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VALUING LIFE AS AN ASSET, AS A STATISTIC, AND AT GUNPOINT*

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Rationalising the stark differences between the human capital and the statistical values of a human life is complicated by the absence of common foundations. We solve a human capital investment model with longevity risk to characterise the human capital. The associated indirect utility yields the willingness to pay against mortality; the marginal willingness to pay solves the value of a statistical life. Indifference between life and certain death characterises the limiting willingness to pay and provides a gunpoint value. A structural estimation reveals similar human capital ($300,000) and gunpoint value ($251,000) and explains a much larger statistical value ($4.98 million) by a strongly concave willingness to pay.

Computing the economic value of a human life is often required in policy, societal as well as legal debates and has long generated a deep interest among researchers.[1] Indeed, life valuations are called upon in public health and safety issues, such as for cost–benefit analyses of life-saving measures in transportation, environmental, or medical settings. They are also important in long-run debates on quality versus quantity of life, such as whether to spend more resources on innovations that foster consumption growth or on those that prolong life expectancy.[2] Moreover, economic life values are resorted to in assessing the tolls of war, in wrongful death litigation, as well as in terminal care cost–benefit analysis.

An agent's willingness to pay (WTP) or to accept (WTA) compensation for changes in death risk exposure is a key ingredient for life valuation. Indeed, a shadow price of a life can be deduced through the individual marginal rate of substitution (MRS) between mortality and wealth. In the same vein, a collective MRS between life and wealth relies on the value of a statistical life (VSL) literature to calculate the societal WTP to save an unidentified (i.e., statistical) life. The VSL's domain of application relates to public health and safety decisions benefiting unidentified persons. In contrast, the human capital (HK) life value relies on asset pricing theory to compute the present value of an identified person's cash flows corresponding to his[3] labour income, net of the measurable investment expenses. HK values are used for valuing a given life, such as

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The authors were granted an exemption to publish their data because access to the data is restricted. However, the authors provided the Journal with temporary access to the data, which allowed the Journal to run their codes. The codes are available on the Journal repository. The data and codes were checked for their ability to reproduce the results presented in the paper. The replication package for this paper is available at the following address: https://zenodo.org/record/5393193.

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[1] Kiker (1966) and Landefeld and Seskin (1982) make reference to human capital-based evaluations of the value of life dating back to Petty (1691). See also Hofflander (1966) for historical perspectives on life valuation.

[2] See Becker *et al.* (2005), Murphy and Topel (2006), Hall and Jones (2007), Jones (2016) and Jones and Klenow (2016) for quality versus quantity of life arbitrages.

[3] We henceforth refer to an agent using the 'he/his' pronouns not to distinguish gender, but solely to alleviate exposition.

in wrongful death litigation,[4] or in measuring the economic costs of armed conflict.[5] Finally, a gunpoint value of life (GPV) measures the maximal amount a person is willing to pay to avoid certain, instantaneous death. The GPV is theoretically relevant for end-of-life (e.g., terminal care) settings, yet, to the best of our knowledge, no empirical evaluation of the gunpoint life value exists.[6]

In practice, both HK and VSL valuations of a human life yield strikingly different measures with HK estimates being much lower than VSL values. For example, Huggett and Kaplan (2016) identify HK values between \$300,000 and \$900,000, whereas the US transportation authority recommends using a VSL-type amount of \$9.4 million (US Department of Transportation, 2016). Although it is well recognised that HK and VSL life values need not be equal,[7] rationalising differences of such magnitude is complicated by the fact that HK and VSL evaluations neither share joint theoretical underpinnings, nor common database, nor encompassing identification strategy.

We contribute to the research on life valuation by providing the first *joint benchmark* estimates of the WTP, HK, VSL and GPV, within the context of a theoretically, and empirically integrated approach. The proposed framework involves solving and structurally estimating a flexible life cycle problem which departs from standard approaches in two key dimensions. First, our model features endogenous financial and human capital accumulation for an agent exposed to financial, depreciation and longevity risks. Human capital benefits income and can be interpreted either as skills (e.g., Ben-Porath, 1967; Heckman, 1976) or as health (e.g., Grossman, 1972; Ehrlich and Chuma, 1990), and is subject to stochastic depreciation shocks (e.g., unemployment, obsolescence or illness). Second, we rely on recursive utility which disentangles attitudes towards risk from those towards inter-temporal substitution. This specification is useful in guaranteeing strict preference for life over death, in allowing more flexible trade-offs between quantity (i.e., longevity) and quality of life (i.e., consumption), as well as in reconciling savings with other financial choices.[8]

Our first main contribution is theoretical and shows that the optimal rules and associated indirect utility function for our human capital model are *sufficient* to fully integrate and characterise the four life valuation measures. This remarkable result can be traced back to two channels. First, the dynamics of capital along the optimal path determine the lifetime flow of income net of investment. This dividend can be capitalised using the stochastic discount factor consistent with the agent's opportunity set to characterise the HK value. Second, the indirect utility calculated at the optimum can be combined with variational analysis (Hicks, 1946) to define the willingness to pay to prevent increases in mortality risk exposure. We show that the marginal WTP defines the theoretical VSL, whereas the limiting WTP identifies the gunpoint value as the maximal willingness to pay that leaves an agent indifferent between living and dying. These four closed-form life valuations precisely pinpoint the contributions of fundamentals (i.e.,

[4] See Symmons (1938), Kiker (1966) and Mishan (1971) for descriptions and discussions of HK and VSL. See Viscusi (2000; 2007) for legal uses of HK and VSL life values. See also Posner and Sunstein (2005) for comparisons between administrative (e.g., VSL used by regulatory agencies) and legal (i.e., HK used in litigation) life value measurement.

[5] See Eden (1972) for a HK analysis of the value of enlisted men and officers' lives lost in Southeast Asian wars.

[6] See Jones-Lee (1974), Cook and Graham (1977) and Eeckhoudt and Hammitt (2004) for related definitions of the GPV, and Philipson *et al.* (2010), Round (2012) and Hugonnier *et al.* (2020) for end-of-life discussions.

[7] See Conley (1976), Shepard and Zeckhauser (1984), Pratt and Zeckhauser (1996) and Viscusi (2000; 2007) for discussions.

[8] See Hugonnier *et al.* (2013) and Córdoba and Ripoll (2017) for discussion of preference for life and additional flexibility in longevity versus wealth trade-offs in recursive preferences. Epstein and Zin (1989; 1991) and Duffie and Epstein (1992) discuss the role of separation in attitudes in reconciling consumption and financial decisions.

preferences, risk distributions, or technology) and of state variables (i.e., wealth and capital levels) thereby allowing us to investigate how the WTP, HK, VSL and GPV are theoretically related to one another.

Our second main contribution is empirical. We *structurally* estimate the model's distributional, technological and preferences parameters by associating human capital to health and by resorting to Panel Study of Income Dynamics (PSID) data that correspond to the optimal consumption, portfolio, as well as health spending and insurance policies. A revealed preference perspective then allows us to combine the estimated deep parameters with observed wealth and health variables to estimate the analytical expressions for the willingness to pay, human capital, statistical and gunpoint values of life. Our encompassing approach thus ensures that the WTP and the three different life values are computed through a single-step estimation, using the same data set, and imposing strict compliance with common theoretical conditions thereby ensuring a shared identification strategy. The structural estimation of the analytical solutions with 2017-PSID data confirms that the HK ($300,000) and GPV ($251,000) are close to one another and that the strong curvature of the WTP explains a much larger VSL ($4.98 million).

Our integrated value of life framework remains an essentially positive exercise in that we do *not* provide a normative ranking of the various life values. Indeed, this paper fully accords with the previous literature that different life valuation methods are not substitutes, but rather complements to one another. Which of these four instruments should be relied on depends on the questions to be addressed. The COVID-19 pandemic may be used to illustrate the relevance of our life valuations. Whereas we do not quantify the high economic costs of increased physical and mental illnesses, our integrated approach offers single-step estimates of the WTP, HK, VSL and GPV that can address four different *ex ante* and *ex post* policy issues associated with the higher mortality risk exposure resulting from the pandemic.[9]

The first policy question is whether the substantial public resources allocated to vaccine development and distribution as well as in compensation for financial losses linked to shutdowns are economically justifiable on the basis of lives saved by the intervention. Our VSL estimate computes the *societal* willingness to pay for a mortality reduction of an unidentified person and is therefore appropriate for the relevance of public spending. The second policy question is whether or not other alternatives such as enforcing social distancing, sanitary measures or vaccination through regulation, fines or subsidies should complement and/or could be more efficient than public spending. Our WTP measure calculates the *individual* marginal rate of substitution between wealth and mortality risk and is therefore applicable to infer the agents' responses to changes in death risk exposure.

Consider next the case where an infected person j's health deteriorates and is admitted to the intensive care unit (ICU). If access to life support in the ICU is constrained, our GPV measure calculates person j's valuation of their *own* life and can be used to decide whether or not terminal care should be maintained or reallocated. If instead j dies as a result of COVID, both our HK and GPV values can be used by courts in litigation against the state, care provider, employer or other agents for insufficient intervention, malpractice or negligence. Indeed, the human capital value gauges person j's tangible losses associated with foregone net income, whereas the GPV also provides a measure of j's intangible 'loss of life's pleasures' relied on by courts for hedonic damages calculations. Both the GPV and HK values complement the VSL and are therefore useful to the government for value-at-risk calculations in deciding whether

[9] See also Atkeson *et al.* (2020), Balmford *et al.* (2020), Glover *et al.* (2020), Hammitt (2020), Pindyck (2020), Viscusi (2020; 2021) and Gollier (2021) for analyses of life values in a COVID-19 context.

or not to spend public funds on prevention, treatment and compensation. The four instruments we recover are thus theoretically (common model, assumptions, definitions) and empirically (structural estimation, common data base) consistent with one another. Our approach is also very flexible and can be adapted to a different model of human capital accumulation (e.g., with ageing, work/leisure choices, etc.) and/or different data bases or stratification of a common data (e.g., general population, tax payers, pro- or anti-vaccine, etc.).

