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From the Heavens to the Helix: The Cost-Benefit Analysis of President Obama's "Moonshot" Call to Cure Cancer

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In his final State of the Union, President Obama called on the scientific community to "make America the country that cures cancer once and for all." Congress has since responded, increasing funding for such research. While this is good in the abstract, it is unclear that it is an objectively correct and productive use of government funds. This article proposes measures by which to analyze the costs and benefits of the government's cancer research funding expenditures. Having done so, the article then offers specific policy recommendations incorporating further cost-benefit analysis to realize the President's aim, namely: weighting grant applications by the cost of the cancer being addressed, increasing the number of grants funded and creating a revolving fund for future funding, converting NIH spending from discretionary to mandatory, expending cooperative partnerships, and collecting more data on grant applications themselves for further analysis.

Keywords: law, economics, bioethics, public policy

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Introduction

On May 25, 1961, President John F. Kennedy declared to a special joint session of Congress that the United States would put a man on the moon before the turn of the decade.[2] It was an historic moment in American triumphalism as much as it was in the scientific community. In his final State of the Union Address, President Barack Obama paid homage to President Kennedy's call but shifted the American people's gaze inward via a new "moonshot": "For the loved ones we've all lost, for the families that we can still save, let's make America the country that cures cancer once and for all."[3] This remarkable announcement came just one month after the President signed a new budget that increased the National Institute of Health's (NIH) funding from $30 to $32 billion—its largest increase in funding in 12 years.[4] Congress has doubled-down on the effort with the 21st Century Cures Act[5] to further expand the government's scientific research efforts. Even more surprising in today's political climate, both parties supported the increases![6]

However, before we blindly embrace this rare example of bipartisan cooperation, we must ask a more foundational question: is this a good use of taxpayer money? Undoubtedly, curing cancer is a good idea in the abstract but is it cost-effective for the government to fund it, let alone increase funding?

Put simply, yes. Medical research at large has been proven to yield incredible economic benefits. In 2003, economists pegged the return on investment ("ROI") for medical research from 1970–1998 at $2.6 trillion per year,[7] while overall investment in medical research totaled $36 billion that year—$13.4 billion in government funding, $18.6 by private industry, and $4 billion by other sources.[8] The economic analysis also highlighted the contributions of certain diseases-specific developments: heart disease, for example, accounted for $3.2 trillion in value gained per year from 1970 to 2000.[9] Its evaluation of cancer, however, was purely speculative, providing only estimates of GDP value added if cancer mortality could be reduced by a given amount.

The government similarly does not perform precise cost-benefit analysis on appropriations for cancer research. When the National Cancer Institute (NCI)—which coordinates much of the government's cancer research—offers Congress a justification for the programs it hopes to fund in its budget request, it does not proffer expectations, let alone quantitative metrics, on proposed programs' efficacies in reducing cancer's incidence or mortality; it does not even discuss similar programs' historical effectiveness.[10] But by performing cost-benefit analysis on cancer research, the scientific community can present more concrete evidence in support of investing in medical research. So while the figures are not offered in the Congressional Justification, we can perform the analysis organically using the raw statistics on cancer's incidence and mortality rates.

To contextualize government investment in medical research, this article first provides a background on how government effectuates treatment developments in the form of decreased cancer incidence and mortality. In Section II, the article offers a brief historical perspective of the United States government's role in medical research investment, including the realization of President Obama's "moonshot." In Section III, a framework is put forward to value research's positive impact in light of how we value life at a given age using a consumption formula, aided in large part by the abovementioned economic analysis framework for medical research,

