UCLA

UCLA Previously Published Works

Title

Less Health Care, More Health: The Inverse U of Medical Spending and Health in the United States.

Permalink

<https://escholarship.org/uc/item/04k6j0vk>

Journal

American journal of public health, 110(12)

ISSN

0090-0036

Author

Zimmerman, Frederick J

Publication Date

2020-12-01

DOI

10.2105/ajph.2020.305981

Peer reviewed

The Optimal Quantity of Medical Spending

Frederick J. Zimmerman, PhD
Department of Health Policy & Management
Fielding School of Public Health
University of California, Los Angeles

Abstract

Both too much and too little medical spending can be harmful to health. There is accordingly an inverted U shape in the relationship between spending on medical services and population health, with the amount of medical spending that maximizes population health somewhere in the middle. Where this optimum occurs is the subject of this analysis. Using international data from 2017, this analysis tests whether the US is to the right of the peak and therefore on the downward-sloping part of the inverse-U curve. It also tests whether the local slope of the association between medical expenditures and life expectancy is significant, and whether it persists when controlling for health behaviors and influences on health. Results suggest that each \$1,000 per year spend on medical services is associated with a loss of life expectancy of between 1.3-1.7 years. The US spends at least 29% more than is optimal for population health.

Keywords: Medical Spending; Population Health;

The Optimal Quantity of Medical Spending

Introduction

Just as for individual patients both too few and too many medical services can be harmful to health, so too at the population level both too much and too little medical spending can be harmful to population health. A society that spends none of its resources on medical services will have poor population-health outcomes. Similarly, a society that spends 100% of its resources on medical services will have nothing left over for education, housing construction and food production, and that society, too, will be unhealthy. There is accordingly an inverted U shape in the relationship between spending on medical services and population health, and the amount of medical spending that maximizes population health is somewhere in the middle. Where this optimum occurs—and where the US finds itself relative to this optimum—is the subject of this analysis.

Reasons Why Medical Spending Might Adversely Affect Population Health

At least as far back as the 1970s, the possibility of an inverse U in medical expenditures was recognized.(1) Life expectancy may decline with very high levels of health expenditures because of public or private opportunity costs or because of direct medical harm.

The public spending foregone in order to afford public expenditures on medical care given a limited budget is what economists call the public opportunity cost.(2) A dollar spent on medical care is a dollar that cannot be spent on other social goods—including on investments that may lead to better population health in long run, including education, housing, income support and public health. Governments have finite budgets, and many states in the US have political and structural constraints on raising taxes to accommodate ever-increasing medical spending. A growing literature now suggests that increases in state medical spending—not only for Medicaid, but for employee and retiree medical benefits as well as prison healthcare—are accompanied by reductions in other categories of spending, particularly higher education and public health.(3-5) At the national level, the public opportunity cost of what has been identified as wasteful

32 spending is enormous. One analysis found that if even a fraction of wasteful medical spending
33 could be recaptured and spent on other programs it could simultaneously fund class-size
34 reductions for all 24 million elementary school children in the US, nurse home-visiting programs
35 for all pregnant women who are either teens or smokers, tobacco cessation for teens sufficient to
36 prevent 300,000 new smokers, and universal high-quality preschool for all US 4-year-olds.(6)
37 Such investments would be truly transformative for health in the US.

38
39 Private opportunity costs are the second mechanism through which medical spending may
40 adversely affect health. From 1995-2015 out-of-pocket costs increased in real per-capita terms
41 by 50%, eating up a large portion of meager wage gains during this period.(7) Over 60% of
42 personal bankruptcies can be conservatively attributed to medical debt.(8) Well short of
43 bankruptcy, research has shown that high premia and deductibles induce families to skip
44 medically necessary care, use more expensive emergency department care, and/or to forego other
45 basic needs.(9) The potential health damage to any of these strategies is clear.

46
47 Finally, excess medical care that is not indicated may cause harm directly or indirectly. Such
48 excessive care increases the opportunities for medical and conceptual mistakes, and may indeed
49 be at greater risk of such mistakes. Estimates of the harm from medical mistakes vary widely,
50 from under 100,000/year to over 400,000/yr.(10)

51
52 Even the estimates at the high end of this range may underestimate the harm from excess medical
53 services as they do not include the adverse effects of inappropriate care that does not qualify as
54 medical mistakes.(11) For example, estimates suggest that some one-quarter of knee
55 replacement surgeries are inappropriate.(12) If some small portion of these 150,000 annual
56 inappropriate surgeries result in adverse events—from hospital-acquired infection to post-
57 surgical depression to opioid addiction—the harm will be significant but not counted as a
58 medical mistake.