The reliance on an integrated approach to life valuation provides answers to a number of open issues.[10] First, to what extent can the four different life valuation concepts be empirically revealed by observed financial and capital choices made by agents? We show that *all* measures are identifiable from a cross-section of the widely used and representative PSID data set from which household consumption, portfolio, health investment and insurance decisions are explained with health and wealth covariates. Second, are the large differences between the HK and VSL due to disjoint theoretical and empirical frameworks? We show that it is not the case; our integrated estimates yields gaps between the two that are of the same order of magnitude as those identified by the segmented, reduced-form HK/VSL literature. Third, how does the (previously un-quantified) gunpoint value compare with these HK and VSL values? We show that our estimated GPV is both theoretically and empirically close to the HK value.

Fourth, what are the theoretical reasons behind the much larger VSL estimates? We show that the estimated individual WTP is increasing, very concave and bounded above in the change in the death risk exposure. The VSL is the marginal willingness to pay (MWTP), whereas the GPV is the limiting WTP. Given that a linear projection with a slope equal to the MWTP necessarily overestimates the upper bound of an increasing and concave WTP, the VSL is much larger than the GPV. Fifth, what role do technological and distributional assumptions play in these life values? We show that the human capital accumulation and risks parameters uniquely pin down the shadow price (i.e., Tobin's q) of human capital. This value of capital can be combined with observed capital and wealth to obtain a net total wealth measure. Human and/or net total wealth condition all four life value measures. Finally, what role do the preferences play? We show that they are absent from the human capital value. Minimal consumption is a key driver for the VSL, WTP and GPV. Attitudes towards risk and time, especially the elasticity of inter-temporal substitution (EIS), determine the VSL and the WTP. However, as death is certain and instantaneous in a gunpoint threat, risk aversion and the EIS play no role in the GPV.

In addition to the segmented research on HK, WTP, VSL and GPV, our paper contributes to the literature on encompassing and on theoretical models of life valuations. First, the links between the WTP, the VSL and a willingness to pay that is equivalent to the GPV have been explored in a static setup by Jones-Lee (1974). In addition, Conley (1976), Shepard and Zeckhauser (1984) and Rosen (1988) use life cycle models of human capital to relate HK and the VSL. However, none of these contributions link all four main valuations in an encompassing framework and none provide joint estimation of the HK, WTP, VSL and GPV measures as we do. Second, our paper is related to theoretical life valuation models. Hugonnier *et al.* (2013); Córdoba and Ripoll (2017); Bommier *et al.* (2019) also study VSL and WTP in the context of life cycle models with recursive preferences. We contribute to these papers by incorporating HK, and GPV as well, by characterising the links between and structurally estimating all four measures with a common database.

[10] We provide a more comprehensive review of the relevant literature in Section A in the Online Appendix.

The rest of the paper is organised as follows. We first present and solve our human capital model in Section 1. The associated optimal rules and welfare are used to characterise the implied life valuations in Section 2. Section 3 reviews the empirical strategy. Section 4 presents the structural parameters and life value estimates. Concluding remarks are presented in Section 5. All supplementary material, including proofs, additional theoretical results, empirical details and robustness checks is regrouped in the Online Appendix.

1. Human Capital Model

1.1. *Economic Environment*

1.1.1. *Overview*

We focus on a continuous-time life cycle model of endogenous human capital (e.g., skills, health) accumulation, subject to exogenous stochastic depreciation (e.g., unemployment, morbidity) and duration (e.g., mortality) shocks. Capital is valuable because of the additional income it procures. In addition to investment, we characterise optimal dynamic choices in consumption/savings, risky portfolio and insurance against capital shocks. We feature generalised recursive, rather than Von Neumann–Morgenstern (VNM) preferences, that separate attitudes towards financial risk from those towards inter-temporal substitution. This characteristic not only better reconciles consumption with financial decisions, but crucially ensures that the agent unconditionally prefers life over death. Our market setting is inherently incomplete with three sources of risks (financial, mortality and capital) and only two assets. However, the model can be recast as an equivalent setting with complete markets and heavier discounting.

All proofs for the current and subsequent sections are regrouped in the Online Appendix B. We also review the effects of some of the model's key theoretical assumptions in the Online Appendix C. These include incorporating work/leisure decisions (Online Appendix C.1), discussing investment versus consumption perspectives of spending on human capital (Online Appendix C.2), allowing for direct utilitarian services (Online Appendix C.3), and endogenous mortality and morbidity risks exposures (Online Appendix C.4) as well as ageing (Online Appendix C.5). Finally, we contrast our model with a well-known alternative in the health capital literature (Online Appendix C.6).

1.1.2. *Planning horizon and human capital dynamics*

The agent's planning horizon is bounded by a stochastic age at death T_m satisfying:

$$\lim_{h\to 0}\frac{1}{h}\Pr\{T_m\in(t,t+h]\mid T_m>t\}=\lambda_m, \tag{1}$$

such that the probability of death by age t is monotone increasing in the arrival rate $\lambda_m>0$:

$$\Pr(T_m\le t)=1-e^{-\lambda_m t}. \tag{2}$$

Subsequent analysis will focus on changes in mortality risk exposure stemming from permanent changes in death intensity λ_m.[11]

The agent invests at rate I_t in his human capital H_t whose law of motion is given by:

$$\mathrm{d}H_t=\left(I_t^{\alpha}H_t^{1-\alpha}-\delta H_t\right)\mathrm{d}t-\phi H_t\mathrm{d}Q_{st}, \tag{3}$$

[11] See also Murphy and Topel (2006) for a similar perspective.

where the Cobb-Douglas parameter $\alpha \in (0, 1)$ captures diminishing returns to investment, $\delta > 0$ measures the continuous deterministic depreciation of human capital in the absence of investments, and $\mathrm{d}Q_{st}$ is the increment of a Poisson process with constant intensity λ_s whose jumps further depreciate the capital stock by a factor $\phi \in (0, 1)$.

The law of motion (3) admits alternative interpretations of human capital. If H_t is associated with skills (e.g., Ben-Porath, 1967; Heckman, 1976), then investment I_t comprises education and training choices made by the agent whereas $\mathrm{d}Q_{st}$ can be interpreted as stochastic unemployment or technological obsolescence shocks that depreciate the human capital stock. If H_t is instead associated with the agent's health (e.g., Grossman, 1972; Ehrlich and Chuma, 1990), then investment takes place through medical expenses or healthy lifestyle decisions whereas the stochastic depreciation occurs through morbidity shocks.

1.1.3. *Budget constraint and preferences*

The agent's income rate is given by:

$$Y_t = Y(H_t) = y + \beta H_t, \tag{4}$$

and includes both an exogenous base income y and a positive income gradient β for human capital capturing higher labour income for skilled or healthy individuals. Individuals can trade in a riskless asset with return r, as well as in two risky assets to smooth out shocks to consumption: stocks and insurance against human capital depreciation. Financial wealth W_t evolves according to the dynamic budget constraint:

$$dW_t = (rW_t + Y_t - c_t - I_t)\,\mathrm{d}t + \pi_t\sigma_S\,(\mathrm{d}Z_t + \theta\mathrm{d}t) + x_t\,(\mathrm{d}Q_{st} - \lambda_s\mathrm{d}t)\,, \tag{5}$$

where $\sigma_S > 0$ is the volatility of the stock, $\theta = (\mu - r)/\sigma_S$ is the market price of financial risk and Z_t is a Brownian motion. In addition to investment I_t, the agent selects consumption c_t, the risky portfolio π_t and the number of units x_t of actuarially fair depreciation insurance. The insurance pays one unit of the numeraire following the occurrence of a depreciation shock $\mathrm{d}Q_{st}$, is priced at intensity λ_s per unit of time and can be interpreted as unemployment insurance (if H_t is associated with skills), or as medical or disability insurance (if H_t is associated with health status).

Following Hugonnier *et al.* (2013) we define the indirect utility of a live agent as:

$$V(W_t, H_t) = \sup_{(c,\pi,x,I)} U_t, \tag{6a}$$

where preferences are given by

$$U_t = E_t \int_t^{T_m} \left(f(c_\tau, U_\tau) - \frac{\gamma|\sigma_\tau(U)|^2}{2U_\tau} \right) \mathrm{d}\tau, \tag{6b}$$

where $\sigma_t(U) = \mathrm{d}\langle Z, U\rangle/\mathrm{d}t$ denotes the volatility of the continuation utility process, and $f(c, u)$ is the Kreps–Porteus aggregator function defined by:

$$f(c, u) = \frac{\rho u}{1 - 1/\varepsilon} \left(\left(\frac{c - a}{u} \right)^{1-\frac{1}{\varepsilon}} - 1 \right). \tag{6c}$$

The preference specification in (6a)–(6c) belongs to the stochastic differential utility class proposed by Duffie and Epstein (1992) and is the continuous-time analogue of the discrete-time recursive preferences of Epstein and Zin (1989; 1991).[12] It is characterised by a subjective discount rate $\rho > 0$, a minimal subsistence consumption level $a > 0$, risk neutrality with respect to both depreciation shocks and death, and disentangles the agent's elasticity of inter-temporal substitution (EIS) $\varepsilon \geq 0$ from his constant relative risk aversion with respect to financial risk $\gamma \geq 0$. As explained in Hugonnier *et al.* (2013) and confirmed in Theorem 1 below, the homogeneity properties of our specification imply that any feasible consumption process $c_t - a \geq 0$ is associated with a positive continuation utility and therefore guarantees preference for living over death: $V_t \geq V^m \equiv 0$, where V^m is the utility at death.

