The Value of a Statistical Life: Evidence from Senior's Medical Expenditures

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Defining Value of a Statistical Life

U.S. Environmental Protection Agency (EPA)

The aggregate dollar amount that a large group of people would be willing to pay for a reduction in their individual risks of dying in a year, such that we would expect one fewer death among the group during that year on average. For instance, if 1,000 individuals are willing to pay \$ 1,000 to reduce risk of death by 0.001, VSL = \$ 1,000 × 1,000 = \$ 1 million

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- Accounts for 70 % of all federal program benefits (Lee & Taylor, 2017)
- Accounts for most of the economic damage from climate change (Hsiang et al., Science 2017)
- **Glaring Inconsistency** : mortality from air pollution and climate change mainly concentrated among seniors, while VSL estimates are based on younger, healthier workers
- **Example** : 75 % of deaths from pollution are for 65 + seniors, while VSL estimates based on people with $\mathbb{E}[age] = 40$

Standard Approaches to VSL Estimation

$$w_{i,j,k} = \alpha \pi_{j,k} + \beta x_{i,j,k} + \epsilon_{i,j,k}$$

$$\begin{aligned} w_{i,j,k} &= \text{worker i's wage rate in occupation, j industry, k} \\ \pi_{j,k} &= \text{annual on the job fatality rate (per 1,000 workers)} \\ x_{i,j,k} &= \text{individual controls} \end{aligned}$$

$$VSL = \alpha \times \text{average hours} \times 1,000$$

- **Issues** : Information, selection, dynamics, risk level
- **Challenge** : Observing the wage-risk trade-off for seniors in data

This Paper

- Design and implement a revealed preference framework for using medical expenditures to identify marginal rates of substitution between consumption and mortality risk (and VSL measures) for people over age 65.

Preview of Methods and Findings

- Derive VSL based on marginal cost of saving a life, adapting aspects of Murphy-Topel (JPE 2006) and Hall-Jones (QJE 2007)
- Novel panel data linking administrative Medicare records to survey data on lifestyle, subjective health and labor market participation
- Identification from supply side variation in medical expenditures documented by Finkelstein, Gentzkow and Williams (QJE 2016)
- VSL for a healthy 66-year old is approximately $ 1.1 million, and then declines with age, mainly due to the arrival of chronic illnesses
- Clean Air Act Reconsidered: Replacing EPA's VSL estimate with ours reduces benefits by 70 %, implying a benefit-cost ratio of 7:1 instead of 25:1

Outline

1. **Model**
2. Data
3. Identification and Estimation
4. Results
5. Conclusion

A Life Cycle Model starting at age, t=65

- Utility for a retired individual at age, t

$$U_{i,t} = u(c_{i,t}, H_{i,t})$$

$$\begin{aligned} c_{i,t} &= \text{consumption} \\ H_{i,t} &= \text{health stock} \end{aligned}$$

- Intertemporal budget constraint :

$$a_{i,t+1} + \gamma_{i,t} m_{i,t} + c_{i,t} = a_{i,t}(1 + r_t) + I_i$$

$a_{i,t}(1 + r)$ = age t asset plus return on investment

I_i = permanent income (e.g: pension, social security)

$\gamma_{i,t} m_{i,t}$ = out-of-pocket medical expenditure given the Medicare co-payment rate

Uncertainty: Health and Survival

- Evolution of the health stock

$$H_{i,t+1} = f(H_{i,t}, m_{i,t}, t, \epsilon_{i,t})$$

$$\begin{aligned} \epsilon_{i,t} &= \text{idiosyncratic health shock} \\ m_{i,t} &= \text{total medical expenditure} \end{aligned}$$

- Survival Function:

$$s_{it} = \exp[-\exp(\beta_1 + \beta_t + H_{i,t}\beta_H + \beta_m m_{i.t})]$$

Individual's Full Dynamic Problem

$$V_{i,t}(a_{i,t}, I_i, H_{i,t}) = \max_{\{c_{i,t}, m_{i,t}\}} u(c_{i,t}, H_{i,t}) + \beta \; s_{i,t}(H_{i,t}, m_{i,t}, t) \; \mathbb{E}[V_{i,t+1}(a_{i,t+1}, I_i, H_{i,t+1})]$$

$$\textit{subject to}$$

$$c_{i,t} + \gamma_{i,t} \; m_{i,t} + a_{i,t+1} = \; y_{it} + a_{i,t}(1 + r_t)$$

$$s_t = \exp(-\exp(\beta_1 + \beta_t + H_{i,t}\beta_H + \beta_m m_{i,} t))$$

$$H_{it+1} = f(H_{i,t}, m_{i,t}, t, \epsilon_{i,t})$$

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$$H_{it+1} = f(H_{i,t}, m_{i,t}, t, \epsilon_{i,t})$$

