMPLOYMENT RISKS

42. This section presents the model-based approach in two different setups. One is based on a valuation “under the veil of ignorance” which is calculated for an “average” representative worker independently of her current employment state, while the second one corresponds to a state-contingent, individual-level valuation that distinguishes between two types of workers, namely the employed and the unemployed.

4.1. Valuation “under the veil of ignorance”

Expected utility of a representative agent

43. We consider a “hypothetical life-cycle individual” facing in each period idyosincratic and uncorrelated vital and unemployment risks and no aggregate risk. The expected utility of a representative agent making calculations under the “veil of ignorance” regarding consumption, c, and stochastic longevity$\tilde{T}$, , prospects is then

$$E\left(\sum_{t=0}^{\tilde{T}} \beta^t u(c(t))\right) = E\left(\sum_{t=0}^{\tilde{T}} \beta^t\right) \cdot E[u(c)],$$

where β is the discount factor and E[] is the unconditional expectation.[10] In this setting, the utility criterion is calculated before the materialization of vital, income and unemployment risks, namely under "the veil of ignorance".

Mortality risk

44. As Becker et al. (2005) and Jones and Klenow (2013), we consider the benchmark case where the survival rate per period, π, is constant over lifetime, so that life expectancy equals $E\,(\tilde{T})$ =T=1/(1- π). Expected utility then becomes

$$\frac{1}{1-\beta\pi} E[u(c)].$$

Unemployment risk

45. In the valuation "under the veil of ignorance", we model unemployment in a very simple way, assuming an idiosyncratic risk of unemployment in every yearly period. As the average unemployment spell duration among our sample is 0.94 years (cf. Table 1 in the data section), this assumption is plausible as a starting point. Expected utility can then be rewritten as

$$\frac{1}{1-\beta\pi}\left[UN \cdot u(c^u) + (1-UN) \cdot u(c^e)\right],$$

where U is the rate of unemployment, and c^u and c^e are consumptions while employed and unemployed. Notice that under the veil of ignorance, and with no aggregate risk, unemployment turnover has no effect on social welfare, which will not be the case with more elaborated models described below. As long as the fractions of employed and unemployed in each period are constant, turnover affects individual but not social welfare.[11]

Indirect utility and calibration

46. For the purpose of studying mean preserving changes in the unemployment rate, it is convenient to write social welfare in terms of average consumption, y, and the effective replacement rate $\tau = c^u/c^e$. Thus,

$$y = UN \cdot \tau \cdot c^e + (1-UN) \cdot c^e = (1-UN+\tau \cdot UN) \cdot c^e.$$

Assume further that average savings are zero so that y also denotes average income. An indirect utility as a function of average income y, the unemployment rate UN and life expectancy T can immediately be derived from above equations:

10 The equality follows from Wald's lemma.

11 Cordoba and Verdier (2008) also find that social mobility per se does not affect social welfare.

$$v(y,UN,\pi)=\frac{1}{1-\beta\pi}\left[UN\cdot u\left(\frac{\tau\cdot y}{1-UN+\tau\cdot UN}\right)+(1-UN)\cdot u\left(\frac{y}{1-UN+\tau\cdot UN}\right)\right].$$

47. To choose the parameters governing the utility function *u*, we calculate the value of a statistical life (henceforth VSL) implied by the model. The VSL is the society's willingness to pay to save one life, and in practice it will be used to calibrate the intercept of the utility function u(.). It is formally calculated as the marginal rate of substitution between income and the survival probability or:

$$VSL=\left|\frac{\partial v/\partial\pi}{\partial v/\partial y}\right|.$$

Risk valuation, choice of references and equivalent incomes

48. The derivation of equivalent incomes for the non-income dimensions longevity and unemployment hinges on the choice of a reference value for comparison. For both risks, we choose the best possible outcome as a benchmark, namely zero unemployment[12] and the highest longevity T^* observed in the sample (Japan).[13] While longevity never interferes with the calculation of unemployment risk valuation, the converse is not true as unemployment and income are not separable in indirect utility. However, this interaction effect is small empirically, and there is little difference between the valuation of mortality risk at zero and non-zero unemployment. Formally, the compensating income differential for achieving zero unemployment and highest longevity verify respectively:

$$v(y,UN,\pi(T))=v(y+\delta^U,0,\pi(T)),$$
$$v(y,UN,\pi(T))=v(y+\delta^T,UN,\pi(T^*)).$$

Equivalent incomes receive closed-form expressions after the specification of the utility function *u(.)* as shown below.

Becker, Philipson and Soarès (2005) framework augmented for the unemployment risk

49. As a convenient starting point for specifying the utility function, several studies such as Becker et al. (2005), Murphy and Topel (2005) or Hall and Jones (2007) consider a Constant Relative Risk aversion (CRRA) utility function with intercept:

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12 The assumption that zero unemployment is the relevant benchmark is in line with empirical studies on life satisfaction that show that even very low levels of unemployment decrease life satisfaction. From a strictly economic viewpoint however the zero unemployment assumption does not necessarily correspond to an optimum to the extent that a positive turn-over increases the efficiency of labour market (as labour can get attracted to the most productive uses).

13 See Blanchet and Fleurbaey (2013) for a discussion of the choice of the benchmark. It is not necessarily the case that zero unemployment may be an optimal outcome from an economic standpoint, as some degree of frictional unemployment may be useful to enable reallocation of labour and capital in most productive units. But in absence of any information on the "optimal level" of frictional unemployment, we simply consider zero unemployment as the benchmark.

$$u(c)=\frac{1}{1-\sigma}(c^{1-\sigma}-\omega^{1-\sigma}),$$

where ω is an imputed consumption leveljust above survival. It represents a level of consumption that is so low that individuals would be indifferent between being alive or being dead. After choosing a CRRA utility function with intercept, and inserting it into the measure of indirect utility derived earlier, one obtains:

$$v(y,UN,\pi)=\frac{1}{(1-\beta\pi)(1-\sigma)}\left(y^{1-\sigma}\frac{1-UN+UN.\tau^{1-\sigma}}{(1-UN+\tau.UN)^{1-\sigma}}-\omega^{1-\sigma}\right).$$

The value of a statistical life (VSL) and equivalent incomes can easily be derived from the latter equation:

$$VSL=\left|\frac{\partial v(y,UN,\pi)/\partial\pi}{\partial v(y,UN,\pi)/\partial y}\right|=\frac{-\beta(1-UN+\tau UN)^{1-\sigma}}{(1-\beta\pi)(1-\sigma)(1-UN+UN\tau^{1-\sigma})}y^{\sigma}\left(y^{1-\sigma}\frac{1-UN+UN\tau^{1-\sigma}}{(1-UN+\tau UN)^{1-\sigma}}-\omega^{1-\sigma}\right),$$

$$\delta^U=y\left[\frac{\left(1-UN+\tau^{1-\sigma}UN\right)^{\frac{1}{1-\sigma}}}{1-UN+\tau UN}-1\right],$$

$$\delta^T=\left(\frac{1-\beta\pi^*}{1-\beta\pi}y^{1-\sigma}+\frac{(1-UN+\tau UN)^{1-\sigma}}{(1-UN+UN\tau^{1-\sigma})}\beta\frac{\pi^*-\pi}{1-\beta\pi}\omega^{1-\sigma}\right)^{\frac{1}{1-\sigma}}-y.$$

These compensating income differentials will be calculated once the utility functions *u(.)* have been calibrated (see later section for an empirical discussion). Notice that under the veil of ignorance δ^U is a single non-contingent willingness to pay in order to eliminate unemployment. Such willingness to pay may be very different among individuals, some of whom are unemployed. We next consider state-contingent compensations.