[2] President John Fitzgerald Kennedy, Special Message to the Congress on Urgent National Needs (May 25, 1961), https://catalog.archives.gov/id/193915.
[3] Press Release, The White House, Remarks of President Barack Obama – State of the Union Address As Delivered (Jan. 13, 2016), https://obamawhitehouse.archives.gov/the-press-office/2016/01/12/remarks-president-barack-obama-%E2%80%93-prepared-delivery-state-union-address.
[4] Jocelyn Kaiser, *2016 spending bill gives NIH $2 billion raise, largest in 12 years*, SCI. (Dec. 18, 2015), http://www.sciencemag.org/news/2015/12/updated-budget-agreement-boosts-us-science.
[5] *See* Pub. L. No. 114-255 (2016).
[6] *See, e.g.*, Sarah Karlin, *NIH sees reversal of fortune with proposed funding boosts*, POLITICO (July 7, 2015), http://www.politico.com/story/2015/07/national-institutes-of-health-funding-119696.html.
[7] *See* Kevin M. Murphy & Robert H. Topel, *The Value Of Health And Longevity*, 114 J. POL. ECON. 871, 872 (2006) (in 1996 USD) [hereinafter Murphy & Topel 2006].
[8] Kevin M. Murphy & Robert H. Topel, *The Economic Value of Medical Research* in MEASURING THE GAINS FROM MEDICAL RESEARCH 41, 41–42 (Kevin M. Murphy & Robert H. Topel eds., 2nd ed. 2003) [hereinafter Murphy & Topel 2003].
[9] *Id.* at 42.
[10] *See generally* NAT'L CANCER INST., DEP'T OF HEALTH & HUM. SERVICES, CONGRESSIONAL JUSTIFICATION FOR FISCAL YEAR 2017 (2016), http://www.cancer.gov/about-nci/budget/congressional-justification/fy2017-nci-congressional-justification.pdf.

done by Professors Murphy and Topel.[11] The next sections review research's progress on some of the 200+ types[12] of cancer from among the most recent data sets available[13] and apply it to the framework to calculate the cost of cancer today, the value saved from improved incidence and mortality rates, and the ROIs for cancer research over a 10-year span, 2002-2012. The results are overwhelmingly positive. Armed with results that support further government investment cancer research, the article addresses how the government should go about allocating its resources: Section V details possible distribution schemes should more money be appropriated—including their ethical considerations—and proposes, unsurprisingly, using cost-benefit analysis to drive distribution. Lastly, suggestions are offered regarding how to change data collection and dissemination for more precise analysis.

I. How Does Funding Translate Into Lab Work, and How Does Lab Work Ultimately Impact the Health Landscape

i. Funding the Lab

Imagine that an established scientist[14] at an academic medical center (AMC) seeking public funding to research a drug with the potential to suppress cancer cell proliferation, she seeks out and applies for any applicable grants at the NIH and NCI.[15] These grants are typically open-ended, or unrestricted by the type of cancer or the type of research, "including (but not limited to) cancer biology, cancer prevention, cancer diagnosis, cancer treatment, and cancer control."[16]

Once she's submitted the grant application to the NCI, there is a mandatory multi-level peer review system.[17] The first level has specialists assess "applications using a new scoring scale of 1 to 9 to list their final impact/priority score"[18] based on the project's significance, investigators, innovation, approach, and environment.[19] Importantly, "[e]ach application is scored in its own right and not in comparison to other applications under consideration."[20] If a grant makes it past this round, it must be cleared by the National Cancer Advisory Board (NCAB), which not only reviews the project but also issues recommendations concerning the budget.[21]

Oddly, "[m]any more grants are approved by the NCAB than can be financed from the NCI budget."[22] As a result, a negotiation process begins to potentially trim some fat off of approved proposals and continue to slice the budget down further.[23] The Director of the NCI makes final funding decisions "based primarily on [Initial Review Group] percentile/impact score ratings of scientific merit, the Institute's program objectives, avoidance of duplicate effort, and other considerations."[24] If a scientist's grant makes the cut, she will be the happy benefactor of the President's new "moonshot."

ii. Getting to the Consumer

After the drug is developed, the scientist will seek to release it into the marketplace. To do so, the Federal