1.2. *Optimal Rules*

1.2.1. *Solving the model*

The agent's dynamic problem (6a)–(6c), subject to (3) and (5) can be recast through the Hamilton–Jacobi–Bellman (HJB) equation:

$$
\begin{aligned}
0 = \max_{\{c,\pi,x,I\}} & \frac{(\pi\sigma_S)^2}{2} V_{WW} + H\left[(I/H)^2 - \delta\right] V_H + [rW + \pi\sigma_S\theta - c + y + \beta H - I - x\lambda_s]\, V_W \\
& + \frac{\rho V(W,H)}{1-\frac{1}{\varepsilon}}\left[\left(\frac{c-a}{V(W,H)}\right)^{1-\frac{1}{\varepsilon}} - 1\right] - \frac{\gamma\,(\pi\sigma_S V_W)^2}{2V(W,H)} - \lambda_m V(W,H) \\
& - \lambda_s V(W,H)\left[1 - \frac{V(W+x, H(1-\phi))}{V(W,H)}\right].
\end{aligned}
$$

It can also be solved in two separate steps:[13]

1. A *hypothetical* infinitely lived agent first solves the optimal investment by maximising the discounted value of the H-dependent part of net income:

   $$P(H_t) = \sup_{I\geq 0} \mathrm{E}_t \int_t^\infty \frac{m_\tau}{m_t}(\beta H_\tau - I_\tau)\,\mathrm{d}\tau,$$

   where

   $$m_t = \exp\left(-rt - \theta Z_t - \frac{1}{2}\theta^2 t\right), \tag{7}$$

   is the stochastic discount factor (SDF) induced by the prices of financial assets. The human wealth $P(H)$ is then combined with the agent's financial wealth and the present value of his base income stream net of minimal consumption expenditures to obtain the agent's net total wealth as:

   $$
   \begin{aligned}
   N(W_t, H_t) &= W_t + \mathrm{E}_t \int_t^\infty \frac{m_\tau}{m_t}\left(Y(H^*_\tau) - I^*_\tau - a\right)\mathrm{d}\tau \\
   &= W_t + \frac{y-a}{r} + P(H_t).
   \end{aligned} \tag{8}
   $$

[12] See also Palacios (2015) for a human capital problem with Duffie and Epstein (1992) preferences.

[13] See Bodie *et al.* (1992), Hugonnier *et al.* (2013), Palacios (2015) and Acemoglu and Autor (2018) for discussion and applications of separability of investment and financial decisions in human capital problems.

An important consequence of this characterisation is that, under market completeness, both the agent's optimal human capital investment I^* and their human wealth $P(H_t)$ can be determined independently of his preferences with respect to time or risk.

2. The finitely lived agent then selects the remaining policies $\bar{c}_t = c_t - a$, π_t and $\bar{x}_t = x_t - \phi P(H_t)$ by maximising utility (6a)–(6c), subject to the law of motion for net total wealth:

$$\mathrm{d}N_t = (rN_t - \bar{c}_t)\mathrm{d}t + \pi_t \sigma_S(\mathrm{d}Z_t + \theta \mathrm{d}t) + \bar{x}_t\,(\mathrm{d}Q_{st} - \lambda_s \mathrm{d}t)\,.$$

The remaining optimal consumption, portfolio and insurance policies as well as indirect utility function reinstate a role for preferences and finite lives and are calculated as functions of $P(H_t)$ and $N(W_t, H_t)$.

1.2.2. *Closed-form solutions*

In the context of our parametric model and under the completeness assumption both optimisation steps described earlier can be carried out, leading to the following result.

THEOREM 1. *Assume that the parameters of the model are such that*

$$(r + \delta + \phi\lambda_s)^{\frac{1}{\alpha}} > \beta, \tag{9a}$$

and denote the Tobin's q of human capital by $B > 0$, the unique solution to:

$$\beta - (r + \delta + \phi\lambda_s)B - (1 - 1/\alpha)(\alpha B)^{\frac{1}{1-\alpha}} = 0, \tag{9b}$$

subject to:

$$r + \delta + \phi\lambda_s > (\alpha B)^{\frac{\alpha}{1-\alpha}}. \tag{9c}$$

Assume further that the marginal propensity to consume out of net total wealth, $A > 0$ satisfies:

$$A(\lambda_m) = \varepsilon\rho + (1-\varepsilon)\left(r - \lambda_m + 0.5\frac{\theta^2}{\gamma}\right) \tag{10a}$$

$$> \max\left(0, r - \lambda_m + \frac{\theta^2}{\gamma}\right). \tag{10b}$$

Then,

1. *the human wealth and net total wealth are given as:*

$$P(H_t) = BH_t \geq 0 \tag{11}$$

$$N(W_t, H_t) = W_t + \frac{y-a}{r} + P(H_t) \geq 0, \tag{12}$$

2. *the indirect utility for the agent's problem is:*

$$V_t = V(W_t, H_t, \lambda_m) = \Theta(\lambda_m)N(W_t, H_t) \geq 0 \tag{13a}$$

$$\Theta(\lambda_m) = \tilde{\rho}A(\lambda_m)^{\frac{1}{1-\varepsilon}} \geq 0, \quad \tilde{\rho} = \rho^{\frac{\varepsilon}{1-\varepsilon}}, \tag{13b}$$

and generates the optimal rules:

$$
\begin{aligned}
c_t^* &= c(W_t, H_t, \lambda_m) = a + A(\lambda_m)N(W_t, H_t) \geq 0, \\
\pi_t^* &= \pi(W_t, H_t) = (\theta/(\gamma\sigma_S))N(W_t, H_t), \\
x_t^* &= x(H_t) = \phi P(H_t) \geq 0, \\
I_t^* &= I(H_t) = \left(\alpha^{\frac{1}{1-\alpha}} B^{\frac{\alpha}{1-\alpha}}\right) P(H_t) \geq 0,
\end{aligned} \tag{14}
$$

where any dependence on death intensity λ_m is explicitly stated.

Conditions (9a)–(9c) encompass transversality restrictions for a finite shadow value of human capital, whereas conditions in (10a)–(10b) are required to ensure positive marginal propensity to consume (MPC) out of net wealth $A > 0$, as well as for minimal consumption requirements $c_t > a$. Restrictions (9a)–(9c), (10a) and (10b) jointly ensure that the continuation utility V_t in (13a) is finite and that the solutions in (14) are well defined. The constant B in (11) can naturally be interpreted as the marginal value (i.e., Tobin's q) associated with human capital. It is implicitly defined in (9a)–(9c) as an increasing function of the income gradient β and a decreasing function of the rate of interest r and the expected depreciation rate $\delta + \phi\lambda_s$.

Three features of the optimal rules are particularly relevant for life valuation. First, the two-step solution method ensures that both human wealth (11) and the net total wealth (12) are independent of the death intensity λ_m. Second and related, the exposure to exogenous death risk λ_m affects welfare only through $\Theta(\lambda_m)$ in (13b) via its impact on the marginal propensity to consume $A(\lambda_m)$. Equation (10a) and (10b) establishes that $A'(\lambda_m) = \varepsilon - 1 \lesseqgtr 0$, i.e., this MPC effect is entirely determined by the elasticity of inter-temporal substitution. An increase in death risk λ_m induces heavier discounting of future utility flows, leading to two opposite outcomes on the marginal propensity to consume. On the one hand, more discounting requires shifting current towards future consumption to maintain utility (i.e., by lowering the MPC). This effect is dominant at low elasticity of inter-temporal substitution $\varepsilon \in (0, 1)$. On the other hand, heavier discounting makes future consumption less desirable prompting the agent to shift future towards current consumption (i.e., by increasing the MPC). This *live fast and die young* effect is dominant at high elasticity of inter-temporal substitution $\varepsilon > 1$. Observe that, separate ε and γ parameters entail that a high EIS can coincide with high risk aversion, a flexibility that cannot be attained under VNM preferences which impose $\gamma = 1/\varepsilon$. Equivalently, whether the agent prefers to live fast and die young or not is independent of his attitudes towards financial risk.

Third, the welfare in (13a) and (13b) is increasing in both wealth and human capital stock and is decreasing and convex in the death intensity λ_m at all EIS levels because:

$$\Theta'(\lambda_m) = -\tilde{\rho} A(\lambda_m)^{\frac{\varepsilon}{1-\varepsilon}} \leq 0 \tag{15a}$$

$$\Theta''(\lambda_m) = \tilde{\rho}\varepsilon A(\lambda_m)^{\frac{2\varepsilon-1}{1-\varepsilon}} \geq 0. \tag{15b}$$

Hence, whereas the sign of the effects of death risk λ_m on the MPC (10a) and (10b) depends on the EIS, preference for life implies that higher mortality exposure unconditionally reduces the marginal value of net total wealth $\Theta(\lambda_m)$ in (13b) and therefore lowers welfare V_t in (13a). Importantly, as shown below in Subsection 2.3, a decreasing and convex effect of death risk on welfare entails that the willingness to pay to avoid increases in mortality is increasing and concave in death risks.

2. Willingness to Pay and Values of Life

2.1. *Overview*

We rely on two channels to calculate the life valuations implied by the solutions in Theorem 1 for the human capital model of Section 1.[14] First the capital dynamics dH_t evaluated at the optimal investment I_t^* yield the optimal path for human capital H_t^* and associated net income $D_t^* = Y(H_t^*) - I_t^*$. This dividend can be capitalised using the model-implied SDF m_t to obtain the HK value of life. Second, Hicksian variational analysis is applied on the indirect utility $V(W_t, H_t, \lambda_m)$ to compute the willingness to pay v_t to avoid increases Δ in death risk λ_m. The marginal WTP v_Δ yields the VSL whereas we show that the limiting WTP yields the gunpoint value.

2.2. *Human Capital Value of Life*

The human capital value of life is the market value of the net cash flow associated with human capital and that is foregone upon death (e.g., Kiker, 1966; Eden, 1972; Conley, 1976; Lewbel, 2003; Huggett and Kaplan, 2013; 2016). In our setting, this net cash flow is the marketed income, minus the money value of investment expenses, where both are evaluated at the optimum:

DEFINITION 1 (HK VALUE OF LIFE). *The human capital value of life is*

$$v_{h,t} = E_t \int_t^{T_m} \frac{m_\tau}{m_t} \left[Y(H_\tau^*) - I_\tau^* \right] d\tau, \tag{16}$$

where m_t is the stochastic discount factor induced by the prices of financial assets, I^* is the agent's optimal human capital investment, and H^* denotes the corresponding path of his human capital process.

We can substitute investment I^* from (14) in the law of motion (3) to recover the optimal path for human capital H^* and corresponding income flow $Y(H^*)$. Recall also that the agent's investment opportunity set induces a unique stochastic discount factor m_t given by (7). Combining both in (16) leads to the following result.