59
60 Also not counted in estimates of medical mistakes are conceptual errors, or missed opportunities
61 to carefully and appropriately identify a medical issue and the appropriate course of treatment. A
62 recent study of conceptual mistakes using unannounced standardized patients found that only

about half of these encounters were free of conceptual errors, and these errors increased dramatically with the complexity of cases, with 91% of the most complex cases experiencing conceptual error.(13)

Of course, not all these medical mistakes or conceptual errors can be avoided, and not all are tied directly or indirectly to excess treatment. But there can be no doubt that by adopting a generally more conservative approach to medical screening and medical treatment, many deaths could be avoided.(2) The problems of overtreatment and overscreening led Fisher and Welch to suggest that when it comes to medical care, “more might be worse.”(14) The empirical question is whether the number is large enough to affect population-level estimates of mortality and life expectancy.

When all of the adverse effects associated with the public and private opportunities costs are added to the direct and indirect iatrogenic harm, it is at least conceivable that a society that spends too much of its resources on medical care may experience worse population health outcomes than would be possible if it reduced its spending. This is the downward-sloping portion of the inverted U. The objective of this analytical essay is to determine whether the level of medical expenditures in the US places it on the downward-sloping portion of the inverse U.

Methods

Regression analysis using international data tested the association of life expectancy and other mortality-related health outcome with medical expenditures per capita using flexible functional forms.

International Data

Medical expenditures per capita were obtained from the Organisation for Economic Cooperation and Development (OECD) for all available years, typically beginning in 1970 and increasingly available up until 2017 for all OECD countries as well as for 7 advanced economies for which data were available: Brazil, China, Colombia, Costa Rica, India, Indonesia, and Russia.(15)

Medical expenditures included all healthcare, all functions, and all financing schemes, and are expressed in constant 2018 dollars at purchasing power parity (PPP) exchange rates.

Data on life expectancy at birth—both overall and separately for men and women—were also from the OECD, as were data for years of potential life lost and for life expectancy at age 65 separately for men and women.⁽¹⁵⁾ Data on health-adjusted life expectancy at birth were obtained from the World Health Organization,⁽¹⁶⁾ as were age-standardized death rates, which were rescaled by dividing by 1000 to obtain annual mortality probabilities. The most recent year of data for which both Medical expenditures and the health outcomes were available was used in each case. This most recent year in the life-expectancy regressions was 2017 for most countries and 2016 for the others; it was 2016 for all countries for health-adjusted life expectancy; and it was 2014, 2015 or 2016 for mortality and years of life lost.

Several potential confounders and mediators included were also collected from the OECD, including percent of population insured,⁽¹⁵⁾ percent of adults who smoke daily,⁽¹⁷⁾ percent who are obese,⁽¹⁷⁾ alcohol consumption in litres/year divided by the population over age 14,⁽¹⁷⁾ and average total out-of-pocket costs (2018 dollars at PPP rates).⁽¹⁵⁾

The strength of environmental protection was represented by the health scale of the Environmental Performance Index.⁽¹⁸⁾ Average annual hours worked per person economically engaged is from the Penn World Tables.⁽¹⁹⁾ Data on the Gini coefficient were from the World Bank,⁽²⁰⁾ as were the poverty headcount ratio—defined as the percent of the population living on less than \$5.50/day at 2011 PPP exchange rates. Average years of total schooling among those aged 25 and above are from the Barro-Lee dataset.⁽²¹⁾

Table 1 reports the means and standard deviations of the variables.

[TABLE 1 ABOUT HERE]

Statistical Analysis

The first step in the modeling is to identify the functional form of the relationship between life expectancy and medical expenditures. This testing was done using fractional polynomial

modeling, which accommodates a very wide variety of shapes of the relationship and also provides a framework within which to formally test the performance of one functional form against others, with the goal of finding the most parsimonious functional form that adequately fits the data.(22) The following transformations of medical expenditures per capita (x) were calculated: $1/x^2$, $1/x$, $1/\sqrt{x}$, $\ln(x)$, $\sqrt{x}$, x , x^2 . A linear model was then estimated, including as covariates each of these transformations, as well as each of these transformations interacted with each of the other transformations, for a total of 35 possible functional forms. These models were then ranked by their likelihood, and chi-square tests tested the significance of each increase in log-likelihood relative to the next best-fitting model. The model chosen was the one with the greatest likelihood for which the next highest log-likelihood was not statistically significantly better at the threshold of $\alpha=0.05$.(22)

Subsequent regressions retained this functional form for medical expenditures per capita and added additional potential confounders (insurance coverage as well as measures of health behaviors, environmental protection, income inequality) and then possible mediators, with educational spending and educational attainment as a proxy for public opportunity costs; and out-of-pocket costs as a proxy for private opportunity costs.