4.2. Tearing the veil of ignorance: a contingent, individual level valuation

50. In reality, the valuation of the unemployment risk is not independent from the current employment situation, and the approach under the veil of ignorance fails to account for an important component reflected by subjective data: the welfare loss from the materialization of the unemployment risk for the unemployed. In life satisfaction data, the unemployed report large decreases in life satisfaction due to their current status, which are not reflected in the approach working under the veil of ignorance. In the following, we look more closely at state-contingent, individual-level valuations.

Indirect utility of the employed and the unemployed in the CRRA case

51. Let $v(s)$ be a shorthand for the actual value function in employment state *s*. Consider recursive formulation whereby the "value function" is equal to the utility of the current period plus the discounted expected value at the beginning of next period conditionally on current state. Formally, the value function satisfies the following recursion:

$$v(s)=u(c(s))+\beta\pi\cdot E[v(s')\,|\,s],\quad s\in\{e,u\},$$
$$E[v(s')\,|\,s]=\rho(s).v(e)+(1-\rho(s)).v(u),$$

where *u(.)* is the CRRA utility function with intercept and $(\rho(e),\rho(u))$ denote the probability of being employed next period conditionally on being currently employed or unemployed respectively. It is convenient to define $w(s)=\frac{1}{1-\sigma}v(s)^{1-\sigma}$. Thus, as shown in the appendix, the value functions for the currently unemployed and the currently employed are given by:

$$w(u)=\frac{1}{1-\beta\pi}\frac{u(c^u)(1-\beta\pi\rho_e)+\beta\pi\rho_u u(c^e)}{1-\beta\pi(\rho_e-\rho_u)},$$
$$w(e)=\frac{1}{1-\beta\pi}\frac{u(c^e)(1-\beta\pi(1-\rho_u))+\beta\pi(1-\rho_e)u(c^u)}{1-\beta\pi(\rho_e-\rho_u)}.$$

Calibration and compensating income differentials

52. The VSL is calculated for each group of workers, while using current income in the computation of the partial derivative vis-à-vis income, in other words:

$$VSL(s)=\left|\frac{\partial w(s)/\partial\pi}{\partial w(s)/\partial c(s)}\right|=\frac{\beta E[w(s')\mid s]}{c(s)^{-\sigma}}.$$

Then, an average VSL for the whole population is computed and confronted withempirical evidence on this same issue (Viscusi and Aldy, 2003) .The average VSL is defined as:

$$VSL=(1-UN).VSL(e)+UN.VSL(u)$$

Although compensating incomes can be derived in a closed-form, their expression is complicated and does not yield any specific insight. In practice, equivalent incomes are calculated numerically for each type *s* of worker (employed/unemployed). Specifically, the compensating differential for eliminating unemployment risk for an individual currently in state *s* solves:

$$w(c(s),\rho(s);c,\rho,\pi(T))=w(c(s)+\delta^U(s),1;c+\delta^U,1,\pi(T)),$$

where c(s), ρ(s) and $\delta^U(s)$ are individual-level variables, while vectors c, ρ, π(T) and δ^U contain entries for both states (employed and unemployed). Notice that the elimination of unemployment risk corresponds to setting ρ(e) = ρ(u) = 1. In other words, the compensating income $\delta^U(s)$ is the amount of money that compensates the worker of type *s* for the absence of unemployment in the calculation of *future* expected utility. In this setting, the associated gain in utility is larger for the unemployed than for the employed, who currently enjoys higher income. As a consequence, the compensating differential of the unemployed $\delta^U(u)$ is larger than the one of the employed $\delta^U(e)$, which simply captures the unemployment risk premium. Similarly, the compensating differential for achieving the highest longevity T* for an individual currently in state *s* solves:

$$w(c(s),\rho(s);c,\rho,\pi(T))=w(c(s)+\delta^T(s),\rho(s);c+\delta^T,\rho,\pi(T^*)).$$

Once worker-specific compensating differentials have been derived, it is then possible to calculate an average value such as:

$$\delta^{U} = (1-UN).\delta^{U}(e) + UN.\delta^{U}(u),$$
$$\delta^{T} = (1-UN).\delta^{T}(e) + UN.\delta^{T}(u).$$

Our calculations show that, $(\delta^{T}, \delta^{T}(e), \delta^{T}(u))$ are marginally different, so that disentangling compensating incomes for the employed and unemployed appears to be important for the unemployment risk but not for the mortality risk.

4.3. Tearing the veil of ignorance in an Epstein-Zin-Weil utility framework

53. In what follows, we similarly use a recursive utility framework that yields, as we show below, a higher valuation to the elimination of unemployment for the unemployed. However, we use a different representation for individual preferences that allows us to introduce specific risk aversion parameters for the vital and unemployment risks. In practice, we use a generalized Epstein-Zin-Weil utility function, which has several conceptual advantages over the CRRA utility function as explained below.

Three issues with the CRRA utility function

54. Both valuations "under the veil of ignorance" or at the individual level may be affected by the choice of a CRRA utility function, which presents mainly three issues. First, the CRRA utility function assumes that individuals are indifferent to the timing of resolution of uncertainty. As discussed in Cordoba and Ripoll (2013), this assumption is analytically convenient but it carries implications that appear implausible, at least in what concerns health and mortality risks. Evidence suggests that in the case of incurable diseases, individuals are not indifferent to the timing of resolutions of uncertainty, but that they rather prefer late resolution, what is sometimes called "protective ignorance." For example, studies regarding predictive genetic testing for the Huntington's disease find that a sizable portion of the population at risk prefers not to know. Individuals cite as the major reasons to avoid being tested "fear of adverse emotional effects after an unfavorable diagnosis, such as deprivation of hope, life in the role of a patient, obsessive searching for symptoms and inability to support one's spouse (Yaniv et al., 2004, p. 320). Wexler (1979) describes the results of 35 interviews with individuals at risk for the disease as follows: "All of the interviewers were painfully aware that the disease is terminal, but for them termination comes not at the moment of death but at the moment of diagnosis. Most fantasize the period following diagnosis to be a prolonged and unproductive wait on death row" (p. 199-220). Studies of HIV testing avoidance also find that many individuals exhibit some type of protective ignorance. For example, Day et al. (2003, p. 665) conclude that the major barriers to voluntary counselling and testing were "fear of testing positive for HIV and the potential consequences, particularly stigmatization, disease and death."