PROPOSITION 1 (HK). *The human capital value of life solving (16) is:*

$$v_h(H, \lambda_m) = C_0(\lambda_m)\,\frac{y}{r} + C_1(\lambda_m) P(H), \tag{17}$$

where the constants $(C_0, C_1) \in [0, 1]^2$ are defined by:

$$C_0(\lambda_m) = \frac{r}{r + \lambda_m} \tag{18a}$$

$$C_1(\lambda_m) = \frac{r - (\alpha B)^{\frac{\alpha}{1-\alpha}} + \delta + \lambda_s \phi}{r + \lambda_m - (\alpha B)^{\frac{\alpha}{1-\alpha}} + \delta + \lambda_s \phi}, \tag{18b}$$

and where human wealth $P(H)$ is given in (11).

Unlike step 1 of the solution method in Subsection 1.2.1, the discounted present value of net income is computed over a (stochastic) finite horizon T_m and must therefore be corrected

[14] We assume throughout this section that the parameters of the model satisfy the regularity conditions (9a)–(9c), (10a) and (10b) and abstract from time subscripts whenever possible to alleviate notation.

for mortality exposure λ_m. The first term in (17) is the present value y/r of the agent's base income $y = Y(0)$ calculated over an infinite horizon and adjusted for the exposure to death risk by multiplying with the constant $C_0 \in [0, 1]$ in (18a). The second term is the present value $P(H)$ of the net human capital cash flow $\beta H_t - I^*$ over an infinite horizon and this value is corrected for finite life by multiplying with the constant $C_1 \in [0, 1]$ in (18b). Both $C_0(\lambda_m)$, $C_1(\lambda_m)$ are decreasing functions of the death intensity λ_m, consistent with a lower HK value for shorter longevity.

2.3. *Willingness to Pay to Avoid a Change in Death Risk*

Next, consider an *admissible* change Δ in the intensity of death from base level λ_m in (1), i.e., one for which the indirect utility remains well defined when evaluated at the modified death exposure. The analysis of the WTP to avoid imminent death risk in a gunpoint setting (discussed in Subsection 2.5) naturally designates the Hicksian equivalent variation (EV), rather than compensating variation (CV), as the relevant measure of willingness to pay (i.e., to accept compensation) to avoid (i.e., to forego) detrimental (i.e., beneficial) changes in mortality.[15] We use standard variational analysis to define the corresponding Hicksian EV as follows:

DEFINITION 2 (HICKSIAN EQUIVALENT VARIATION). *Let $\mathcal{A}$ be the admissible set of permanent changes $\Delta \geq -\lambda_m$ in death intensity such that the condition (10a) and (10b) of Theorem 1 holds when λ_m is evaluated at $\lambda_m^* = \lambda_m + \Delta$. Then the equivalent variation to avoid $\Delta \in \mathcal{A}$ is implicitly given as the solution $v = v(W, H, \lambda_m, \Delta)$ to:*

$$V(W - v, H; \lambda_m) = V\left(W, H; \lambda_m^*\right), \tag{19}$$

where $V(W, H; \lambda_m)$ is an indirect utility function.

For unfavourable changes $\Delta > 0$, the EV (19) indicates a willingness to pay $v > 0$ to remain at base risk instead of facing higher mortality. For favourable changes $\Delta < 0$, the EV is a willingness to accept compensation equal to $-v > 0$ to forego lower risk. The properties of the willingness to pay v with respect to the increment in death risk follow directly from those of the indirect utility $V(W, H; \lambda_m)$. In particular, we can substitute $v(W, H, \lambda_m, \Delta)$ in (19), take derivatives and re-arrange to obtain:

$$v_\Delta = -\frac{V_{\lambda_m}}{V_W} \tag{20a}$$

$$v_{\Delta\Delta} = \frac{V_{\lambda_m \lambda_m} - V_{WW}(v_\Delta)^2}{-V_W}, \tag{20b}$$

where a subscript denotes a partial derivative. Monotonicity $V_W \geq 0$ and preference for life over death $V_{\lambda_m} \leq 0$ therefore induce a willingness to pay v that is increasing in Δ, whereas the diminishing marginal utility of wealth $V_{WW} \leq 0$ and of survival probability $V_{\lambda_m \lambda_m} \geq 0$ are sufficient to induce a concave WTP function in mortality risk exposure.

Relying on the indirect utility given in (13a) and (13b) for the human capital problem in Section 1 allows us to solve for the Hicksian variation as follows:

[15] Whereas paying out the WTP to remain alive under a gunpoint threat is rational, accepting compensation against certain and instantaneous death when terminal wealth is not bequeathed and life is preferred to death cannot be. As we abstract from bequests in our benchmark model in Section 1, we therefore adopt the EV, rather than CV perspective and focus on the WTP to avert unfavourable risks in subsequent analysis. For completeness, the extension to CV measures is nonetheless presented in Online Appendix C.7.

PROPOSITION 2 (HICKSIAN EV). *The equivalent variation solving (19) is:*

$$v(W, H, \lambda_m, \Delta) = \left[1 - \frac{\Theta(\lambda_m^*)}{\Theta(\lambda_m)}\right] N(W, H). \tag{21}$$

It is increasing and concave in Δ *with*

$$\inf_{\Delta \in \mathcal{A}} v(W, H, \lambda_m, \Delta) = \left[1 - \frac{\Theta(0)}{\Theta(\lambda_m)}\right] N(W, H) \tag{22a}$$

$$\sup_{\Delta \in \mathcal{A}} v(W, H, \lambda_m, \Delta) = N(W, H), \tag{22b}$$

where net total wealth $N(W, H)$ *is given in (12) and its marginal value* $\Theta(\lambda_m)$ *is given in (13b).*

The WTP in (21) equals zero if either $\Delta = 0$ or if the agent's elasticity of inter-temporal substitution $\varepsilon = 1$. Indeed, for unit elasticity, the MPC A in (10a), and therefore the marginal utility of net total wealth Θ (13b), are both independent from λ_m. Moreover, the properties in (15a) and (15b) established that the indirect utility $V(W, H; \lambda_m)$ in (13a) is decreasing and convex in the death intensity λ_m. Consequently, the weights $\Theta(\lambda_m^*)/\Theta(\lambda_m) \in [0, 1]$ for detrimental changes $\Delta \geq 0$ and the willingness to pay is an unconditionally increasing function of net total wealth $N(W, H)$. Combining (15a) and (15b) with (20a) and (20b) confirms a monotone increasing and concave willingness to pay to avoid increases in death risk exposure in (21), consistent with standard economic intuition of diminishing marginal valuation of additional longevity (e.g., Philipson *et al.*, 2010; Córdoba and Ripoll, 2017).

The lower bound on the WTP in (22a) is obtained by setting $\Delta = -\lambda_m$ yielding the WTA a compensation in order to forego zero death risk exposure.[16] From equations (10a), (10b) and (13b) this bound exists and is finite. Equation (22b) further establishes that the willingness to pay is bounded above by net total wealth $N(W, H)$. When the elasticity of inter-temporal substitution is larger than one, this upper bound corresponds to the asymptotic WTP. When the EIS is below one, the upper bound corresponds to a maximal admissible WTP satisfying the transversality constraint (10a) and (10b) (see Online Appendix B.3).

2.4. *Value of a Statistical Life*

2.4.1. *Theoretical VSL*

The VSL is the marginal rate of substitution between life and wealth evaluated at base risk (e.g., Eeckhoudt and Hammitt, 2004; Murphy and Topel, 2006; Bellavance *et al.*, 2009; Andersson and Treich, 2011; Aldy and Smyth, 2014). Adapted to our setting, the VSL is defined as:

DEFINITION 3 (VSL). *The value of a statistical life* $v_s = v_s(W, H; \lambda_m)$ *is the negative of the marginal rate of substitution between the probability of death and wealth computed from the indirect utility* $V(W, H; \lambda_m)$ *evaluated at base risk:*

$$v_s = -\frac{V_{\lambda_m}(W, H; \lambda_m)}{V_W(W, H; \lambda_m)}, \tag{23}$$

where $V(W, H; \lambda_m)$ *is an indirect utility function.*

Using Definition 3 and welfare (13a) and (13b), we can calculate the theoretical expression for the VSL for the parametrised model as follows.

[16] See also Eeckhoudt and Hammitt (2004) for a WTP to fully eliminate mortality risk.

PROPOSITION 3 (VSL). *The value of a statistical life solving (23) is:*

$$v_s(W, H, \lambda_m) = \frac{1}{A(\lambda_m)} N(W, H), \tag{24}$$

where the marginal propensity to consume $A(\lambda_m)$ is given in (10a) and (10b) and net total wealth $N(W, H)$ is given in (12).

The statistical life value is unconditionally positive, increasing in net worth and decreasing in the MPC. Hence, both the WTP to avoid admissible detrimental changes (21) and the VSL (24) are unconditionally increasing in wealth and the shadow value of human capital BH. Observe that because the MPC out of wealth is typically low (e.g., see Carroll, 2001, for a review), and because $A(\lambda_m)$ is the MPC out of both $N(W, H)$ and W, the VSL is expected to be significantly larger than net disposable resources $N(W, H)$.

2.4.2. *Relation between theoretical and empirical VSL*

We can rely on the WTP property (20a) to rewrite the VSL in (23) as a marginal willingness to pay v_Δ:

$$v_s(W, H; \lambda_m) = \frac{\partial v(W, H; \lambda_m, \Delta)}{\partial \Delta} = \lim_{\Delta \to 0} \frac{v(W, H; \lambda_m, \Delta)}{\Delta}. \tag{25}$$

Contrasting the theoretical definition of the VSL as a MWTP in (25) with its empirical counterpart reveals the links between the two measures. Indeed, the empirical VSL commonly relied on in the literature can be expressed as:

$$v_s^e(W, H; \lambda_m, \Delta) = \frac{v(W, H; \lambda_m, \Delta)}{\Delta}, \tag{26}$$

for small increment $\Delta = 1/n$, where n is the size of the population affected by the change in mortality risk. The theoretical measure of the VSL in (25) is the limiting value of its empirical counterpart in (26) when the change $\Delta \to 0$ or, equivalently, when population size $n \to \infty$. The importance of the bias between the empirical and theoretical VSLs ($v_s^e - v_s$) will consequently depend on the curvature of the willingness to pay v, as well as on the size and sign of the change Δ, an issue to which we will return shortly.