To put these analyses into historical context, life expectancy is graphed against medical expenditures per capita over several decades.

Given that multiple years of data are available it is tempting to consider the use of country-level fixed-effects in these analyses. A recent review of 3 centuries of medical costs in the United States finds that although estimates of real per capita spending are useful for cross-sectional comparisons, the institutional processes that drive differences in medical costs unfold over multiple decades.(23) As such the use of fixed effects is inappropriate in this context.

All analyses were performed using Stata version 15.

Results

In the international regression, the functional form chosen was:

$$Life\ Expectancy = \beta_0 + \beta_1 \cdot Medex + \beta_2 \cdot Medex \cdot \ln(Medex)$$

where Medex is medical expenditures per capita. This model has significantly better likelihood than the next best model with $p=0.002$.

Figure 1 shows the relationship between medical expenditure and life expectancy at birth using this functional form. Also shown are other mortality-related health outcomes. As can be seen, the functional form is similar in each case.

Because of the nonlinear relationship, the sign and statistical significance of the coefficient on medical expenditures varies across the range of the data. At low levels—roughly from India to Chile—medical expenditures per capita are positively associated with life expectancy and this relationship is highly statistically significant. For intermediate values—roughly from Spain to Switzerland—the relationship is flat and not statistically significant. In each panel, the R^2 of the model is reported, along with the p-value of the marginal association, in the neighborhood of the US value, of the health outcome with medical expenditures. For each of the outcomes the downward slope of this relationship (or upward in the case of years of life lost and mortality) is significant at the $p<0.05$ level. A table in Appendix 1 provides full results for these unadjusted regressions.

As a robustness check on the functional form, life expectancy at age 65 (chosen because of its relatively weak curvature) was regressed on medical expenditures per capita for all countries except for the US. The results for the functional form are similar and are shown in Appendix 2.

[FIGURE 1 ABOUT HERE]

Table 2 presents the results of the 6 regressions across countries that adjust the relationships between life expectancy at birth and medical expenditures per capita for potential confounders and possible mediators.

[TABLE 2 ABOUT HERE]

Across countries, neither any of the potential confounders nor any of the possible mediators meaningfully reduces the magnitude of the coefficient on medical expenditures nor its significance. The relationship between medical expenditures and life expectancy is in fact quite consistent, negative and significant, across all regressions. Each \$1,000 of additional medical spending per capita is associated with a reduction of life expectancy of between 1.3 and 1.8 years.

[FIGURE 2 ABOUT HERE]

Figure 2 shows the evolution in the relationships between life expectancy and medical expenditures per capita over time. In the top panel of Figure 2 the relation is graphed and a non-linear function is fit without the US included. As can be seen, an inverted U shape is clearly visible in both 2000 and 2010 even without the US. In the bottom panel the US is included, and here an inverted U shape is clear, but only *after* 1980.

Discussion

This analysis tests the association of a marginal dollar spent on medical care with life expectancy—the association, that is, of one additional dollar beyond that which is already being spent. Yet there are two types of effects that medical expenditures may have on health and therefore two distinct margins. One is the expansion of medical care to those who do not otherwise have access to medical care. This margin can be thought of as the extensive margin or expanding the number of people served by medical care. The other margin is the intensive margin, or the intensity of medical care service use among those already insured. This analysis tests the associations of medical spending with health outcomes at both margins independently. The insurance variable tests the extensive margin—the expansion of medical care to those who need it. The coefficients of insurance coverage are almost universally positive in these regression results, consistent with a positive effect of most medical care on health. By controlling for insurance, the level of medical expenditures per capita measures the other margin—the effect of ever more intensive medical services among those already insured. The

generally negative coefficients of this variable are consistent with an adverse effect of overly intensive medical service use. The fact that obesity and other health behaviors are not significant confounders in international regressions should not in fact surprise us. Although these factors are clearly related to health outcomes, they have been shown to have a weak relationship to medical spending.(23)

This consistently negative relationship between medical expenditures and life expectancy persists even when many plausible causal reasons for this relationship are controlled. The robustness of the magnitude of this significant negative association of medical expenditures with life expectancy at the US value builds support for the possibility that it is the independent influence of excessive medical spending itself—and not some unobserved confounder—that lies behind the association.