55. Secondly, the CRRA utility function does not disentangle risk aversion and intertemporal substitution, so that it is at odds with the standard economic intuition that individuals value more a good when it is scarce than when it is abundant. In the case of mortality, this framework predicts that the marginal utility of survival is constant, a natural consequence of a formulation in which utility is linear in probabilities. This means that a patient in the model values equally a procedure that provides one additional percentage point of survival regardless of whether the chances of survival without the procedure are 5% or 95% . A CRRA utility function in which the elasticity of inter-temporal substitution (EIS) is equal to the inverse of the coefficient of relative risk aversion (RRA) is the standard way of obtaining a representation in which utility is linear in probabilities and individuals are indifferent to the timing of resolution of uncertainty. In contrast, as proposed in Cordoba and Ripoll (2013), an Epstein-Zin-Weil utility function disentangles the EIS from the RRA and yields a representation in which individuals prefer late resolution of mortality uncertainty and in which the marginal utility of survival is decreasing in survival. Specifically, this can be achieved when the EIS is lower than the inverse of the CRRA. As we

show later, disentangling the EIS from the RRA is key to partially reconcile the subjective monetary valuations with the model-based valuations obtained from models of health and unemployment.

56. A third piece of evidence regarding the limitations of the CRRA utility function, at least in regards to health issues, is that it is inconsistent with available evidence regarding the value of statistical life (VSL). The VSL is an estimate of the social willingness to pay to save one life, and it is widely used for policy analysis. For example, in the United States the Environmental Protection Agency employs a VSL of $6.3 million for cost-benefit analysis, while the Department of Transportation uses $5.8 million. Evidence compiled in Viscusi and Aldy (2003) suggests that the VSL-to-income ratio is decreasing in income. In other words, poorer individuals seem to value life relative to their annual income more than richer people do. Contradicting this evidence, the CRRA utility function predicts that the VSL-to-income ratio increases with income. Similarly, the CRRA implies that life could be a bad rather than a good for poor individuals whose consumption is below a certain minimum consumption level (see Cordoba and Ripoll, 2013).[14]

Utility of the employed and the unemployed in the Epstein-Zin-Weil case

57. We extend the non-expected utility model of mortality risk[15] in Cordoba and Ripoll (2013) to also include unemployment risk. The main feature of this extension is the disentangling of three distinct parameters: one that controls inter-temporal substitution, one that controls unemployment risk aversion, and one that controls mortality risk aversion.

58. Consider two states $s=(e,u)$, where $s=e$ corresponds to employed and $s=u$ to unemployed. Let $v(s)$ be the indirect utility of individual in state s, which is given by

$$v(s)=\left[(c(s))^{1-\sigma}+\beta\left[\pi\cdot E\left[v(s')^{1-\eta}\mid s\right]^{\frac{1-\gamma}{1-\eta}}+(1-\pi)\cdot B^{1-\gamma}\right]^{\frac{1-\sigma}{1-\gamma}}\right]^{\frac{1}{1-\sigma}}, \quad (3)$$

14 Other utility functions drawn from behavioural economics have been considered. Firstly, the well-known Easterlin paradox (Easterlin, 1974, 1995) pointing at the relative stagnation of average happiness despite sharp increases in income is classicaly explained by the presence of relative income terms in the utility function (Clarck et al., 2008). Income, whenever received in employment or unemployment, is evaluated relative to others, namely with respect to a given reference income *X*. Many examples of utility functions reflecting inter-dependent preferences (Pollack, 1976), "keeping up with the Joneses" effects (Ljungqvist and Uhlig, 2000) or habits (Caroll et al., 1997, 2000) are exemplified in the economic literature. However, relative evaluation *per se* is unable to account for the large shadow price of unemployment found in subjective well-being studies. Secondly, another effect at play, namely *loss aversion*, has been examined. Indeed, Kahneman et al. (1991) conclude from experiments that individuals are about twice as sensitive to losses as they are to gains. They label loss aversion the observation that the marginal utility of agents is larger in the domain of losses than in the domain of gains. Building on the latter two ideas, we constructed a behavioural utility function with loss aversion below a certain reference threshold, in practice average income, so that the unemployed would displays loss aversion. This type of utility function had however the unpleasant property of displaying negative values in the income loss domain, implying that some unemployed workers have lower utility than a dead person. This inconsistency arises from the mutually exclusive objectives of setting up a utility function with a low curvature at the reference income (in order to obtain a low imputed consumption if dead) and a high curvature immediately below the average income.

15 Non-expected utility models depart from the classical expected utility framework that displays some refutable implications pinpointed by several authors, including Maurice Allais and more recently Daniel Kahneman and Amos Tversky. It turns out that empirically speaking, a majority of subjects express preferences that are inconsistent with expected utility.

where as in Cordoba and Ripoll (2013) π is the survival probability, β the discount factor, $1/\sigma$ is the EIS, γ is the coefficient of risk aversion vis-à-vis mortality risks, and B reflects a benchmark level of consumption at which individuals would be indifferent between being alive or dead. In addition,

$$E\left[v(s')^{1-\eta} \mid s\right] = \rho_s v(e)^{1-\eta} + (1-\rho_s)v(u)^{1-\eta},$$

where ρ_s is the conditional probability of being employed given status s the period before, while η is the coefficient of "unemployment risk aversion." When the value of being dead is normalized to zero (B = 0), which requires $\gamma \in (0,1)$, equation (3) simplifies to,

$$v(s) = \left[(c(s))^{1-\sigma} + \tilde{\beta}(\pi) \cdot E\left[v(s')^{1-\eta} \mid s\right]^{\frac{1-\sigma}{1-\eta}} \right]^{\frac{1}{1-\sigma}},$$

where $\tilde{\beta}(\pi) \equiv \beta\pi^{\frac{1-\sigma}{1-\gamma}}$ can be interpreted as the "effective discount factor." Given the facts that $\pi < 1$ and most calibrations of σ indicate that $\sigma > 1$, restriction $\gamma \in (0,1)$ implies that $\tilde{\beta}(\pi) > \beta$, so that individuals under this non-expected utility model are intrinsically more patient. This captures the preference for late resolution of death uncertainty documented above, which in general holds when $\sigma > \gamma$.

59. The standard expected utility model can be obtained as a special case when $\sigma = \gamma = \eta$. The advantage of this specification is twofold. First, since it can accommodate the case $\sigma > \gamma$, then the model is consistent with a decreasing marginal utility of survival and with a preference for late resolution of death uncertainty. Second, since it can accommodate the case $\eta > \sigma$, it is in principle possible to generate larger model-based valuations of eliminating unemployment risk, because the larger the η, the larger the aversion to unemployment risk.