Assumption

- Individuals are offered a menu of price and procedures with probabilities of success
- Individuals make informed decisions on medical expenditures

Expression for VSL

- From the FOCS:

$$\frac{\beta\,\mathbb{E}[V_{i,t+1}(a_{i,t+1}, I_i, H_{i,t+1})]}{u_c(c_{i,t}, H_{i,t})} + \beta\frac{s_{i,t}}{u_c(c_{i,t}, H_{i,t})}\,\mathbb{E}\left[\frac{\partial V_{t+1}(a_{i,t+1}, I_i, H_{i,t+1}) f_m / s_m}{\partial H_{it+1}}\right]$$

$$= \frac{\gamma_{i,t}}{\partial s_{i,t}/\partial m_{i,t}}$$

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$$= \qquad \underbrace{\frac{\gamma_{i,t}}{\partial s_{i,t}/\partial m_{i,t}}}_{marginal\ \ private\ \ cost\ \ of\ \ reducing\ \ mortality\ \ risk}$$

- Rationality imposes the condition that optimum medical expenditure equates marginal benefits of reducing mortality risk to its marginal cost

Expression for VSL

- From the FOCS:

$$\underbrace{\frac{\beta\,\mathbb{E}[V_{i,t+1}(a_{i,t+1}, I_i, H_{i,t+1})]}{u_c(c_{i,t}, H_{i,t})}}_{value\ \ from\ \ surviving\ \ next\ \ period} + \underbrace{\beta\frac{s_{i,t}}{u_c(c_{i,t}, H_{i,t})}\,\mathbb{E}\left[\frac{\partial V_{t+1}(a_{i,t+1}, I_i, H_{i,t+1})f_m/s_m}{\partial H_{it+1}}\right]}_{additional\ \ value\ \ from\ \ improved\ \ future\ \ health\ \ stock}$$

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- In the special case, $\gamma_{i,t} = 1$, the statistic is interpreted as the marginal social cost of saving a life

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Data

- Confidential Medicare Current Beneficiary Survey (MCBS)
  - 4-year rotating panel survey
  - Drop if spending = 0 (6 %), working (8 %), or in Medicare Advantage (25 %)
  - 20,684 people observed during 2005-2011 (39,946 person-years)
  - Education, income, smoking, ADL, IADL, self-assessed health
- Linked CMS administrative data
  - 2005-2011 for MCBS + random 10 % sample of seniors (7.4 million)
  - Gender, race, birth date, death date, residential location
  - Annual medical expenditures (gross & out-of-pocket)
  - Diagnoses for 35 chronic medical conditions

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Econometric Model

$$1 - s_{i,t} = 1 - \exp[-\exp(\beta_1 + H'_{i,t}\beta_H + \beta_t + \beta_m m_{i,t})]$$

$1 - s_{i,t}$ = 1 if dies in $t+1$

$m_{i,t}$ = gross medical expenditure

β_t = age dummies

$H_{i,t}$ = *health controls* : ever-smoke, race, gender, education, self-reported health status, ADL and IADL limitations , HCC scores

- **Threats to Identification**
  - Simultaneity bias due to correlation between m and latent health

IV Estimation: Two - Stage Control Function

$$1 - s_{i,t} = 1 - \exp[-\exp(\beta_1 + H'_{i,t}\beta_H + \beta_t + \beta_m m_{i,t})]$$

- First-stage Regression:

$$m_{i,t} = \pi_1 + \pi_z Z_{i,t} + H'_{i,t}\pi_H + \pi_t + \nu_{i,t},\ \textit{given}\ \mathbb{E}[\nu_{i,t}|Z_{i,t}] = 0$$

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- Second-Stage Regression:

$$1 - s_{i,t} = 1 - \exp[-\exp(\beta_1 + H'_{i,t}\beta_H + \beta_t + \beta_m m_{i,t} + \hat{\nu}_{i,t})]$$

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- Terza et al. (JHE 2008) find control-function approach outperforms 2SLS in this context which I confirm through Monte-Carlo simulations