Countries engage in a variety of strategies to right-size medical expenditures. While some states and health systems in the US have experimented modestly with some of these strategies, none have been widely embraced, and some have been explicitly prohibited by the US Congress. No state, for example, has a government agency that restricts what can be reimbursed according to cost-effectiveness criteria, as does the United Kingdom; no state places geographic limits on where medical personnel can practice so that all parts of the state, including rural areas, are neither under-served nor over-served, as does Germany; no state prohibits medical advertising, as do most of the other wealthy countries. Even where states have adopted major initiatives to right-size medical spending, as with Maryland's global budget, the initiatives have been either too modest or too new to have provided any meaningful brake on medical expenditures to date.(24)

Taken together these results suggest that the US is past the peak of the inverted U, but how far past? It is possible to use the regression results to identify the maximum value of medical expenditures per capita at which the downward slope is not significant. This value is about \$7,500, approximately what Switzerland spends, and some 29% lower than what the US does.

Not only does the cost of medical care drive down investments in the social determinants of health, but poor social conditions drive up the cost of medical care. The impact of early childhood investments, education, and income-support programs among the elderly(25) are but a few of the many areas in which investment in the social determinants of health have been shown to have large benefits to health. Such investments will undoubtedly reduce the cost of medical care for the population as a whole. Even controlling for health, improvements in education and economic status make medical care more efficient by promoting more consistent adherence to medical regimes. One recent economic study finds that, controlling for local and hospital-specific factors, hospitals in areas in the top tertile of public health spending per capita are about 2% more efficient than hospitals in areas in the bottom tertile.(26)

A vicious cycle has been allowed to develop in the US, in which poor health and social conditions drive up the cost of medical care, and medical spending raises costs and reduces health.

Limitations

This analysis has important limitations. The most obvious is that the long time-frames on which both medical expenditures and life expectancy evolve, combined with a small number of political jurisdictions within which they can evolve, limit the sample sizes. Small sample sizes in turn limit the kinds of statistical methods that can be used to produce valid causal inferences. The work here must interpreted in light of this limitation. The contribution of this work is not to be dispositive, but to rather to provide face-validity for the hypothesis that, at the margin, US spends so much on medical expenditures that health is imperiled.

Another limitation is in the quality of the data. Life expectancy can be measured accurately, but the measure of medical expenditures is not an exact science.(27) Similarly, many of the potential confounders and mediators are surely measured imprecisely.

Conclusion

277 Healthcare must be distinguished from medical care.(28) Indeed there seem to be sharp tradeoffs
278 between the two. Intersectoral interventions are not only essential for good health,(29) but
279 neglecting them while lavishly funding intensive medical services seems to be adversely
280 affecting population health.

281
282 One often hears that any attempt to limit medical spending will impair health or indeed cost
283 lives. The results of this analysis provide no support for this position, and some qualified
284 support for the opposite position. Cutting medical expenditures is never easy, but nothing
285 suggests it will be harmful, and it may indeed promote improved health.