Calibration and compensating income differentials

60. A formula to compute the VSL can be derived from the model above. The formula is key for the calibration of the model, as it allows us to identify the value of the coefficient of mortality risk aversion γ. The VSL corresponds to the marginal rate of substitution between income and survival. In this non-expected utility model the VSL for state s is given by,

$$VSL(s) = \left| \frac{\partial v(s)/\partial \pi}{\partial v(s)/\partial c(s)} \right| = \frac{\tilde{\beta}'(\pi) E\left[v(s')^{1-\eta} \mid s\right]^{\frac{1-\sigma}{1-\eta}}}{(1-\sigma)c(s)^{-\sigma}}.$$

For given state s, the VSL corresponds to the change in the weight that the individual gives to the future as proxied by the derivative $\tilde{\beta}'(\pi)$, times the future expected lifetime utility $E\left[v(s')^{1-\eta} \mid s\right]^{\frac{1-\sigma}{1-\eta}}$ where s' is the unknown future state, divided by the marginal utility of consumption (income) $(1-\sigma)c(s)^{-\sigma}$. As before, we aggregate across states by using the fraction of unemployed UN as computed above. In other words,

$$VSL = (1-UN) \times VSL(e) + UN \times VSL(u).$$

Then, we can compute a state-dependent willingness to pay, which takes more the perspective of the individual, either as currently employed or unemployed. In this case, the health premium $\delta^T(s)$ of an individual in state s, who consumes $y(s)$ and lives in a country with survival probability π and replacement rate τ is given by

$$v(c(s), \rho(s); c, \rho, \pi(T)) = v(c(s) + \delta^T(s), \rho(s); c + \delta^T, \rho, \pi(T^*)),$$

while the unemployment premium $\delta^U(s)$ for an individual in state s solves

$$v(c(s), \rho(s); c, \rho, \pi(T)) = v(c(s) + \delta^U(s), 1; c + \delta^U, 1, \pi(T)).$$

Under this perspective, the aggregate compensating income differentials are similarly given by

$$\delta^k = (1 - UN) \times \delta^k(e) + UN \times \delta^k(u), \qquad k \in \{T, U\}.$$

4.4. Choice of parameters

4.4.1. CRRA utility functions

61. Two parameters, namely the Relative Risk Aversion (RRA) parameter σ and the imputed consumption if dead B, determine the shadow price of the vital risk. The shadow price of the unemployment risk only depends on the RRA parameter, which in the CRRA case is also the inverse of the EIS.

62. Imputed consumption D is calibrated on the VSL as estimated by Viscusi and Aldy (2003). The latter authors assess a VSL comprised between 4 and 9 millions (2004) USD in the United States, and they derive the tighter range of 5.5-7.6 millions USD per statistical life using a meta-analysis. Several studies or cost-benefit analyses by government agencies (see Dockins et al., 2004, Murphy and Topel, 2005) use the average value of 6.3 millions USD used as a benchmark by the US Environmental Protection Agency.

63. Importantly, the VSL pertains to adult workers and ignores the (unrevealed) VSL of the child. However, surveys based on stated-preferences suggest a significantly larger VSL for the child (Hammitt and Haninger, 2010, Alberini *et al*, 2010). Thus calibrating expected utility over a lifetime on the statistical value of an adult's remaining lifetime is inconsistent.

64. A simple way of ensuring consistency between the model and the empirical evidence is therefore to use life expectancy at age 20 rather than life expectancy at birth. In practice, we propose a simple adjustment of life expectancy $T' = T - 20$. As life expectancy at age 20 is not available for all countries, the latter adjustment is more convenient. Moreover, differences in child mortality are not large in our sample of OECD countries.

65. Table 5 shows the parameters yielding a VSL of 6.3 millions USD in the United States in 2004. For the CRRA utility functions, w find that all imputed consumptions if dead are very low. In all calculations, parameter σ is taken equal to 1.25 as in Murphy and Topel (2005), which matches the benchmark EIS of 0.8. [16]

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[16] Interestingly, larger values of the RRA σ imply a larger shadow price of unemployment, but also a larger imputed consumption if dead B in order to match the VSL. At $\sigma \approx 6$, the value of B that yields a 6.3 millions USD is beyond 15

4.4.2. Epstein-Zin-Weil utility function

66. In the particular case where $\sigma = \eta$, the VSL can be expressed in closed-form (see appendix). In the general case, there is no such formula and the VSL is calculated numerically. As the Epstein-Zin-Weil utility function allows disentangling risk aversion from the elasticity of inter-temporal substitution, we fix the latter at $\sigma = 1.25$ in all calculations.

67. To calibrate the health-related risk aversion γ and its unemployment-related counterpart η, we calculate the VSL over a grid of those two parameters. The VSL happens to be equal to 6.3 millions USD for $\gamma = 0.676$ whatever the value of η. We therefore select the latter value for γ. The unemployment risk aversion parameter η is allowed to move freely. We now turn to the comparison of "objective" (model-based) and subjective valuations of the two latter risks.

Table 5 – Calibration of the models

	CRRA			Epstein-Zin-Weil	
	Ex-ante with life expectancy at birth	Ex-ante with T'=T-20	Recursive with T'=T-20	Recursive with T'=T-20 and low unemployment risk aversion	Recursive with T'=T-20 and high unemployment risk aversion
D	351	267	284	0	0
σ	1.25	1.25	1.25	1.25	1.25
η	-	-	-	1.25	25
γ	-	-	-	0.676	0.676
Implied VSL (USA 2004)	6.3	6.3	6.3	6.3	6.3

5. IS THERE A LAW OF ONE SHADOW PRICE?

5.1. Is there a law of one shadow price?

68. Table 6 and Figure 2 report the compensating incomes calculated from the two approaches. For the subjective one, we select shadow prices derived from the inclusion of the unemployment rate into life satisfaction regressions (Table 3 Column 3) or from the inclusion of the income risk measure that aggregates information on both unemployment and the replacement rate (Table 4 Column 4).

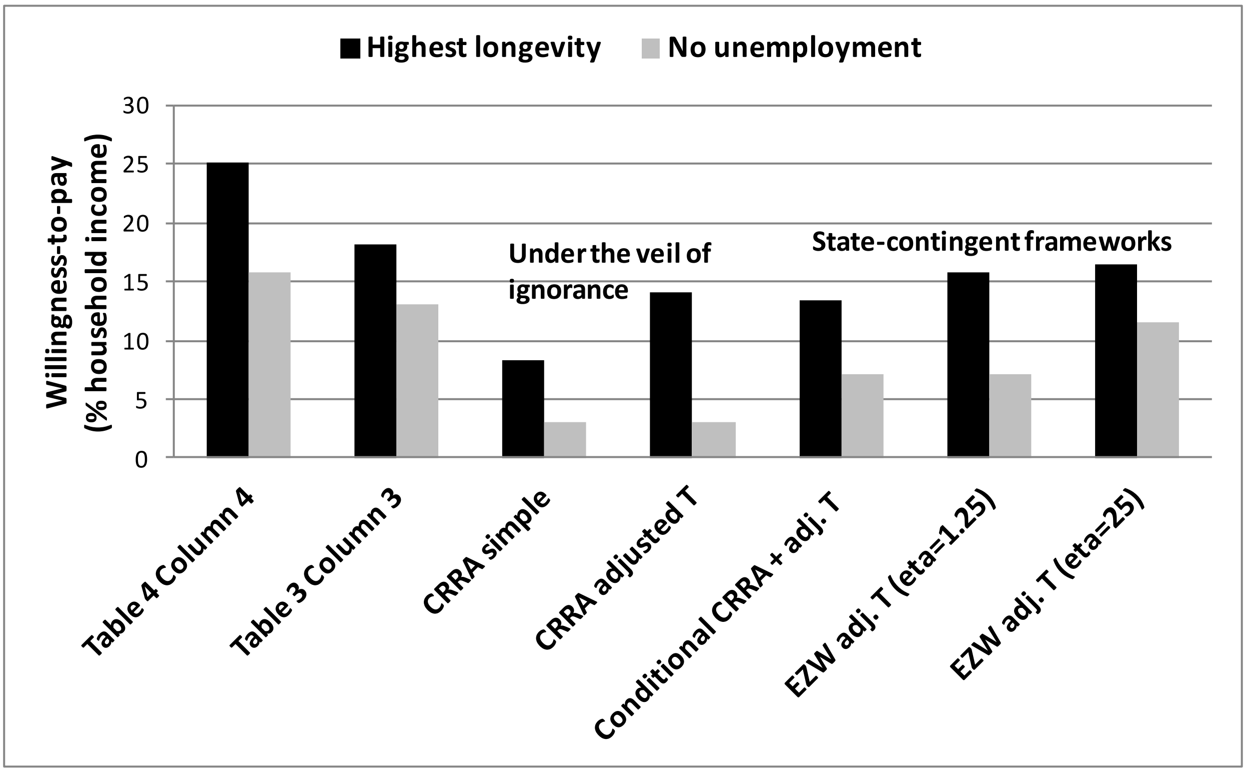
69. As shown on Figure 2, the valuations of health derived from subjective data are larger than the model-based counterpart derived from the simple CRRA framework under the veil of ignorance (third set of bars) by a factor of three. Interestingly, adjusting life expectancy to account for the remaining lifetime of an adult (i.e. using $T' = T - 20$) helps a lot reconciling model-based and subjective health shadow prices (fourth set of bars). Then, the Epstein-Zin-Weil utility function raises the valuation of health among low-income countries, and hence the average valuation. As a result, the subjective valuation of health as given by the second set of bars is almost equal to the model-based valuation provided by the Epstein-Zin-Weil utility function.