2.4.3. *Relation between empirical VSL and collective WTP*

We can use our theoretical measure for the individual WTP to compute the collective willingness to pay to save a human life. Given a finite population of agents indexed $j \in \{1, 2, \ldots, n\}$ and a set of social weights $\boldsymbol{\eta} \in \mathbb{R}_+^n$, we can assume homogeneous parameters across agents[17] and exploit the linearity of the WTP function (21) in wealth and human capital to derive the collective WTP as:

$$\sum_{j=1}^{n} \eta_j v_j(W_j, H_j, \lambda_m, \Delta) = \left[1 - \frac{\Theta(\lambda_m^*)}{\Theta(\lambda_m)}\right] \sum_{j=1}^{n} \eta_j N(W_j, H_j).$$

Imposing identical unit weights $\eta_j = 1, \forall j$ yields:

$$\sum_{j=1}^{n} v_j(W_j, H_j, \lambda_m, \Delta) = \left[1 - \frac{\Theta(\lambda_m^*)}{\Theta(\lambda_m)}\right] nN(\bar{W}, \bar{H}) = nv(\bar{W}, \bar{H}, \lambda_m, \Delta).$$

[17] Parametric homogeneity across agents is a key assumption for identification purposes in our empirical strategy (Section 3).

Evaluating the last equation at $\Delta = n^{-1}$ yields the empirical VSL (26) measure commonly used in the literature:

$$\sum_{j=1}^{n} v_j(W_j, H_j, \lambda_m, \Delta) = \frac{v(\bar{W}, \bar{H}, \lambda_m, \Delta)}{\Delta} = v_s^e(\bar{W}, \bar{H}, \lambda_m, \Delta),$$

i.e., under unit weights, the empirical VSL v_s^e is the collective WTP, corresponding to n times the individual WTP evaluated at mean wealth and human capital.

2.5. *Gunpoint Value of Life*

2.5.1. *Theoretical GPV*

We next resort to the gunpoint value as a additional life valuation measure. To do so, we adapt the Hicksian EV in Definition 2 to define the GPV as follows:

DEFINITION 4 (GPV). *The gunpoint value v_g is the WTP to avoid certain, instantaneous death and is implicitly given as the solution to:*

$$V(W - v_g, H; \lambda_m) = V^m, \tag{27}$$

where $V(W, H; \lambda_m)$ is an indirect utility, and V^m is the finite utility at certain death.

The willingness to pay v_g can be interpreted as the maximal amount paid to survive an *ex ante* unexpected and *ex post* credible highwaymen threat. Unlike the HK, the gunpoint value does not uniquely ascribe the economic worth of an agent to the capitalised net labour income that agent generates. Moreover, the GPV is theoretically computable at any admissible death intensity and applicable in life-or-death situations. As such, it is well suited in end-of-life terminal care decisions where neither the HK nor the VSL are appropriate (Philipson *et al.*, 2010).

Combining Definition 4 with the indirect utility (13a) and (13b), and noting that $V^m \equiv 0$ for preferences (6a)–(6c) reveals the following result for the GPV:

PROPOSITION 4 (GPV). *The gunpoint value of life solving (27) is:*

$$v_g(W, H) = N(W, H), \tag{28}$$

where $N(W, H)$ is the net total wealth in (12).

In the absence of bequest motives, the agent who is forced to evaluate life at gunpoint would be willing to pay the hypothetical (i.e., step 1) value of pledgeable resources. The discussion of net total wealth in (8) establishes that this amount corresponds to their entire financial wealth W, plus the capitalised value of their net income along the optimal path $Y(H^*) - I^*$. However, the previous discussion emphasised that the minimal consumption level a is required at all periods for subsistence. Its cost therefore cannot be pledged in a highwaymen threat and must be subtracted from the gunpoint value. Indeed, it can be shown (Hugonnier *et al.*, 2013, prop. 2) that net total wealth $N(W, H)$ is equal to:

$$N(W_t, H_t) = \mathrm{E}_t \int_t^{\infty} \frac{m_\tau}{m_t} \left(c_\tau^* - a\right) \mathrm{d}\tau. \tag{29}$$

To survive, the agent is thus willing to pledge the net present value of their optimal consumption stream (net of unpledgeable minimal subsistence), at which point they become indifferent between living and dying. This result can be traced to recursive preferences under which the foregone utility is measured in the same units as the foregone excess consumption. Interestingly, because net total wealth is independent from the agent's other preferences $(\rho, \varepsilon, \gamma)$ and from the death intensity (λ_m), so is the GPV. Because death is certain and instantaneous when life is evaluated at gunpoint, the attitudes towards time and risk, as well as the level of exposure to death risk become irrelevant.

2.5.2. *Relation with other life valuations*

Combining (29) with Proposition 1 shows that the difference between the gunpoint (28) and HK (17) values of life can be expressed as:

$$\begin{aligned} v_g(W_t, H_t) - v_h(H, \lambda_m) &= W_t - \frac{a}{r} + \mathrm{E}_t \int_{T_m}^{\infty} \frac{m_\tau}{m_t} \left(Y(H_\tau^*) - I_\tau^* \right) \mathrm{d}\tau, \\ &= W_t - \frac{a}{r} + (1 - C_0)\,\frac{y}{r} + (1 - C_1)\,P(H_t). \end{aligned}$$

The first two terms reflect the financial wealth and (capitalised) minimal consumption that affect net total wealth and therefore optimal consumption and welfare, but have no effects on optimal investment and therefore on the optimal path for net income $Y(H^*) - I^*$. The third and last terms show the mortality risk adjustments $(C_0, C_1) \in [0, 1]^2$ on the net cash flow that are present in the HK value but not in the GPV. The gunpoint value is therefore expected to be larger than the human capital value, except in the cases where financial wealth W_t is low relative to minimal consumption requirements a/r.

The links between the willingness to pay in (21) and the GPV in (28) are intuitive and follow directly from the properties of the WTP. Indeed, the gunpoint value corresponds to the admissible upper bound (22b) on the willingness to pay to avoid a change in death risk exposure:

$$v_g(W, H) = \sup_{\Delta \in \mathcal{A}} v(W, H, \lambda_m, \Delta). \tag{30}$$

This upper bound exists and is finite by admissibility, i.e., compliance with transversality restrictions. Moreover, comparing (24) and (28) establishes that:

$$v_g(W, H) = A(\lambda_m) v_s(W, H, \lambda_m). \tag{31}$$

Estimates of the marginal propensity to consume $A(\lambda_m)$ out of assets are typically low, ranging between 2% and 9% for housing wealth and around 6% for financial wealth (e.g., Carroll *et al.*, 2011, p. 58). Consequently, the predicted gap between the GPV and VSL is positive and large.

To gain further insight on the WTP–VSL–GPV links it is useful to set $t = 1$ in the probability of death (2) and evaluate for:

$$\mathcal{P} \equiv \Pr(T_m \leq 1) = 1 - e^{-\lambda_m},$$

a monotone increasing function of λ_m. The willingness to pay $v(\Delta_{\mathcal{P}}) = v(W, H; \mathcal{P}, \Delta_{\mathcal{P}})$ can then be analysed over changes $\Delta_{\mathcal{P}} \in [-\mathcal{P}, 1 - \mathcal{P}]$ from base risk $\mathcal{P}$ and is plotted in Figure 1. This graph emphasises the central role of the WTP and illustrates why the theoretical VSL is expected to be larger than its empirical counterpart, and both are expected to be much larger than the GPV.

From properties (20a) and (20b), the WTP (solid line) is an increasing, concave function of the change in death risk $\Delta_{\mathcal{P}}$. The theoretical VSL v_s in (25) is the marginal willingness to pay, i.e., the slope of the dashed tangent evaluated at base death risk $(\Delta_{\mathcal{P}} = 0)$. It is equivalent to the linear

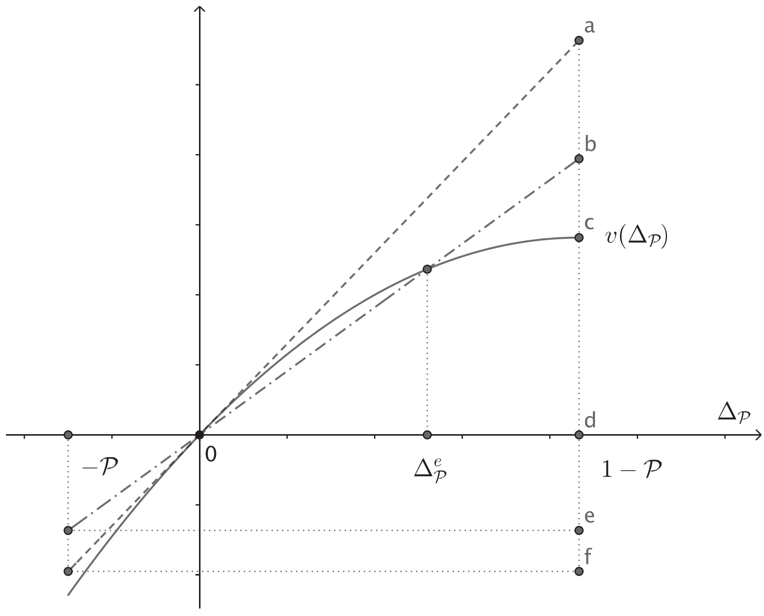

Fig. 1. *Willingness to Pay and Life Valuations.*

Notes: $\Delta_{\mathcal{P}} \in [-\mathcal{P}, 1-\mathcal{P}]$ is change in the probability of death from base exposure $\mathcal{P} = 1 - e^{-\lambda_m}$. $v(\Delta_{\mathcal{P}}) = v(W, H; \mathcal{P}, \Delta_{\mathcal{P}})$ (solid line) is the WTP to avoid $\Delta_{\mathcal{P}}$. $v_s = v'(0)$ is the theoretical VSL in (25), i.e., the slope of tangent (dashed line) and equal to distance [a,f]. $v^e_s = v(\Delta^e_{\mathcal{P}})/\Delta^e_{\mathcal{P}}$ is the empirical VSL in (26) is slope of dash-dotted line and equal to distance [b,e]. $v_g = \sup_{\Delta_{\mathcal{P}}}(v)$ is the GPV in (27) is equal to distance [c,d].

projection corresponding to the total wealth spent to save one person (i.e., when $\mathcal{P} + \Delta_{\mathcal{P}} = 1.0$) and is equal to the distance [a,f]. The empirical VSL v^e_s in (26) is computed for a small (i.e., infra-marginal) change $\Delta^e_{\mathcal{P}} > 0$ and is the slope of the dash-dotted line; equivalently, it is the linear projection represented by the distance [b,e]. The empirical VSL measure v^e_s will thus understate its theoretical counterpart v_s when $\Delta^e_{\mathcal{P}} \gg 0$ and when the WTP is concave. Moreover, equation (30) establishes that the gunpoint value corresponds to the admissible upper bound on the WTP, i.e., the limiting WTP when death is certain as represented by the distance [c,d] in Figure 1. A concave WTP entails that a linear extrapolation under either the theoretical, or the empirical VSL will thus overstate the gunpoint value attributed to one's own life, as confirmed from our discussion of (31).