[11] Murphy & Topel 2006, *supra* note 7; Murphy & Topel 2003, *supra* note 8.
[12] *What is Cancer?*, CANCER RESEARCH UK, http://www.cancerresearchuk.org/about-cancer/what-is-cancer (last visited Jan. 22, 2017).
[13] *See generally* A. Blythe Ryerson et al., *Annual Report to the Nation on the Status of Cancer, 1975-2012, Featuring the Increasing Incidence of Liver Cancer*, 122 CANCER 1312 (2016).
[14] This is an important qualification. For scientists without a track record, there are different grants and application procedures to build credibility. Because these comprise fewer of the NIH grants for cancer research, this Note focuses on established scientists.
[15] This paper excludes private funding sources and limits public funding to the NCI and NIH. Many other funding sources exist, even in government, where there is an additional central clearinghouse of grants that includes grants for all federal agencies and all medical research. *See* GRANTS.GOV, HTTP://WWW.GRANTS.GOV (LAST VISITED JAN. 22, 2017). Thus, while applicable, *most* cancer research grants come from the NIH and NCI. The notable exception is the Defense Department, whose medical research is beyond this Article's scope.
[16] *PAR-15-023: National Cancer Institute Program Project Applications (P01)*, NAT'L INSTS. OF HEALTH, http://grants.nih.gov/grants/guide/pa-files/PAR-15-023.html.
[17] *See* Public Health Service Act § 492, 42 U.S.C. § 289 (2012).
[18] *See* NAT'L CANCER INST., THE NCI CONSUMER'S GUIDE TO PEER REVIEW 28-29 (2009), http://deainfo.nci.nih.gov/PeerReview/GuideCompleteBook.pdf.
[19] NAT'L INST. OF HEALTH ORIENTATION FOR THE NATIONAL CANCER ADVISORY BOARD 35 (2013), http://deainfo.nci.nih.gov/advisory/ncab/orientationbook.pdf [hereinafter ORIENTATION BOOK]. There are additional review criteria, such as the animal or human subjects' protections, minority inclusion, or biohazards. *Id*. at 35, 38. Admittedly, each question is subjective and thus prone to unfair influence, such as evaluating if the applicant is "well suited to the project," the strength of their previous accomplishments and leadership, and their organizational structure. *Id*. at 35.
[20] *See* NCI CONSUMER'S GUIDE, *supra* note 18, at 30. (2009).
[21] *See* ORIENTATION BOOK, *supra* note 19, at 39.
[22] ORIENTATION BOOK, *supra* note 19, at 52.
[23] *See* NAT'L CANCER INST., U.S. DEP'T OF HEALTH & HUM. SERVICES, THE GRANT PROCESS: THE LIFECYCLE OF A GRANT 41–45 (2015).
[24] ORIENTATION BOOK, *supra* note 19, at 52.

Drug Agency (FDA) must extensively test the drug.[25] This process begins with the developer conducting thorough testing on animals "to gather basic information on the safety and efficacy of the compound being investigated/researched."[26] If the drug is sufficiently safe, the "sponsor submits an Investigational New Drug (IND) Application to FDA . . . and develops a plan for testing [the] drug on humans," that "does not place human subjects at unreasonable risk of harm."[27]

Once approval is granted, clinical human trials are developed in three phases. Phase 1 tests the drug on twenty to eighty "healthy volunteers . . . to determine what the drug's most frequent side effects are and, often, how the drug is metabolized and excreted."[28] Phase 2, which employs up to 300 participants, obtains preliminary data on whether the drug works in people who have a certain disease or condition.[29] Finally, Phase 3 "gathers more information about safety and effectiveness" by testing the drug on anywhere from several hundred to about 3,000 people," [30] If the drug's efficacy and side effects meet required standards and pass a final review from "[a] team of [Center for Drug Evaluation and Research] physicians, statisticians, chemists, pharmacologists, and other scientists," the drug will be approved for public sale and consumption.[31]

How long does the review process take? "[S]cientific explorations often only produce tangible output after *many* years."[32] A 1990 study "found evidence that on average it takes 20 years for basic research to produce tangible economic results!"[33] More recent studies confirm similar, if only slightly better, delays. A 2014 RAND study cites a 15-year time lag particular to some cancer research.[34] Similar lags can be found in other diseases' time from research to marketplace.[35] And though no research has parsed out whether the lag differs between the private and the public sectors, it stands to reason that no such difference would exist.[36]

II. From Humble Origins to Moonshots: a brief history of U.S. Government Investments in Cancer Research

To best understand the policies proposed by the President and potential alternatives, an understanding of the history of government-funded medical research is informative.