000 USD, a threshold that is larger than the average household income in many countries of our sample. This is why we stick to the value of $\sigma \approx 1.25$ when using the CRRA utility function.

Table 6 – Comparison of Subjective and Model-based Valuation of Vital and Unemployment Risks by Country - 2009

	SUBJECTIVE Table 3 column 3		SUBJECTIVE Table 3 Column 4		CRRA non-adjusted T w=351		CRRA adjusted T w=276		CRRA recursive and adjusted T w=284		EPSTEIN-ZIN-WEIL adjusted T eta=1.25 gam=0.676		EPSTEIN-ZIN-WEIL adjusted T eta=25 gam=0.676	
	T	U	T	U	T	U	T	U	T	U	T	U	T	U
AUS	-1856	-2470	-2691	-3752	-916	-568	-1592	-568	-1571	-1336	-1581	-1381	-1579	-1700
AUT	-3698	-2134	-5268	-2475	-1893	-162	-3239	-162	-3180	-662	-3265	-657	-3262	-801
BEL	-3903	-3239	-5537	-3345	-1968	-335	-3361	-335	-3310	-1346	-3479	-1286	-3501	-1835
CAN	-3054	-3651	-4381	-4305	-1547	-667	-2664	-667	-2634	-1703	-2661	-1784	-2673	-2035
CHE	-1169	-1795	-1706	-2132	-569	-119	-994	-119	-974	-619	-982	-571	-971	-835
CHL	-1912	-1540	-2681	-2575	-637	-1349	-1117	-1349	na	na	na	na	na	na
CZE	-4307	-1793	-5924	-2109	-1946	-243	-3286	-243	-3237	-881	-4092	-844	-4194	-1374
DEU	-3956	-3332	-5619	-2709	-2027	-169	-3462	-169	-3400	-964	-3515	-899	-3519	-1181
DNK	-4251	-2088	-5949	-2049	-2049	-148	-3478	-148	-3416	-602	-3892	-611	-3923	-704
ESP	-1621	-5885	-2350	-4145	-743	-829	-1297	-829	-1289	-2692	-1386	-2708	-1399	-3294
EST	-4317	-2682	-5794	-2493	-1816	-713	-3052	-713	-3051	-1782	-4332	-1787	-4618	-2703
FIN	-3405	-2953	-4830	-2719	-1631	-284	-2795	-284	-2751	-1001	-3035	-1026	-3048	-1179
FRA	-2448	-3830	-3529	-3715	-1219	-417	-2109	-417	-2078	-1519	-2111	-1496	-2109	-1929
GBR	-3704	-3332	-5275	-4393	-1874	-799	-3209	-799	-3180	-1960	-3281	-1980	-3325	-2755
GRC	-2762	-3140	-3939	-4173	-1262	-976	-2178	-976	-2172	-2264	-2445	-2280	-2530	-4127
HUN	-4616	-1958	-6136	-2113	-1990	-358	-3319	-358	-3286	-1173	-4712	-1156	-5018	-2192
IRL	-3368	-4538	-4795	-3477	-1649	-526	-2829	-526	-2795	-2034	-2983	-1957	-3013	-2739
ITA	-1662	-2707	-2405	-3644	-755	-713	-1316	-713	-1305	-1827	-1425	-1829	-1456	-3635
JPN	0	-1933	0	-3392	0	-646	0	-646	0	-1339	0	-1369	0	-1932
KOR	-2022	-998	-2888	-2319	-836	-411	-1454	-411	na	na	na	na	na	na
LUX	-4631	-2841	-6597	-3369	-2568	-237	-4372	-237	-4297	-973	-4089	-946	-4088	-1225
MEX	-2934	-901	-4008	-2043	-1084	-850	-1863	-850	-1871	-1220	-2847	-1262	-3165	-3511
NLD	-2861	-1518	-4099	-2171	-1405	-126	-2422	-126	-2375	-519	-2497	-502	-2488	-662
NOR	-2997	-1519	-4306	-2404	-1547	-141	-2664	-141	-2614	-501	-2599	-508	-2585	-604
NZL	-1858	-1734	-2667	-2433	-783	-460	-1364	-460	-1348	-1020	-1618	-1056	-1628	-1310
POL	-4188	-1766	-5673	-2616	-1783	-540	-3005	-540	-2985	-1222	-4114	-1233	-4317	-1967
PRT	-3509	-2811	-4919	-3338	-1570	-604	-2684	-604	-2662	-1724	-3216	-1705	-3315	-2919
RUS	-6279	-1630	-7931	-2041	-2985	-391	-4786	-391	na	na	na	na	na	na
SVK	-4819	-2645	-6473	-2903	-2123	-716	-3548	-716	-3542	-1869	-4831	-1895	-5215	-3733
SVN	-3478	-1824	-4889	-2505	-1584	-339	-2709	-339	-2671	-1119	-3164	-1132	-3273	-3050
SWE	-1927	-3277	-2789	-3423	-925	-415	-1609	-415	-1585	-1308	-1650	-1333	-1646	-1595
USA	-7797	-5191	-10849	-7080	-4456	-1929	-7416	-1929	-7423	-3775	-7254	-3906	-7505	-4984
Average	**-3291**	**-2614**	**-4590**	**-3074**	**-1567**	**-537**	**-2662**	**-537**	**-2655**	**-1412**	**-3002**	**-1417**	**-3081**	**-2156**

Figure 2 – Average Compensating Income Differentials for Vital and Unemployment Risks



70. Turning to the valuation of unemployment, the subjective shadow prices appear to be at least four times larger than that derived from the simple CRRA framework under the veil of ignorance. Adopting state-contingent, individual-level valuations with the CRRA utility function divides the latter ratio by two as shown by the fifth set of bars. Finally, subjective and model-based shadow prices of unemployment can be matched by setting a (very) large risk aversion in the Epstein-Zin-Weil utility function. While a RRA coefficient of 25 seems largely excessive regarding the existing evidence on portofolio management and financial risks, the RRA pertaining to the risk of unemployment is, to the best of our knowledge, unexplored territory. As a result, the Epstein-Zin-Weil utility function can also account for the subjective shadow price of unemployment.