References

1. Lalonde M. A new perspective on the health of Canadians. Ottawa, Canada: Ministry of National Health and Welfare; 1974.
2. Brownlee S, Chalkidou K, Doust J, Elshaug AG, Glasziou P, Heath I, et al. Evidence for overuse of medical services around the world. *The Lancet* 2017;390(10090):156-168.
3. Fossett JW, Burke C. Medicaid and State Budgets in FY 2004: Why Medicaid is so Hard to Cut. Albany, NY: The Nelson A. Rockefeller Institute of Government; 2004.
4. Tran LD, Zimmerman FJ, Fielding JE. Public health and the economy could be served by reallocating medical expenditures to social programs. *SSM—Population Health* 2017;3(December):185-191.
5. Bradley EH, Canavan M, Rogan E, Talbert-Slagle K, Ndumele C, Taylor L, et al. Variation In Health Outcomes: The Role Of Spending On Social Services, Public Health, And Health Care, 2000–09. *Health Affairs* 2016;35(5):760-768.
6. McCullough JC, Zimmerman FJ, Fielding JE, Teutsch SM. A Health Dividend for America: The Opportunity Cost of Excess Medical Expenditures. *American Journal of Preventive Medicine* 2012;43(6):650-654.
7. Kaiser Family Foundation. Per capita out-of-pocket expenditures have grown since 1970—Analysis of National Health Expenditure (NHE) Data. 2019. https://www.healthsystemtracker.org/chart-collection/u-s-spending-healthcare-changed-time/#item-nhe-trends_per-capita-out-of-pocket-expenditures-1970-2018, accessed 1/22/20.
8. Himmelstein DU, Thorne D, Warren E, Woolhandler S. Medical Bankruptcy in the United States, 2007: Results of a National Study. *The American Journal of Medicine* 2009;122(8):741-746.
9. Artiga S, Ubri P, Zur J. The Effects of Premiums and Cost Sharing on Low-Income Populations: Updated Review of Research Findings. Menlo Park, CA: Kaiser Family Foundation; 2017.
10. James JT. A New, Evidence-based Estimate of Patient Harms Associated with Hospital Care. *Journal of Patient Safety* 2013;9(3):122-128.
11. Makary MA, Daniel M. Medical error—the third leading cause of death in the US. *BMJ* 2016;353:i2139.
12. Cobos R, Latorre A, Aizpuru F, Guenaga JI, Sarasqueta C, Escobar A, et al. Variability of indication criteria in knee and hip replacement: an observational study. *BMC Musculoskeletal Disorders* 2010;11(1):249.
13. Weiner SJ, Schwartz A, Weaver F, Goldberg J, Yudkowsky R, Sharma G, et al. Contextual Errors and Failures in Individualizing Patient Care: A Multicenter Study. *Annals of Internal Medicine* 2010;153(2):69-75.
14. Fisher ES, Welch HG. Avoiding the unintended consequences of growth in medical care: how might more be worse? *Jama* 1999;281(5):446-453.
15. OECD. Health at a Glance 2019: OECD Indicators. Paris: OECD Publishing; 2019.
16. World Health Organization. The Global Health Observatory. 2019. <https://www.who.int/data/gho>, accessed
17. OECD. Non-medical Determinants of Health. 2019. <https://stats.oecd.org>, accessed October 11, 2019.

18. Wendling ZA, Emerson JW, Esty DC, Levy MA, de Sherbinin A, al. e. 2018 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy; 2018.
19. Feenstra RC, Inklaar R, Timmer MP. The Next Generation of the Penn World Table. American Economic Review 2015;105(10):3150-3182. available for download at www.ggd.net/pwt.
20. The World Bank. World Bank Open Data. 2019. <https://data.worldbank.org/>, accessed
21. Barro RJ, Lee JW. A new data set of educational attainment in the world, 1950–2010. Journal of Development Economics 2013;104:184-198.
22. Royston P, Altman DG. Regression Using Fractional Polynomials of Continuous Covariates: Parsimonious Parametric Modelling. Journal of the Royal Statistical Society: Series C (Applied Statistics) 1994;43(3):429-453.
23. Getzen TE. The Growth of Health Spending in the United States From 1776 to 2026. In: Oxford Research Encyclopedia of Economics and Finance. Oxford: Oxford University Press; 2019.
24. Roberts ET, McWilliams JM, Hatfield LA, Gerovich S, Chernew ME, Gilstrap LG, et al. Changes in Health Care Use Associated With the Introduction of Hospital Global Budgets in Maryland. JAMA Internal Medicine 2018;178(2):260-268.
25. Arno PS, House JS, Viola D, Schechter C. Social security and mortality: The role of income support policies and population health in the United States. Journal of Public Health Policy 2011;32(2):234-250.
26. Hunt DJ, Link CR. Better outcomes at lower costs? The effect of public health expenditures on hospital efficiency. Applied Economics 2019:1-15.
27. Lassman D, Sisko AM, Catlin A, Barron MC, Benson J, Cuckler GA, et al. Health spending by state 1991–2014: Measuring per capita spending by payers and programs. Health Affairs 2017;36(7):1318-1327.
28. Kindig D. Do You Really Mean *Health* Expenditures? Health Affairs 2012;Health Affairs Blog(August 7).
29. Kottke TE, Stiefel M, Pronk NP. “Well-being in all policies”: promoting cross-sectoral collaboration to improve people’s lives. Preventing chronic disease 2016;13.