On July 16, 1798, President John Adams signed the Seaman's Act,[37] mandating every ship's captain pay the port's collector 20 cents per seaman per month

[25] *Development & Approval Process (Drugs)*, U.S. FOOD & DRUG ADMIN., DEP'T. OF HEALTH & HUM. SERVICES, http://www.fda.gov/Drugs/DevelopmentApprovalProcess/.
[26] U.S. FOOD & DRUG ADMIN., DEP'T. OF HEALTH & HUM. SERVICES, DRUG APPROVAL PROCESS 1 http://www.fda.gov/downloads/Drugs/ResourcesForYou/Consumers/UCM284393.pdf. "Because rats and mice have so many biological similarities to humans, they make up 90 to 95 percent of the mammals in biomedical research. . . . Other mammals commonly found in research are guinea pigs, rabbits, hamsters, and farm animals such as pigs and sheep. Most of these animals are specifically bred and raised for research." *Types of animals*, UNIV. OF NEB. MED. CTR., http://www.unmc.edu/animalsinresearch/treatment/types-of-animals.html.
[27] DRUG APPROVAL PROCESS, *supra* note 26, at 1.
[28] *Id.*
[29] *The FDA's Drug Review Process: Ensuring Drugs Are Safe and Effective*, U.S. FOOD & DRUG ADMIN., DEP'T HEALTH & HUM. SERVICES, http://www.fda.gov/drugs/resourcesforyou/consumers/ucm143534.htm.
[30] *Id.*
[31] *See generally* DRUG APPROVAL PROCESS, *supra* note 26. Reviews of drug labeling and the manufacturing facility are also involved. *Id.*
[32] Ian M. Cockburn & Rebecca M. Henderson, *Publicly Funded Science and the Productivity of the Pharmaceutical Industry* 1, 8–9 *in* 1 INNOVATION POLICY AND THE ECONOMY (Adam B. Jaffe, Josh Lerner & Scott Stern eds. 2001) (emphasis added) (*citing* James D. Adams, *Fundamental Stocks of Knowledge and Productivity Growth*, 98 J. POL. ECON. 673 (1990)).
[33] *Id.*
[34] *See generally* SUSAN GUTHRIE ET AL., INVESTIGATING TIME LAGS AND ATTRIBUTION IN THE TRANSLATION OF CANCER RESEARCH: A CASE STUDY APPROACH (RAND 2014), http://www.rand.org/content/dam/rand/pubs/research_reports/RR600/RR627/RAND_RR627.pdf.
[35] *See, e.g.*, MARTIN BUXTON ET AL., MEDICAL RESEARCH: WHAT'S IT WORTH?. (RAND EUROPE 2008), https://www.mrc.ac.uk/publications/browse/medical-research-whats-it-worth/ (finding "a mean lag between research and impact of [cardiovascular disease] between ten and 25 years, with a mid-point of 17 years.").
[36] In some cases, developmental drugs will be available for one of the FDA's expedited review programs: Fast Track Designation, breakthrough therapy designation, accelerated approval, and priority review designation. These programs all offer essentially the same premise: expedited and preferential review if a drug can make a substantive impact in a highly necessary field. *See generally* CTR. FOR DRUG EVALUATION AND RESEARCH & CTR. FOR BIOLOGICS EVALUATION AND RESEARCH, DEP'T OF HEALTH & HUM. SERVICES, GUIDANCE FOR INDUSTRY: EXPEDITED PROGRAMS FOR SERIOUS CONDITIONS – DRUGS AND BIOLOGICS (2014), http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/UCM358301.pdf; Food and Drug Administration Modernization Act of 1997, Pub. L. No. 105-115, 111 Stat. 2296, 21 U.S.C. § 356 (2012).
[37] An Act for the relief of sick and disabled seamen, Pub. L. No. 77, 1 Stat. 605 (1798).

aboard "to provide for the temporary relief and maintenance of sick or disabled seamen, in the hospitals or other proper institutions now established[.]"[38] What's more,

> if any surplus shall remain of the monies to be collected . . . after defraying the expense of such temporary relief and support, that . . . together with such private donations as may be made for that purpose (which the President is hereby authorized to receive) shall be invested [and, when financially reasonable, liquidated] to purchase or receive cessions or donations of ground or buildings... and to cause buildings, when necessary, to be erected as hospitals for the accommodation of sick and disabled seamen.[39]

This was the first act of government-funded healthcare, albeit not yet funding medical research. That would come nearly a century later: precipitated by 1878's yellow fever epidemic,[40] Congress created the National Board of Health (NBH),[41] the country's "first organized, comprehensive Federal medical research effort."[42]