Instrument for medical expenditure

- Medical expenditure vary widely across the US (Fisher et al. 2003a; 2003b)
- Finkelstein (QJE, 2016) concludes half of this is due to supply-side factors (physician's practice styles, institutions, infrastructure)

Intuition for the Instrument

Similar seniors living in different regions face different menus of treatment options, leading to variation in medical spending and survival unrelated to latent health

Idetifying Assumption

The supply side factors do not systematically vary over time i.e. no GE effects

Constructing the instrument exploiting migration data

- Calculating the instrument for the 306 Hopsital Referral Regions (HRR):

$$m_{i,j,s} = \alpha_i + \gamma_j + \tau_s + X'_{i,s}\beta + \epsilon_{i,s}$$

$m_{i,j,s}$ = i's medical expenditure in region j and year, s

α_i = individual fixed effects

γ_j = place fixed effects

τ_s = year fixed effects

- $X_{i,s}$ includes age bin dummies and relative year fixed effects

$$\rho_{i,t} = t - t^*$$

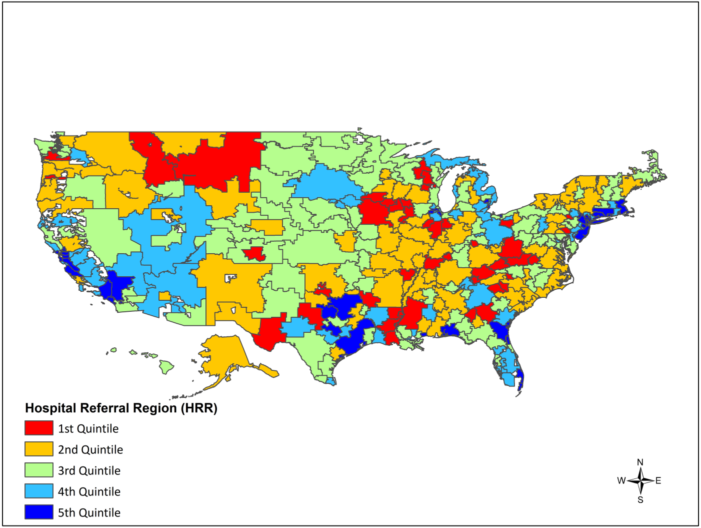
t^* = year of move

- Estimated for movers with constant observed health

- γ_j's are then used as instrument (place fixed effects)

$$\hat{\gamma}_j = m_{i,j,s} - \hat{\alpha}_i - \hat{\tau}_s - X'_{i,s}\hat{\beta} - \hat{\epsilon}_{i,s}$$

Geographical distribution of the Instrument



Estimation Results

	One-stage	Instrumental Variable			
	(1)	(2)	(3)	(4)	(5)
Coefficient on	**0.023*** **	**-0.105** **	**-0.093** **	**-0.092** **	**-0.124** **
Medical Spending	(0.001)	(0.045)	(0.045)	(0.047)	(0.058)
Average Marginal Effect		**-0.004** **	**-0.004** **	**-0.004** **	**-0.005** **
($1,000)		(0.001)	(0.002)	(0.002)	(0.002)
F-Stat Excl. Instrument		81	77	76	45
Demographics			X	X	X
Hospital Quality				X	X
Hospital Characteristics					X
No. of individuals	20,684	20,684	20,684	20,684	20,684

- First-stage results suggest a dollar-for-dollar increase in medical expenditure due to supply-side factors