3. Structural Estimation

3.1. *Overview*

To estimate the willingness to pay and the three life valuations, we first follow a long tradition associating the agent's human capital to his health (e.g., see the Hicks lecture by Becker, 2007, for a review). Second, we estimate the technological, preferences and parameters for the model outlined in Section 1 by contrasting the theoretical decisions in Theorem 1 to their observed counterparts in PSID. Third, the estimated structural parameters can then be combined with

Table 1. *Parametric Restrictions.*

Equation	$\mathbf{B}_0^i(\mathbf{\Theta})$	$\mathbf{B}_W^i(\mathbf{\Theta})$	$\mathbf{B}_H^i(\mathbf{\Theta})$
Y_j	y	0	β
c_j	$a + A(\mathbf{\Theta})(\frac{y-a}{r})$	$A(\mathbf{\Theta})$	$A(\mathbf{\Theta})B(\mathbf{\Theta})$
π_j	$\frac{\theta}{\gamma\sigma_S}(\frac{y-a}{r})$	$\frac{\theta}{\gamma\sigma_S}$	$\frac{\theta}{\gamma\sigma_S}B(\mathbf{\Theta})$
x_j	0	0	$\phi B(\mathbf{\Theta})$
I_j	0	0	$[\alpha B(\mathbf{\Theta})]^{1/(1-\alpha)}$

Note: Parametric restrictions for econometric model (32), expressions for $B(\mathbf{\Theta})$, $A(\mathbf{\Theta})$ given in equations (9a)–(9c), (10a) and (10b).

observed wealth and health statuses to compute the closed-form expressions for the life valuations in Section 2.

3.2. *Econometric Model*

We adopt a cross-sectional perspective to estimate our human capital model and compute the associated life valuations. For identification purposes, we assume that all agents $j = 1, 2, \ldots, n$ take their wealth W_j and health H_j statuses as given and:

1. follow the optimal rules in Theorem 1 in selecting consumption c_j, portfolio π_j, insurance x_j, and investment I_j;
2. share homogeneous preference, technological and distributional parameters, i.e., $\mathbf{\Theta}_j = \mathbf{\Theta} \in \mathbb{R}_+^k, \forall j$.

The non-linear multivariate econometric model for $\mathbf{Y}_j = [Y_j, c_j, \pi_j, x_j, I_j]'$ is written as:

$$\mathbf{Y}_j = \mathbf{B}_0(\mathbf{\Theta}) + \mathbf{B}_W(\mathbf{\Theta})W_j + \mathbf{B}_H(\mathbf{\Theta})H_j + \mathbf{u}_j, \quad \mathbf{u}_j \sim \text{NID}(0, \Sigma). \tag{32}$$

The 5×3 matrix of reduced-form parameters (RFP) $\mathbf{B}(\mathbf{\Theta})$ are linked to the preference, technological and distributional parameters in $\mathbf{\Theta}$ by the closed-form expressions (14) and are summarised in Table 1. Importantly, focusing on the optimal rules conveniently eliminates any endogeneity issue because the allocations in $\mathbf{Y}_j$ are expressed in feedback form using the (pre-determined) wealth W_j and health H_j state variables. Under the assumption that the $\mathbf{u}_j$ in (32) are (potentially correlated) Gaussian error terms, we can then rely on a non-linear maximum likelihood (ML) estimator to estimate a subset:

$$\mathbf{\Theta}^e = (y, \beta, \delta, \alpha, \lambda_s, \lambda_m, a, \gamma, \varepsilon),$$

of the structural parameters in $\mathbf{\Theta} = \{\mathbf{\Theta}^e, \mathbf{\Theta}^c\}$. Following standard practices, the remaining subset of the structural parameters

$$\mathbf{\Theta}^c = (\phi, \mu, r, \sigma_S, \rho),$$

is calibrated either following a thorough search procedure (ϕ), or at usual values in the literature (other parameters).

The two cornerstones of our empirical strategy are a (*i*) fully structural and (*ii*) a cross-sectional estimation. This framework presents both advantages and disadvantages. First, a pure structural, rather than (mixed) reduced-form estimation guarantees a one-to-one mapping with the theoretical model. However, it omits other covariates, such as age, gender, marital status, presence of children, education, and so on, which very likely affect the trade-offs between wealth and life. For example, concerns for surviving spouse or children might increase or reduce (if attenuated through bequests) the utility cost of mortality and the WTP to prevent death. Second, a cross-sectional estimation is sufficient for identification purposes (see Online Appendix D.1), which increases the attractiveness of our approach when panel databases are not available. However, it omits relevant information from individual dynamics, cohort effects, and opportunities to account for unobserved heterogeneity. For example, the observed life cycle of health and wealth is not relied on, whereas unobserved bequest motives, healthy behaviour, myopia, or preference for leisure over consumption cannot be accounted for through fixed effects. Indeed, a rigorous structural, cross-sectional estimation implies that the $\mathbf{B}_0(\mathbf{\Theta})$ in (32) is fully constrained in Table 1; adding arbitrary agent-specific constants is neither appropriate nor identifiable (see Online Appendix D.2). Admittedly, the information from both observable and unobservable characteristics is relevant for life valuations, yet it is difficult to predict how they would impact our estimated values. Our estimation choices imply a necessary trade-off between realism and modelling rigour and we leave alternatives on the research agenda.

3.3. *Data*

We use a sample of 7,949 US individuals obtained from the 2017 wave of the PSID (Institute of Social Research, 2020) and weighted with corresponding individual and family weights (Chang *et al.*, 2019). All nominal variables in per capita values (i.e., household values divided by household size)[18] and scaled by 10^{-6} for the estimation. The agents' independent and dependent variables are constructed as follows.

We first define financial wealth W_j as the sum of risky (i.e., stocks in publicly held corporations, mutual funds, investment trusts, private annuities, individual retirement accounts (IRAs) or pension plans) plus riskless assets (i.e., checking accounts plus bonds plus remaining IRAs and pension assets). We next proxy the health variable H_j through the respondent's polytomous self-reported health statuses (poor, fair, good, very good and excellent) that are linearly converted to numeric values.[19] On the one hand, French (2005) raises the issue that agents in the PSID may understate their true health in order to justify being out of the labour force. In our case, this could lower our value for H_t and could bias upwards our estimate of β in the income equation. Both would result in a lower value of human wealth $P(H_t) = BH_t$ and, consequently, lower life values. On the other hand, however, self-assessed morbidity and mortality indicators have been shown to be valid predictors of actual health outcomes, such that this potential bias might not be as acute as feared.[20] Moreover, other approaches, such as specifying unobserved health as a latent variable, and estimating its effect on self-reported status, or on other health indicators as well as on investment have been shown to be valid alternatives in modelling health processes (e.g.,

[18] We discuss the relevance and empirical effects of resorting to other equivalence scale measures as alternatives to per capita scaling in Online Appendix E.4.

[19] In particular, values of 1.0 (poor health), 1.75 (fair), 2.5 (good), 3.25 (very good) and 4.0 (excellent) are ascribed to the self-reported health variable of the household head.

[20] See in particular Hurd and McGarry (1995), Hurd *et al.* (2001), Crossley and Kennedy (2002), Hurd and McGarry (2002) and Benjamins *et al.* (2004) for discussions and evidence on validity of self-reported statuses, sickness and longevity indicators.

Erbsland *et al.*, 2002; Wagstaff, 2002). However, our conversion, while admittedly arbitrary, is much simpler to implement and fairly robust to scaling errors.[21]

The dependent variables in $\mathbf{Y}_j$ are the household income, consumption, portfolios, health insurance and health expenditures. First, we use total family income to calculate Y_j. Second, a comprehensive measure of consumption is absent in the PSID data. We therefore follow an interpolation approach to infer c_j from the reported food, utility and transportation expenditures.[22] Third, the risky portfolio π_j is calculated as the share of financial wealth W_j being held in risky assets. Fourth, health insurance x_j is measured by spending on health insurance premium. Finally, health investment I_j are computed using the out-of-pocket spending on hospital, nursing home, doctor, outpatient surgery, dental expenditures and prescriptions in-home medical care.[23]

Table 2 presents summary statistics for all, elders (65 and more) and adults (age 21–64). The mean age is 45 for all, 73 for elders and 40 for adults. The mean health status is 2.85, between good and very good and predictably declines with age. Mean per capita financial wealth is low at $62,000, highly skewed and over three times higher for elders. A non-negligible share is invested in risky assets. Mean income is also low ($23,000) and highly skewed and falls for elders. Spending is mainly in non-durable consumption goods ($12,350) and much lower for health insurance and expenditures ($820).

4. Estimation Results

4.1. *Structural Parameters*

Table 3 reports the estimated (standard errors in parentheses) and calibrated (with superscripts ^{c}) parameters for our benchmark model. Overall, the former are precisely estimated and are consistent with other estimates for this type of model (e.g., Hugonnier *et al.*, 2013; 2020).