The 20th century brought new approaches to government-funded medical research that underpins our system today. In 1901, $35,000 was appropriated to build a facility to "investigat[e] contagious and infectious diseases and matters pertaining to public health."[43] Congress repealed the captain's tax and directly appropriated scientific research funds in 1906.[44] By the end of World War I, Congress permitted outsourcing research to scientists not directly employed by the government (termed extramural research today).[45] The first federally recognized lab devoted to cancer research was established in 1922 and housed at Harvard.[46]

The Ransdell Act of 1930[47] ushered in the next major milestone, reorganizing and expanding the purview of existing research labs and housing them under one roof: the newly-created National Institute of Health.[48] More, the Act established fellowship programs like to those the NIH employs today.[49] The decade's other major development was the creation of the National Cancer Institute under the Public Health Service in 1937 [50] after multiple failed attempts to appropriate moneys for cancer research in both the late 1920s[51] and early 1930s.[52] The NCI was designed with five main missions:

> (a) To conduct, assist, and foster researches, investigations, experiments, and studies relating to the cause, prevention, and methods of diagnosis and treatment of cancer; (b) To promote the coordination of researches conducted by the Institute and similar

[38] *Id.* § 3.
[39] *Id.* § 4. The United States Marine Hospital Service (MHS) was established to execute the law. *See* OFFICE OF HISTORY, NAT'L INST. OF HEALTH, *Legislative Chronology*, https://history.nih.gov/research/sources_legislative_chronology.html [hereinafter *Legislative Chronology*].
[40] W.G. Smillie, *The National Board of Health 1879-1883*, 33 AM. J. PUB. HEALTH & NATION'S HEALTH 925, 926 (1943).
[41] An Act to Prevent the Introduction of Infectious or Contagious Disease into the United States and to Establish a National Board of Health, 20 Stat. L. 484 (1879).
[42] *Legislative Chronology*, *supra* note 39 *citing* An act to prevent the introduction of contagious or infectious diseases into the United States, 21 Stat. 5 (1879).
[43] NATIONAL INSTITUTE OF HEALTH, A SHORT HISTORY OF THE NATIONAL INSTITUTES OF HEALTH 2, https://history.nih.gov/exhibits/history/docs/page_02.html.
[44] The first year's appropriation was one hundred and seventy thousand dollars. An Act Making appropriations for sundry civil expenses of the Government for the fiscal year ending June thirtieth, nineteen hundred and seven, and for other purposes, Pub. L. 59-383, 34 Stat. 697 (1906).
[45] An Act Making appropriations for the support of the Army for the fiscal year ending June 30, 1919, 40 Stat. 845 (1918). The Interdepartmental Social Hygiene Board created by the Act was: To select certain universities, college[s], or other suitable institutions or organizations, to which allotment of money may be made for the purpose of discovering more effective medical measures in the prevention and treatment of venereal diseases; and for the purpose of discovering and developing more effective educational measures in the prevention of venereal diseases. ANNUAL REPORT OF THE SURGEON GENERAL OF THE PUBLIC HEALTH SERVICE OF THE UNITED STATES FOR THE FISCAL YEAR 1919, 234 (1919). Interestingly, the Act was driven in large part because "at any given time typically one-third of active soldiers were laid low by sexually transmitted infections (STIs)," but was controversial because it permitted quarantining individuals—particularly women—suspected of having venereal diseases. MELISSA HOPE DITMORE, PROSTITUTION AND SEX WORK 53 (2011).
[46] *See Legislative Chronology*, *supra* note 39.
[47] Pub. L. 71-251, 46 Stat. L. 379 (1930).
[48] *Id.* § 1.
[49] *Id.* §§ 2, 3.
[50] *See* National Cancer Institute Act, Pub. L. 75-244, 50 Stat. L. 559 (1937). The Act appropriated $750,000 to build the facilities required and $700,000 per year to conduct the research and carry out the Act, *id.* §§ 7(a)–(b), totaling less than 0.001% of government spending. And it established a framework for accepting charitable donations. *Id.* § 6.
[51] *See, e.g.*, S. 5589, 69th Congr. (1927) (authorizing an award of $5 million to successfully cure cancer—and prove it); S. 3554, 70th Congr. (1928) (to "investigate the means and methods for affording Federal aid in discovering a cure for cancer"); S. 466, 70th Congr. (1929) (a nearly identical bill); S. 4531, 71th Congr. (1929).
[52] *See, e.g.*, H.R. 6100, 75th Congr. (1937) ("to control and prevent the spread of the disease of cancer" with $1 million annually appropriated); H.R. 6767, 75th Congr. (1937) (appropriating $2,400,000 for overhead costs and $1 million annually thereafter for a National Cancer Center); H.R. 7931, 75th Congr. (1937).