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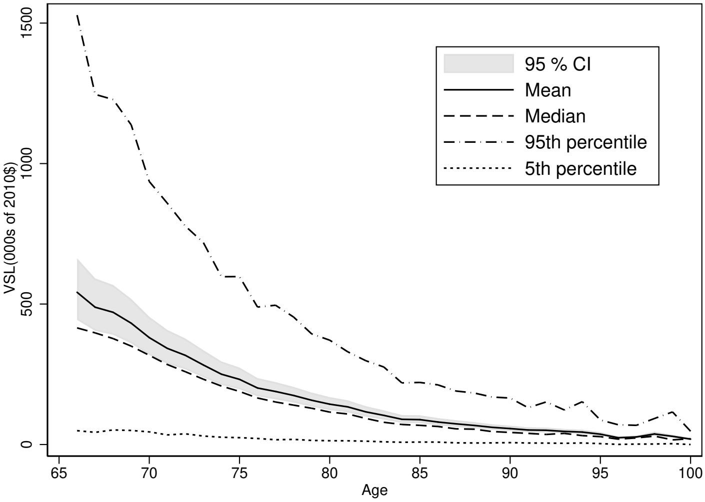
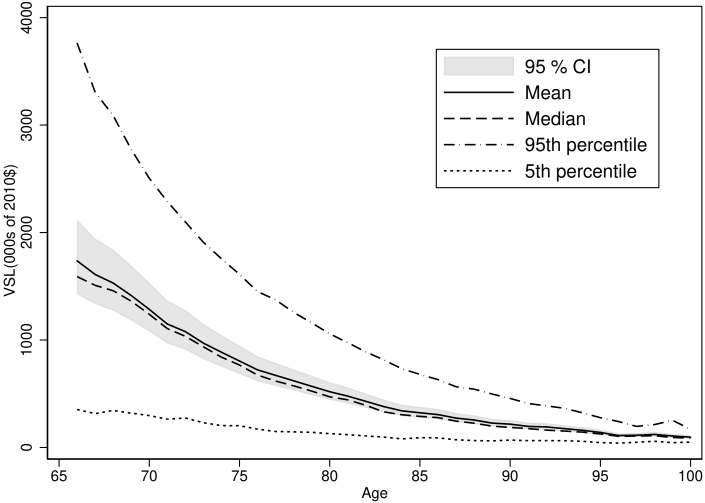
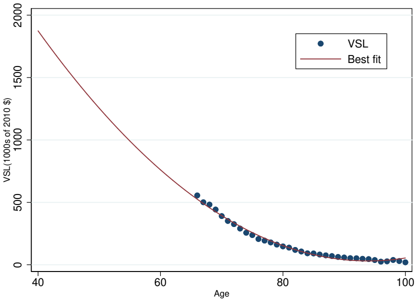
Private Value of a Statistical Senior's Life



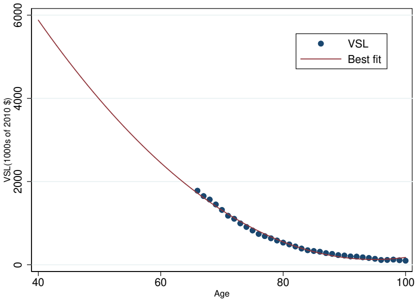
The 'Social Value' of a Statistical Senior's Life



Out-of-Sample Predictions

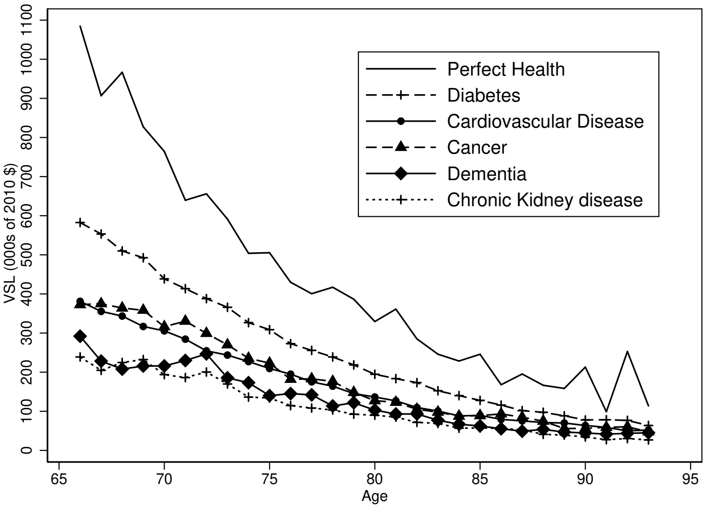


(a) Private VSL



(b) Social VSL

Heterogeneity by Medical Conditions



Policy Application: Evaluating CAAA (1990)

Type of Benefit	Billions of 2010 $		
	Estimates with private valuation	Estimates with social valuation	EPA (2011)
Total Mortality Benefit	284	340	1,328
All Other Benefit	130	130	130
Total Benefit	414	470	1,458

- The above estimates yields a benefit-cost ratio of 7:1 rather than 25:1 as envisaged by EPA

Conclusion

- New microeconometric framework for estimating VSL
- Standard hedonic wage estimate for VSL ($ 8 - $ 10 mill) overstates the average senior's WTP to reduce mortality risk by an order of magnitude
- A "plug and chug" approach to using our VSL measures for policy would greatly reduce benefit-cost ratios for policies targeting air pollution, climate change and energy, but doing so may be wrong
- **For Future Research** : Consider complementarity between quantity and quality of life