First, the health law of motion parameters in Table 3 (panel a) are indicative of significant diminishing returns in adjusting health status ($\alpha = 0.7413$). Deterministic depreciation is important ($\delta = 3.70\%$) and morbidity is non-negligible with additional depletion of $\phi = 1.36\%$,[24] and average waiting time between occurrence of $\lambda_s^{-1} = 10.0$ years. Both elements suggest that the health shocks that we are capturing are consequential, rather than benign. Second, exposure to mortality risk is also important ($\lambda_m = 0.0342$), corresponding to a remaining expected lifetime of $\lambda_m^{-1} = 29.2$ years, somewhat lower than observed in the data.[25] Third, the income parameters in Table 3 (panel c) are indicative of a significant positive effect of health on labour income ($\beta = 0.0061$), as well as an estimated value for base income that is close to poverty thresholds ($y \times 10^6 = \$12,700$).[26] The financial parameters (μ, σ_S, r) are calibrated from the observed moments of the S&P500 and 30-days T-Bills historical returns.

[21] Indeed, note further that the optimal investment in (14) is proportional to health. Consequently, the health growth determining the optimal capital path is constant and invariant to the scaling in H_t. We also experimented with non-linear scaling by replacing the affine with a Box–Cox transformation of H_t with no significant effects on our results.

[22] See Skinner (1987) and Guo (2010) for interpolation details. See also Andreski *et al.* (2014) for comparison and validation of PSID consumption data with consumer expenditures estimates.

[23] We discuss the effects of discrepancies between investment I_t and out-of-pocket expenses O_t in Online Appendix C.2.

[24] Hugonnier *et al.* (2013) estimate $\phi = 1.11\%$ using pooled PSID data from 1999 to 2007.

[25] The remaining life expectancy at age 45 in the United States in 2017 was 36.1 years (all), 34.2 (males) and 37.9 (females) (Arias and Xu, 2019).

[26] The 2017 poverty threshold for single-agent households was $12,500 (US Census Bureau, 2020).

Table 2. *PSID Sample Statistics.*

	Mean	SD	Min	Max
Panel a. Age t				
– All	45	16	18	99
– Elders	73	7	65	99
– Adults	40	12	18	64
Panel b. Health H				
– All	2.85	0.77	1	4
– Elders	2.61	0.83	1	4
– Adults	2.89	0.75	1	4
Panel c. Wealth W (\$000)				
– All	62.38	364.59	0	21,250
– Elders	213.75	621.67	0	11,400
– Adults	39.75	301.86	0	21,250
Panel d. Stock πW (\$000)				
– All	36.70	312.10	0	20,500
– Elders	130.58	500.08	0	10,900
– Adults	22.67	270.36	0	20,500
Panel e. Income Y (\$000)				
– All	23.49	34.78	0	850
– Elders	19.20	39.36	0	552
– Adults	24.13	34.00	0	850
Panel f. Consumption C (\$000)				
– All	12.35	13.23	0	337
– Elders	16.46	20.71	0	337
– Adults	11.74	11.58	0	251
Panel g. Insurance x (\$000)				
– All	0.15	0.60	0	17
– Elders	0.25	0.91	0	13
– Adults	0.14	0.54	0	17
Panel h. Health investment I (\$000)				
– All	0.67	2.20	0	88
– Elders	1.60	5.12	0	88
– Adults	0.53	1.21	0	24

Notes: Statistics for 2017 PSID data used in estimation. Sample size: All (7,949 obs.); Elders ($t \geq 65$, 1,034 obs.); Young ($t < 65$, 6,915 obs.). Scaling for self-reported health is 1.0 (poor), 1.75 (fair), 2.50 (good), 3.25 (very good) and 4.0 (excellent).

The preference parameters in Table 3 (panel d) indicate realistic aversion to financial risk ($\gamma = 2.4579$). The estimated minimal consumption level is somewhat larger than base income ($a \times 10^6 = \$13,400$). As for other cross-sectional estimates using survey data (Gruber, 2013; Hugonnier *et al.*, 2020), the elasticity of inter-temporal substitution is close to, but larger than one ($\varepsilon = 1.0212$), and is consistent with a *live fast and die young* effect whereby a higher risk of death increases the marginal propensity to consume.[27] The null hypothesis of VNM preferences $H_0 : \gamma = 1/\varepsilon$ is unambiguously rejected in favour of our non-expected utility specification.

[27] Our elasticity is also close to the calibrated EIS values of $1/\sigma = 1.25$ used by Córdoba and Ripoll (2017), as well as values of 1.17 for PSID data in Vissing-Jorgensen and Attanasio (2003) and Huggett and Kaplan (2016); and of 1.5 in Bansal and Yaron (2004) and Palacios (2015).

Table 3. *Estimated and Calibrated Structural Parameter Values, Benchmark Model.*

Parameter	Value	Parameter	Value
Panel a. Law of motion health (3)			
α	0.7413	δ	0.0370
	(0.0155)		(0.0011)
ϕ	0.0136^c		
Panel b. Sickness (3) and death (1) intensities			
λ_s	0.1000	λ_m	0.0342
	(0.0112)		(0.0001)
Panel c. Income (4) and wealth (5)			
y	0.0127	β	0.0061
	(0.0004)		(0.0001)
μ	0.1080^c	r	0.0480^c
σ_S	0.2000^c		
Panel d. Preferences (6a)–(6c)			
γ	2.4579	ε	1.0212
	(0.0542)		(0.0004)
a	0.0134	ρ^c	0.0500
	(0.0007)		
Panel e. MPC and Tobin's q (10a), (10b), and (9a)–(9c)			
A	0.0504	B	0.0709
	(0.0057)		(0.0084)

Notes: Estimated structural parameters (standard errors in parentheses); c: calibrated parameters. Econometric model (32), estimated by ML, subject to the regularity conditions (9a)–(9c), (10a) and (10b).

Finally, Table 3 (panel e) reports the composite parameter estimates of interest. The marginal propensity to consume out of wealth $A = 5.04\%$ is well in line with other estimates (e.g., Carroll *et al.*, 2011). The estimate for the human capital Tobin's q is $B = 0.0709$ is consistent with a large share of human capital $P(H) = BH$ in net total wealth $N(W, H)$.[28]

4.2. *Estimated Valuations*

We next compute and report the life valuations calculated at the estimated parameters in Table 3. We rely on a bootstrap procedure with 500 iterations to evaluate the associated standard errors in order to account for both the parametric uncertainty and data distribution over (H, W).

4.2.1. *Human capital value of life*

The HK value of life $v_h(H)$ given in (17) is reported in Table 4 (panel a). Consistent with predictions, the human capital values are independent from W and increasing in H, ranging from \$206,000 (poor health) to \$358,000 (excellent health), with a mean value of \$300,000. These figures are realistic and compare advantageously with other HK estimates in the literature and provide a first out-of-sample confirmation that the structural estimates are reasonable.[29]

[28] When evaluated at the mean health and wealth level in Table 2, we estimate an average net total wealth $N(W, H)$ in (8) of \$251,000, 81% of which is attributable to human wealth $P(H)$.

[29] Huggett and Kaplan (2016, benchmark case, p. 38, fig. 7.a) find HK values starting at about \$300,000 at age 20, peaking at less than \$900,000 at age 45 and falling steadily towards zero afterwards.

Table 4. *Estimated Values of Life (in thousand dollars), Benchmark Model.*

	Wealth quintile				
Health level	1	2	3	4	5
Panel a. HK $v_h(W, H, \lambda_m)$ in (17)					
Poor			205.82 (0.63)		
Fair			243.89 (1.09)		
Good			281.96 (1.56)		
Very Good			320.03 (2.03)		
Excellent			358.10 (2.50)		
All			299.52 (1.91)		
Panel b. VSL $v_s(W, H, \lambda_m)$ in (24)					
Poor	1133.74 (14.83)	1136.12 (27.61)	1165.90 (41.01)	1392.54 (54.59)	10176.75 (68.23)
Fair	2189.44 (14.82)	2192.79 (27.59)	2224.82 (41.00)	2457.36 (54.60)	6177.30 (68.23)
Good	3245.13 (15.04)	3248.90 (27.54)	3282.59 (41.06)	3540.56 (54.56)	8141.83 (68.43)
Very Good	4300.82 (20.80)	4304.93 (29.29)	4337.73 (40.81)	4592.25 (54.85)	10442.69 (69.09)
Excellent	5356.52 (112.18)	5360.61 (77.37)	5395.18 (62.98)	5631.50 (83.18)	12921.37 (89.00)
All			4980.38 (49.08)		
Panel c. GPV $v_g(W, H)$ in (28)					
Poor	57.12 (0.03)	57.24 (0.06)	58.74 (0.09)	70.16 (0.12)	512.70 (0.15)
Fair	110.30 (0.03)	110.47 (0.06)	112.09 (0.09)	123.80 (0.12)	311.21 (0.15)
Good	163.49 (0.03)	163.68 (0.06)	165.38 (0.09)	178.37 (0.12)	410.18 (0.15)
Very Good	216.67 (0.05)	216.88 (0.06)	218.53 (0.09)	231.36 (0.12)	526.10 (0.15)
Excellent	269.86 (0.25)	270.07 (0.17)	271.81 (0.14)	283.71 (0.18)	650.97 (0.20)
All			250.91 (2.39)		

Notes: Averages of individual values in the PSID sample, computed at estimated parameter values in Table 3, column (1). Bootstrapped standard errors in parentheses (500 replications), corrected for scaling used in estimation.

4.2.2. *Value of statistical life*

Table 4 (panel b) reports the statistical life values in (24) by observed health and wealth statuses. The VSL mean value is \$4.98 million, with valuations ranging between \$1.13 million and \$12.92 million. These values are well within the ranges usually found in the empirical VSL literature.[30] The concordance of these estimates with previous findings provides additional

[30] A meta-analysis by Bellavance *et al.* (2009, p. 452, table 6) finds mean values of \$6.2 million (2000 base year, corresponding to \$8.6 million, 2016 value). Survey evidence by Doucouliagos *et al.* (2014) ranges between \$6 million and \$10 million. Robinson and Hammitt (2016) report values ranging between \$4.2 million and \$13.7 million. Finally, guidance values published by the US Department of Transportation were \$9.6 million in 2016 (US Department of Transportation, 2016), whereas the Environmental Protection Agency relies on central estimates of \$7.4 million (2006), corresponding to \$8.8 million in 2016 (US Environmental Protection Agency, 2017). León and Miguel (2017) find VSL

out-of-sample evidence that our structural estimates are well grounded. Importantly, our theoretically and empirically integrated approach confirms the large VSL–HK gaps identified in the empirical literature.