> researches conducted by other agencies, organizations, and individuals; (c) To procure, use, and lend radium as hereinafter provided; (d) To provide training and instruction in technical matters relating to the diagnosis and treatment of cancer; (e) To provide fellowships in the Institute from funds appropriated.[53]

The organization successfully helped facilitate cancer research for decades without much change until President Nixon's National Cancer Act of 1971 (NCA).[54] As the commencement of what would come to be called the "War on Cancer"[55]—the NCA empowered the NCI Director to coordinate all cancer-related NIH programs, including encouraging cooperation with the private sector and state research organizations.[56]

The NCA's effect on NCI's overall budget and its future trajectory cannot be overstated. Before the NCA was enacted, the NCI *averaged* 0.0571% of the federal budget since its inception, maxing out at 0.1399% in 1963.[57] The National Cancer Act Amendment of 1974[58] upped the ante even more, appropriating up to 0.2% of federal spending on cancer research.[59] Its impact would be short-lived, though: Reagan's election, "particularly with a constrained federal budget in an era of aggressive deregulation,"[60] cut the NCI's budget significantly.[61]

Beyond one structural change in 1985, which required the NCI to "assess the incorporation of state-of-the-art cancer treatment into clinical practice and the extent to which cancer patients receive such treatments and include the results of such assessments,"[62] the lion's share of legislation relating to the NCI amended its mission and research emphasis to reflect the issues of the day, including breast[63], blood,[64] gynecologic,[65] cervical,[66] and pediatric cancers.[67] However, recent upticks in funding over the last few years have come in a redoubled effort to cure cancer.[68]

III. Deriving the Formula to Evaluate Gains From Medical Research Improvements.

i. Conceptual Theory

Before delving into cancer researchers' successes, it is vital to understand how extending life benefits the economy. Extending life is not a "broken window fallacy"[69]: that would require viewing changes in