Table 1: Sample Descriptive Statistics

	Mean or %	SD
Life expectancy at birth	79.61	(3.78)
Medical expenditures per capita (thousands USD at PPP)	3.51	(2.11)
<i>Potential Confounders</i>		
Percent insured	95.50%	
Average alcohol consumption per capita (liters)	8.39	(3.11)
Percent adults who smoke	18.74%	
Percent adults who are obese	21.99%	
EPI Environmental index	80.39	(19.33)
Gini coefficient	0.35	(0.069)
Poverty rate (%)	8.30%	
<i>Possible Mediator: Public Opportunity Costs</i>		
Average years of schooling	10.45	(2.06)
Educational Spending as a percent of GDP	5.20	(1.25)
<i>Possible Mediator: Public Opportunity Costs</i>		
Out-of-Pocket Spending (thousands USD)	0.60	(0.31)
<i>N</i>	43	

Notes: SD=standard deviation; USD=US Dollars; PPP=purchasing power parity exchange rates; GDP=Gross Domestic Product; EPI= Environment Performance Index. The means are calculated across countries unweighted by population. For additional source notes and definitions, see text.

Table A2: Regressions of Life Expectancy at Birth on Medical Expenditures per Capita with Various Control Variables—Across Countries and States

	Potential Confounders				Possible Mediators	
	(1)	(2)	(3)	(4)	(5)	(6)
Medical expenditures per capita (thousands USD)	-1.367** (-2.197 - -0.537)	-1.705** (-2.384 - -1.027)	-1.278** (-2.112 - -0.443)	-1.765** (-2.681 - -0.849)	-1.582** (-2.385 - -0.779)	-1.439** (-2.308 - -0.570)
Percent insured	0.034 (-0.025-0.092)	0.055* (0.005-0.105)	0.017 (-0.047-0.081)	0.008 (-0.055-0.072)	0.028 (-0.030-0.086)	0.032 (-0.027-0.091)
Percent adults who smoke		-0.037 (-0.112-0.038)				
Average alcohol consumption per capita		-0.411** (-0.589--0.233)				
Percent adults who are obese		-0.046 (-0.116-0.023)				
EPI Environmental index			0.041 (-0.023-0.105)			
Gini coefficient				10.159 (-0.954-21.272)		
Average years of schooling					-0.504** (-0.869--0.138)	
Educational spending as a percent of GDP					-0.048 (-0.510-0.413)	
Average out-of-pocket expenses						0.793 (-1.776-3.362)
Observations	43	43	43	43	41	43
R-squared	0.794	0.887	0.803	0.811	0.843	0.796

Note: USD=US Dollars

Figure 1: Flexible-Form Regressions of Mortality-Related Health Outcomes on Medical Expenditures per Capita

Figure 2: Historical Relationships of Life Expectancy to Medical Expenditures per Capita (2018 US \$)

Appendix

Unadjusted Regression Results

Table A1: Results of marginal effects centered on the US value—Unadjusted

	coefficient	Std. Err.	p-value	(95% Confidence Interval)
<i>Life Expectancy at Birth</i>				
Medical Expenditures per Capita ^a R ² = 0.776; N=43	-1.614	0.354	<0.001	(-2.328 - -0.899)
<i>Health-Adjusted Life Expectancy at Birth</i>				
Medical Expenditures per Capita R ² =0.744; N=43	-1.594	0.357	<0.001	(-2.316 - -0.871)
<i>Life Expectancy at Birth for Women</i>				
Medical Expenditures per Capita R ² = 0.480; N=37	-0.751	0.255	0.006	(-1.269 - -0.234)
<i>Life Expectancy at Birth for Men</i>				
Medical Expenditures per Capita R ² = 0.558; N=37	-0.621	0.287	0.038	(-1.205 - -0.036)
<i>Years of Potential Life Lost^b</i>				
Medical Expenditures per Capita R ² =0.583; N=27	11.149	2.862	0.001	(5.242 - 17.056)
<i>Mortality Percentage^c</i>				
Medical Expenditures per Capita R ² = 0.451; N=40	-0.044%	0.020	0.033	(0.004% - 0.084%)

Note: each row represents the result of a separate, unadjusted regression.

a. Medical expenditures per capita in 2017 US dollars at purchasing power exchange rates

b. Per 1,000 population aged 0-69

c. Age-standardized death rate per 100 people in the population

Appendix 3

This figure shows the relationship of Life Expectancy to Medical Expenditures Per Capita (exppercap) both with and without the US included. In both cases the relationship takes the form of an inverse U. The functional forms are quadratic and the fractional polynomial form identified in the text. The sides of the turquoise rectangle identify the peak values of the inverse U in regressions with and without the US included. Other mortality outcomes produce similar results.

Figure A1: Regression of Life Expectancy at Age 65 on Medical Expenditures Per Capita