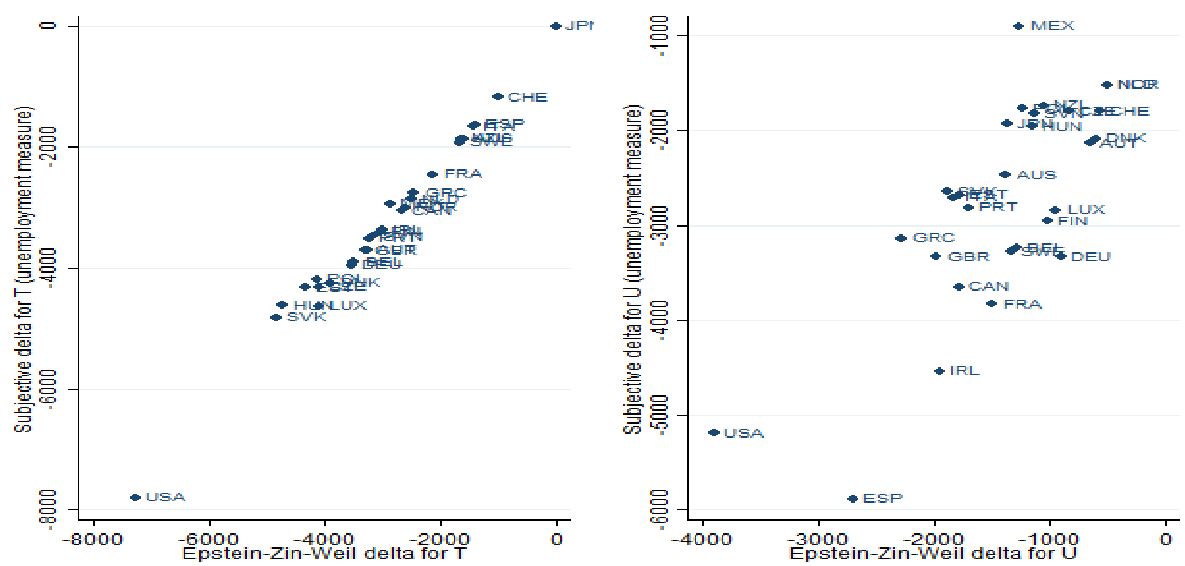
71. Table 6 reveals a few interesting differences across countries. For instance, the Epstein-Zin-Weil utility function yields higher compensating differentials for longevity relative to the CRRA case among lower-income countries. For instance, the willingness-to-pay for a longer life is about 50% larger in Eastern European countries (e.g. CZE, EST) or emerging countries (e.g. MEX) with Epstein-Zin-Weil preferences than with a CRRA utility function (both with adjusted longevity).

72. Next, Table 7 and Figure 3 depict the degree of cross-country correlations in the valuation of vital and unemployment risks across the various approaches. As health valuation depends on a single variable, namely longevity, it is not surprising to find very large correlations across the different methodologies. Only the average levels may differ. As the valuation of unemployment depends on both unemployment and the replacement rate, the degree of correlation is somewhat lowered. The model-based approach that displays the highest correlations with both subjective valuations is the Epstein-Zin-Weil utility function with low risk aversion. State-contingent valuations under CRRA utility also deliver comparable correlations with both subjective valuations. However, as shown in Table 6, the CRRA utility does not perform as well matching the levels of average valuations in the sample.

Table 7 – Table of cross-country correlations between compensating differentials

	Life expectancy		Unemployment	
	Subjective 1	Subjective 2	Subjective 1	Subjective 2
Subjective 2	0.99	1	0.78	1
CRRA	0.98	0.98	0.4	0.7
CRRA adjusted T	0.97	0.98	0.4	0.7
CRRA U. flows	**0.97**	**0.98**	**0.77**	**0.86**
Epstein-Zin-Weil low risk aversion	**0.99**	**0.99**	**0.76**	**0.87**
Epstein-Zin-Weil high risk aversion	0.99	0.97	0.45	0.62

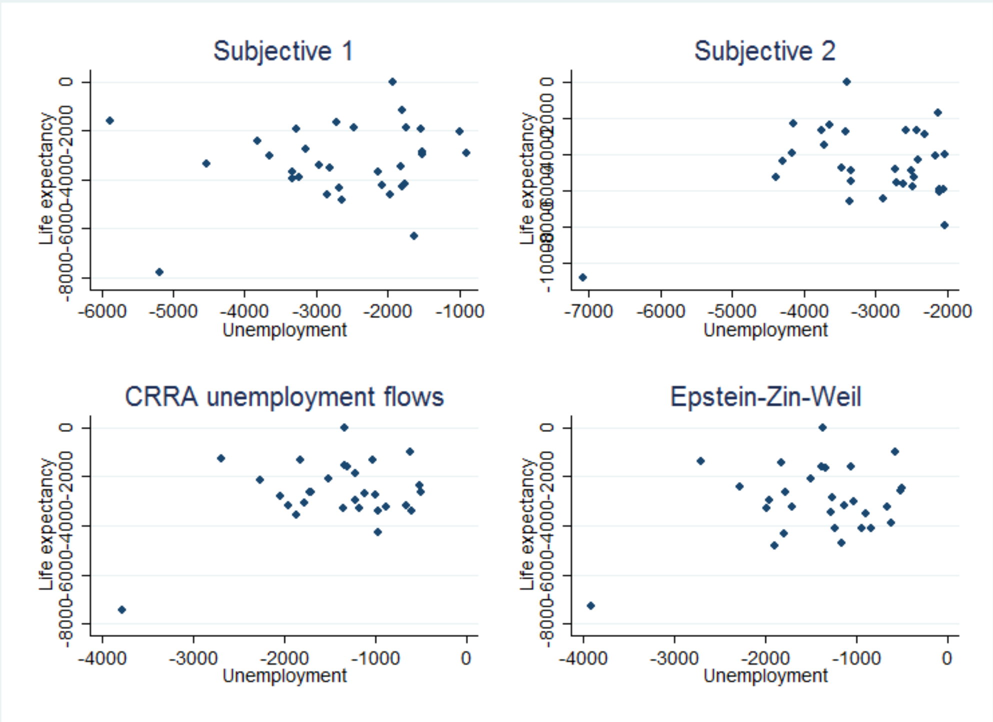
Figure 3 – Subjective and Model-based Valuations of the Vital and Unemployment Risks



5.2. *Welfare across OECD Countries*

73. Figure 4 describes the compensating income differentials for health with respect to those of unemployment across various settings (the two subjective valuations, the state-contingent model-based valuations under both the CRRA framework and Epstein-Zin-Weil with low risk aversion). The United States stands out as an outlier for both risks, as this country is characterized by relatively low longevity, high unemployment (in 2009), low replacement rates, and high income. Countries that consistently display large unemployment compensating differentials are either high-unemployment countries (e.g. ESP, IRL, FRA) or low-replacement rate countries (e.g. MEX, CHL, GRC, GBR). Then, large compensating income differentials for longevity are observed in Russia and Eastern European countries (e.g. SVK, EST, POL).