[53] National Cancer Act, *supra* note 50, § 2. The history of government-funded medical research necessarily considers all 27 NIH subsidiary Institutes. But to trace the history of cancer research, a more appropriate path focuses on the NCI's growth specifically.
[54] Pub. L. No. 92-218, 85 Stat. 778 (1971).
[55] *See*, *e.g.*, Thomas C. Erren et al., *What Do We Know 40 Years After Nixon Declared the 'War on Cancer'? On the Origin, Prevention and Treatment of Cancer*, 27 J. CANC. EDUC. 597, 597 (2012) *citing* Remarks on Signing the National Cancer Act of 1971, Richard M. Nixon, Dec. 23, 1971, http://www.presidency.ucsb.edu/ws/?pid=3275.
[56] *See* 42 U.S.C. § 281 (1972). It is interesting to note, however, that the text of the statute refers to coordinating such activities "with the National Cancer Program," *id*., yet "legislation never fully defined the concept of a national cancer program, which remains a topic of individual interpretation to this day," Anna D. Barker & Hamilton Jordan, *Legislation History of the National Cancer Program*, *in* CANCER MEDICINE (6th ed., Kufe et al., eds. 2003), http://www.ncbi.nlm.nih.gov/books/NBK13873/.
[57] *See* Appendix.
[58] Pub. L. No. 93-352, 88 Stat. 358 (1974).
[59] *See id*. § 107; Appendix.
[60] BENJAMIN J. HURLBUT, EXPERIMENTS IN DEMOCRACY: HUMAN EMBRYO RESEARCH AND THE POLITICS OF BIOETHICS 77-78 (2017).
[61] *See* Appendix.
[62] Health Research Extension Act of 1988, Pub. L. No. 99-158 § 112, 99 Stat. 820 (1985).
[63] NIH Revitalization Act of 1993, Pub. L. No. 103-43, 107 Stat. 122, 42 U.S.C. § 201 (1993). This included biological and environmental markers, *id.* §1911, and mandating a certain percentage of the NCI's budget be dedicated to cancer control, *id.* §402.
[64] *See* Hematologic Cancer Research Investment and Education Act of 2002, Pub. L. No. 107-172, 116 Stat. 541 (2002).
[65] Gynecologic Cancer Education and Awareness Act of 2005, Pub. L. No. 109-475 (2005).
[66] *See* Breast Cancer and Environmental Research Act of 2007, Pub. L. No. 110-354, 122 Stat. 3984 (2007); National Breast and Cervical Cancer Early Detection Program Reauthorization Act of 2007, Pub. L. No. 110-18, 121 Stat. 80 (2007).
[67] *See* Caroline Pryce Walker Childhood Cancer Act of 2007, Pub. L. No. 110-287, 122 Stat. 2649 (2007).
[68] *See supra* notes 4–5 and accompanying text.
[69] This theory shows it is logically false that *creating* work—breaking a window to pay the repairman to fix it—grows the economy because it excludes opportunity cost: Suppose it cost six francs to repair the damage, and you say that the accident brings six francs to the glazier's trade – that it encourages that trade to the amount of six francs – I grant it; I have not a word to say against it; you reason justly. The glazier comes, performs his task, receives his six francs, rubs his hands, and, in his heart, blesses the careless child. All this is that which is seen. But if, on the other hand, you come to the conclusion, as is too often the case, that it is a good thing to break windows, that it causes money to circulate, and that the encouragement of industry in general will be the result of it, you will oblige me to call out, "Stop there! Your theory is confined to that which is seen; it takes no account of that which is not seen." It is not seen that as our shopkeeper has spent six francs upon one thing, he cannot spend them upon another. It is not seen that if he had not had a window to replace, he would, perhaps, have replaced his old shoes, or added another book to his library. In short, he would have employed his six francs in some way, which this accident has prevented. M. FREDERICK BASTIAT, THAT WHICH IS SEEN AND THAT WHICH IS NOT SEEN: THE UNINTENDED CONSEQUENCES OF GOVERNMENT SPENDING 2 (1850).

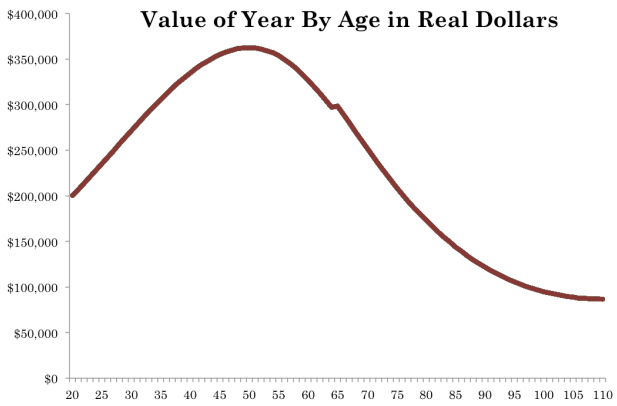
mortality to reflect prolonging one's life as a vehicle to fund the individuals providing medical support. This is wrong. Rather, consider life as a consumption model. An extension of life means the individual will therefore consume longer, adding total economic value. Working backwards, we can measure the *value* added by extending life.

If we model life as a consumption function, we would intuitively

> expect that older individuals may value reducing risks to their lives less because they have shorter remaining life expectancies. The commodity they are buying through risk reduction efforts is less than that for younger people. Carrying this logic to its extreme, the value of a statistical life (VSL) would peak at birth and decline steadily thereafter.[70]

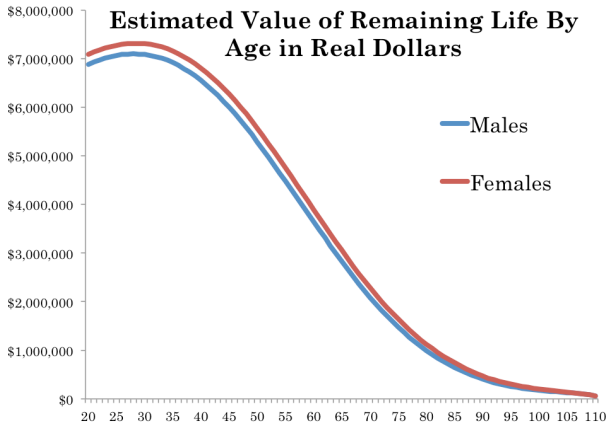
However, due to changes in consumption preferences, wages, and risks of death over time, empirical evidence shows the VSL looks like an inverted-U shape over time.[71]