It is also possible to assess a measure of the marginal versus infra-marginal WTP bias by calculating the empirical VSL measure in (26). Setting $\Delta = 1/n = 1/7949$ and $\lambda^*_{m0} = \lambda_m + \Delta$, we recover an aggregate VSL of \$4.97 million, which, as expected, is lower, but close to the mean theoretical value of $v_s(W, H, \lambda_m) =$ \$4.98 million. This result confirms that the theoretical and empirical values are close to one another, i.e., the individual MWTP is well approximated by the collective WTP corresponding to the empirical VSL when $\Delta = 1/n$ is small (i.e., the sample size is large).

The VSL is increasing in both wealth and especially health. Positive wealth gradients have been identified elsewhere (Bellavance *et al.*, 2009; Andersson and Treich, 2011; Adler *et al.*, 2014) whereby diminishing marginal value of wealth and higher financial values at stake both imply that richer agents are willing to pay more to improve survival probabilities. The literature has been more ambivalent with respect to the health effect (e.g., Murphy and Topel, 2006; Andersson and Treich, 2011; Robinson and Hammitt, 2016). On the one hand, better health increases the value of life that is at stake, on the other hand, healthier agents face lower death risks and are thus less willing to pay to attain further improvements (or prevent deteriorations). Given that our benchmark model abstracts from endogenous mortality and better health increases net total wealth $N(W, H)$, our estimates unambiguously indicate that the former effect is dominant and that improved health raises the VSL.[31]

4.2.3. *Gunpoint value*

Table 4 (Panel c) reports the gunpoint values in (28). The mean GPV is \$251,000 and the estimates are increasing in both health and wealth and range between \$57,000 and \$651,000. The gunpoint is thus of similar magnitude to the HK value of life and both are much lower than the VSL. Indeed, this finding was already foreseeable from equation (31) indicating that the VSL/GPV ratio is inversely proportional to the marginal propensity to consume. Given that our estimates in Table 3 (panel e), reveal that $A(\lambda_m) = 5.04\%$, we identify a VSL that is 19.84 times larger than the GPV.

As mentioned earlier, no equivalent estimates of the gunpoint value are to be found in the literature. In order to gain perspective, we can compare with the net worth of households, using the more comprehensive measures computed by the US Census Bureau. Accounting for the value of all financial, pension, residential and durables assets net of outstanding debt reveals median (mean) values of \$107,000 (\$390,000) in 2017 (US Census Bureau, 2021, tables 1, 5) which provides additional evidence that our v_h, v_g measures are realistic.

4.2.4. *Willingness to pay*

We emphasised that both the empirical and theoretical VSL will overstate the GPV corresponding to the upper bound on the concave willingness to pay. To help visualise this gap, Figure 2 is the estimated counterpart to Figure 1 and plots the willingness to pay $v(W, H, \lambda_m, \Delta)$ as a function

amounts ranging from \$577,000 to \$924,000 calculated from a willingness to pay to face death risk in transportation to the international airport in Sierra Leone.

[31] Online Appendix C.4 allows for endogenous morbidity and mortality risks exposure. The estimation of that model confirms that the effects on life valuations are moderate and that the VSL remains increasing in health (Hugonnier *et al.*, 2021, table 2, panel b).

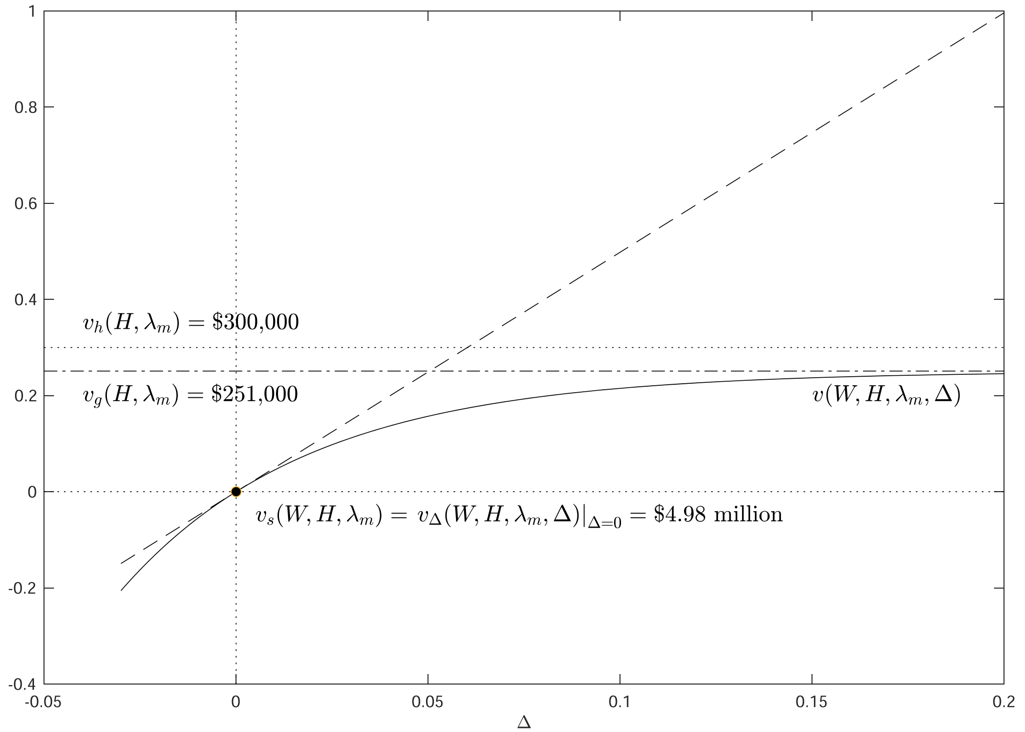

Fig. 2. *Estimated WTP, HK, VSL and GPV (in millions).*
Notes: At estimated parameter values, for mean wealth and health levels. $v(W, H, \lambda_m, \Delta)$ (solid line) is the WTP to avoid an increase Δ in death intensity λ_m; $v_h(H, \lambda_m)$ (dotted line) is the HK value; $v_g(W, H)$ (dashed-dotted line) is the GPV value. $v_s(W, H, \lambda_m)$ is the VSL and is the slope of the dashed tangent to the WTP evaluated at $\Delta = 0$.

of Δ calculated from (21) at the estimated parameters and relying on the mean wealth and health status.

The strongly concave estimated WTP in Figure 2 is informative as to why the VSL is much larger than the human capital and gunpoint values. Indeed, an agent with average health and wealth statuses is willing to pay \$33,000 to avoid an increase of $\Delta = 0.0071$ which shortens his current horizon of 29.9 years by 5 years and would pay \$246,000 to avoid an increase of $\Delta = 0.2013$ which lowers expected remaining lifetime by 25 years. This last value is already close to the HK and GPV values of \$300,000 and \$251,000, which are both much lower than the VSL of \$4.98 million. Equivalently, the linear extrapolation of marginal values that is relied on in the VSL calculation overstates the willingness to protect one's own life when the WTP is very concave in the death risk increment, as foreshadowed in our discussion of (24) and (31).

Online Appendix E presents additional robustness checks. We first discuss age effects with estimation stratified between younger and older agents (Online Appendix E.1). We next stratify by time and re-estimate the model before and after the Affordable Care Act (ACA, aka Obamacare) became operational in 2014 to isolate the effects of health insurance (Online Appendix E.2). Finally, we estimate the Grossman (1972) and Ehrlich and Chuma (1990) (GEC) alternative model (Online Appendix E.3). Overall, these additional tests confirm the robustness and relevance of our results.

5. Conclusion

We contribute to the life valuation literature by providing the first *joint benchmark* estimates of willingness to pay, HK, VSL and gunpoint values in the context of a theoretically and empirically integrated approach. First, a flexible life cycle model of human capital accumulation is solved in closed form. Second, its optimal rules as well as associated indirect utility are combined with asset pricing and Hicksian variational analysis to calculate analytical expressions for the willingness to pay to avoid changes in death risk as well as the human capital, statistical and gunpoint values of life. Third, the estimation of the optimal rules using PSID-2017 data provides structural estimates of the four life valuation concepts. Our integrated approach thus allows for theoretically and empirically rigorous estimates of life valuations that are directly linked and comparable to one another. We confirm the large discrepancies with an average HK value of \$300,000 and a VSL of \$4.98 million and show that the gunpoint value of \$251,000 is similar to the HK. We also show that the much larger VSL is entirely attributable to the strongly concave estimated WTP.

The robustness of our results along many dimensions is reviewed and confirmed in the Online Appendix. First, our theoretical model abstracts from, yet is isomorphic to, one with utilitarian health services and endogenous labour/leisure choices. Second, it is readily adaptable to accommodate endogenous morbidity and mortality risk exposures, discrepancies between out-of-pocket medical expenses and health investment, ageing or well-known human capital modelling alternatives. Third, although our setting assumes full insurance coverage against health shocks, we show that empirical results remain similar at periods where coverage actually differs (i.e., pre- and post-ACA samples). Finally, qualitatively similar predictions were derived for the popular GEC model of human capital accumulation. However, given that this model is nested in ours, formal testing rejected the corresponding set of restrictions.

The human capital, willingness to pay, statistical life and gunpoint values of life remain specialised tools that are complementary to one another and are applicable in specific contexts. Our encompassing approach provides single-step measurement of all four in fully integrated theoretical and empirical environments. Such a framework could be useful for mortality costs in the COVID pandemic. Indeed the HK, WTP, VSL and GPV may identify trade-offs between resource allocations for treatment or prevention, the cost–benefits analyses of shutdowns, or the eventual litigation associated with individual, medical or policy negligence.

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Additional Supporting Information may be found in the online version of this article:

Online Appendix
Replication Package

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