Figure 4 – Compensating Income Differentials for Vital and Unemployment Risks - 2009



74. To describe the levels of welfare at the country level, we select the estimates from the subjective valuation with an unemployment measure (Table 3 Column 3), which are broadly consistent with Epstein-Zin-Weil valuations.

75. Figure 5 depicts equivalent incomes among OECD countries, namely the sum of average household income and compensating incomes for the vital and unemployment risks. The correlation between equivalent income and household income is large (0.94) and so is the correlation of country ranks (0.93). This reflects the first-order importance of household income on economic welfare. However, the (negative) contributions of compensating incomes to equivalent income are far from being negligible, and sometimes involve large changes in country ranks. A telling example is the United States, which ranks first out of 29 in terms of household income, but only fifth in terms of equivalent income.

76. Moreover, compensating incomes represent a sizeable proportion of household income, about 30% on average and a much higher proportion among lower-income countries. As shown on Figure 6, the sum of longevity and unemployment compensating incomes represents more than 50% of household income in Estonia, Hungary and Slovakia, where longevity is quite far from OECD standards.

Figure 5 – Equivalent Incomes among OECD Countries – 2009

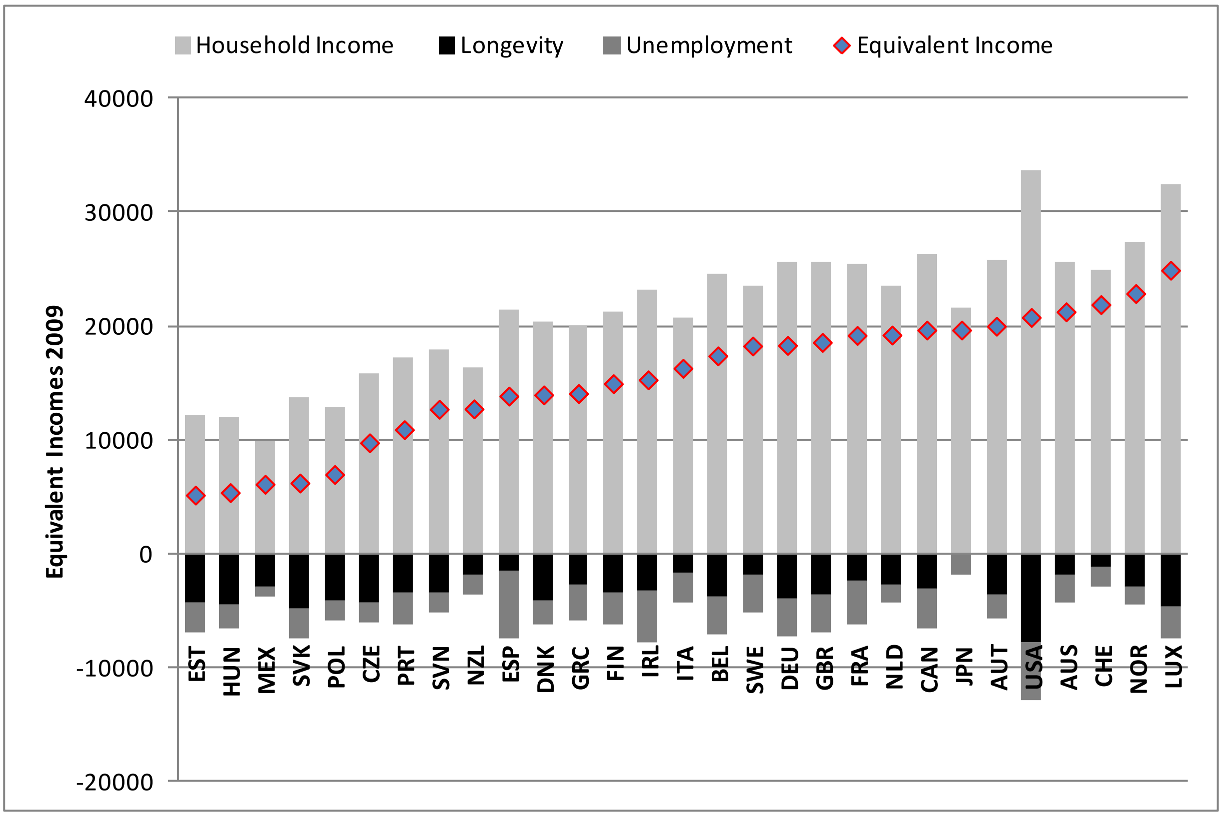
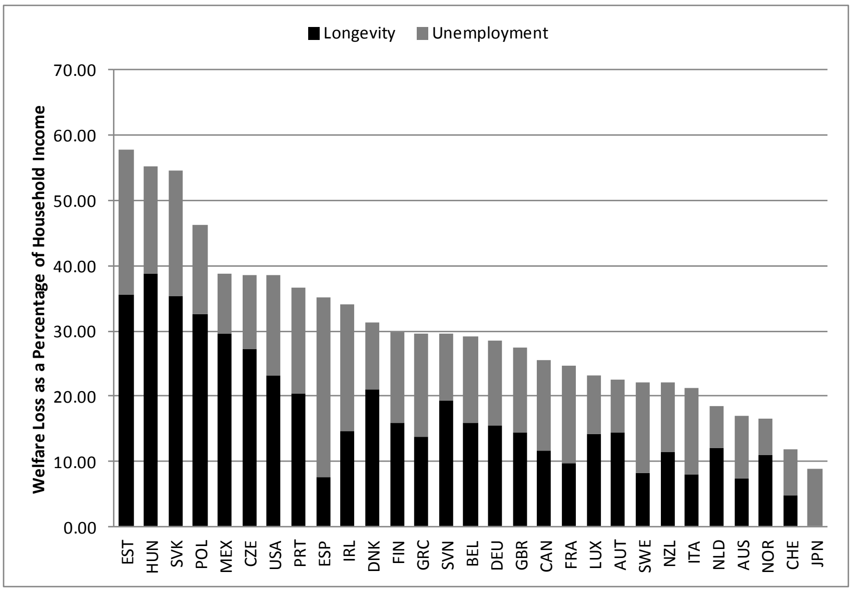


Figure 6 – Sum of Compensating Incomes as a Percentage of Household Disposable Income, 2009



6. CONCLUSION

77. This paper builds a measure of living standards encompassing household disposable income, unemployment and longevity, while using two different sets of “shadow prices” for non-income variables. The valuations of vital and unemployment risks estimated from life satisfaction data (“subjective shadow prices”) and those derived from model-based approaches and calibrated utility functions (“model-based shadow prices”) are shown to be broadly consistent with each other under a set of conditions. Subjective shadow prices appear to be inflated by the downward bias on the income variable in life satisfaction regressions conducted at the individual level, while the latter bias is largely removed when running regressions at the country level. On the other hand, model-based shadow prices are underestimated from: i) the valuation of the unemployment risk under the veil of ignorance (i.e. for a representative agent); ii) the use of a Constant Relative Risk Aversion utility function that does not disentangle relative risk aversion and the elasticity of intertemporal substitution; iii) calibration issues as the Value of a Statistical Life pertains to an adult life rather than the whole life cycle.

78. This paper paves the way for the construction of series of aggregate living standards among OECD countries, and for the inclusion of inequality (e.g. across educational groups or across gender) in the fundamental dimensions of living standards. Before that, it will be necessary to examine the robustness of shadow prices estimates to various proxy variables (e.g. employment rather than unemployment, health life expectancy rather than life expectancy etc…) and different econometric methods or life satisfaction databases. This research agenda is currently being pursued in Boarini et al. (2015).

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APPENDIX

A.1. Derivation of unemployment risk measures

Consider the following set of utility and life satisfaction definition:

$$U^1 = E(\tilde{y})(1+\lambda CV(\tilde{y}))\exp(\gamma T), \quad \lambda < 0 \quad \text{with} \quad LS = a + \alpha \log(U^1) + \varepsilon^1 \qquad \text{(A1)}$$

and denote y as the average of the stochastic disposable income $\tilde{y}$, which is equal to employment income y^e with probability $1-u$ and to $\tau.y^e$ with probability un (the unemployment rate, while τ denotes the replacement rate). Average income verifies:

$$y = y^e(1 - un + \tau.un) \qquad \text{(A2)}$$

Consider utility U^1. The variance of $\tilde{y}$ is equal to $(y^e)^2(1-u) + \tau^2(y^e)^2 u - y^2$. Taking stock of (A2), we obtain after a few algebraic manipulations the following expression for the coefficient of variation in income:

$$CV(\tilde{y}) = \frac{1-\tau}{1-un+\tau.un}(un - un^2)^{1/2} \qquad \text{(A3)}$$

Taking logs of utility U^1 and using (A1) yields:

$$LS = a + \alpha\left(\log(y) + \log(1+\lambda CV(\tilde{y})) + \gamma T\right) + \varepsilon^1 \qquad \text{(A3)}$$

Empirically, the distribution of $CV(\tilde{y})$ across countries and time has mean 0.12 and standard deviation 0.06. It can reasonably be viewed as small, and one hypothesizes that the following approximation does hold: $\log(1+\lambda CV(\tilde{y})) \approx \lambda CV(\tilde{y})$. This hypothesis appears to be valid as the relative elasticity of $CV(\tilde{y})$ in table 3 column 3 is equal to -3.823/3.893 so that $\lambda \approx -1$. This confirms that $\lambda CV(\tilde{y})$ is relatively small. The specification of the regression depicted in Table 3 column 3 follows.

A.2. Solutions for the state-contingent valuations under CRRA utility

The closed form solution is as follows:

$$w(e) = u(c(e)) + \beta\pi[\rho_e w(e) + (1-\rho_e)w(u)] = u(c(e)) + \beta\pi[\rho_e(w(e)-w(u)) + w(u)]$$

and

$$w(u) = u(c(u)) + \beta\pi[\rho_u w(e) + (1-\rho_u)w(u)] = u(c(u)) + \beta\pi[\rho_u(w(e)-w(u)) + w(u)].$$

This is a system of two linear equations in two unknowns, *w(u)* and *w(e)*. Substracting one from the other:

$$w(e) - w(u) = u(y(e)) - u(y(u)) + \beta\pi[(\rho_e - \rho_u)(w(e)-w(u))]$$

or

$$w(e) - w(u) = \frac{u(y(e)) - u(y(u))}{1-\beta\pi(\rho_e - \rho_u)}$$

Plugging this result into *w(u)* yields :

$$w(u) = \frac{1}{1-\beta\pi}\frac{u(c(u))(1-\beta\pi\rho_e) + \beta\pi\rho_u u(c(e))}{1-\beta\pi(\rho_e - \rho_u)}.$$

Furthermore,

$$w(e) = \frac{1}{1-\beta\pi}\left\{\frac{u(c(e))(1-\beta\pi(1-\rho_u)) + \beta\pi(1-\rho_e)u(c(u))}{1-\beta\pi(\rho_e - \rho_u)}\right\}.$$

A.3. Special case of the Epstein-Zin-Weil utility function with $\sigma = \eta$

Although the general Epstein-Zin-Weil model described above does not admit a closed-form solution, one exists for the case in which $\sigma = \eta$, which we adopt as a benchmark case. Below we set $\sigma = 1.25$, a standard value under CRRA utility. From this perspective, the case $\sigma = \eta$ corresponds to a lower bound on the willingness to pay for the elimination of unemployment risk, as values $\eta > \sigma$ are needed to generate more substantial premiums.

In this special case, welfare for an unemployed individual is given by

$$w(u) = \frac{1}{1-\tilde{\beta}(\pi)}\frac{c(u)^{1-\sigma}}{1-\sigma}\left\{\frac{1-\tilde{\beta}(\pi)(\rho_e - \rho_u\tau^{\sigma-1})}{1-\tilde{\beta}(\pi)(\rho_e - \rho_u)}\right\},$$

while that for the employed individual is

$$w(e) = \frac{1}{1-\tilde{\beta}(\pi)}\frac{c(e)^{1-\sigma}}{1-\sigma}\left\{\frac{1-\tilde{\beta}(\pi)(1-\rho_u - \tau^{1-\sigma}(1-\rho_e))}{1-\tilde{\beta}(\pi)(\rho_e - \rho_u)}\right\}.$$

Notice that in the absence of unemployment, individual lifetime utility would reduce to

$$w(c) = \frac{1}{1-\tilde{\beta}(\pi)}\frac{c^{1-\sigma}}{1-\sigma},$$

which corresponds to the present value of all future utility flows discounted at the effective rate $\tilde{\beta}(\pi)$. Thus the terms in brackets in equations for *w(u)* and *w(e)* above capture additional effect of unemployment risk on individual welfare.

Aggregate welfare in the case $\sigma = \eta$ is given by

$$W(y) = (1-UN)\times w(e) + UN \times w(u)$$

which reduces to the following simple expression

$$W(y) = \frac{1}{1-\tilde{\beta}(\pi)} \frac{y^{1-\sigma}}{1-\sigma} \frac{1-UN+UN\tau^{1-\sigma}}{\left(1-UN+UN\tau\right)^{1-\sigma}}.$$

Similarly, closed form solutions can be obtained for the health and unemployment premiums, which are given by

$$\delta_h = y\left(\left(\frac{1-\tilde{\beta}(\pi^*)}{1-\tilde{\beta}(\pi)}\right)^{\frac{1}{1-\sigma}} - 1\right)$$

and

$$\delta_u = y\left(\frac{\left(1-UN+UN\tau^{1-\sigma}\right)^{\frac{1}{1-\sigma}}}{1-UN+UN\tau} - 1\right).$$

As expected, the unemployment equivalent income is equal to the one derived with a CRRA utility function.