Consumption, and thus value, is based on what one is expected to earn in a year. Therefore, expected wages and non-wage income dictate the value of a year as a function of time, $V(t)$. Murphy and Topel found, based on wages and expected non-wage income, the value of a year at a given age is as follows[72]:



The two most important lessons to be gleaned from the curve are its slow start due to low initial wages,[73] and its eventual downslope due to lesser consumption (a function of lesser income likely due to wages being replaced by pension funds and social security benefits). The miniature spike around age sixty-five is likely due to a brief overlap in which pension and or social security benefits have kicked in while the individual is still receiving working wages.

Risk weighting the likelihood of death by cancer versus the wages to be earned, the value of life remaining at any given age is represented graphically below:



Again, the value of remaining life is slightly lesser at 20 than at, say, 30 because wages rise only slightly at the beginning of one's career, insufficiently offsetting a higher mortality risk via cancer in one's youth.

ii. Where Do These Curves Come From

Deriving the value of medical research via its impact on incidence and survival rates mirrors Murphy and

[70] Joseph E. Aldy & W. Kip Viscussi, *Age Variations in Workers' Value of a Statistical Life* 2 (Harvard John M. Olin Discussion Paper Series, Paper No. 468, 2004), http://www.law.harvard.edu/programs/olin_center/papers/pdf/468.pdf. *See also* W. Kip Viscusi, *The Value of Life* 12 (Harvard John M. Olin Discussion Paper Series, Paper No. 517, 2005), http://www.law.harvard.edu/programs/olin_center/papers/pdf/Viscusi_517.pdf ("If capital markets were perfect, then VSL would steadily decline with age, reflecting the shortening of life expectancy.").

[71] *See, e.g.*, Joseph E. Aldy & W. Kip Viscussi, *Labor market estimates of the senior discount for the value of statistical life*, 53 J. ENVTL. ECON. & MGMT. 377, 378 (2007); Donald S. Shepard & Richard Zeckhauser, *Survival versus Consumption*, 30 MGMT. SCI. 423, 433 (1984); Per-Olov Johansson, *On the definition and age-dependency of the value of statistical life*, 25 J. RISK & UNCERTAINTY 251, 255 (2002); Joseph E. Aldy & W. Kip Viscussi, *Age Differences in the Value of Statistical Life: Revealed Preference Evidence* 2–18 (Resources for the Future Discussion Paper 07-05, 2007), http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-07-05.pdf.

[72] Email from Robert H. Topel, Isidore Brown and Gladys J. Brown Distinguished Service Professor, University of Chicago Booth School of Business, to Russell A. Spivak, Student, Harvard Law School (Mar. 28, 2016) (on file with author). Again, I thank Professor Topel.

[73] Consumption at the beginning of one's career that is aided by others doesn't directly factor into the model, but is incorporated generally as a function of the older generation's wage, which influences consumption.

Topel's methodology. First, we begin with the way a consumption function values the total utility of one's life. Generally, the value of remaining life, $V(t)$, equals total consumption from time=t to time=∞ (as infinity assumes death and zero utility). But how does consumption fit in? Consider it a byproduct of life—one consumes so long as they are alive.

Break $V(t)$ down into one's health, modeled as $H(t)$, and one's survival, modeled as $S(t)$. Following Murphy and Topel's framework, if we "consider a world populated by identical individuals that discount the future at a constant rate, [r], and competitive capital and insurance markets,"[74] we can model an individual's value as:

$$V(t) = \int_{t=0}^{t=\infty} e^{-rt} \cdot H(t)u\big(c(t), l(t)\big) \cdot S(t)\, d(t)$$

In this analysis, one's health is a stand in for one's quality of life, derived by the utility in consumption, $c(t)$, and nonmarket leisure time, $l(t)$. On the other hand, the survival function is the probability that one survives from birth to time t.

An individual's willingness to pay for an improvement in health or longevity—as measured by the survival function—is therefore the change in utility from the marginal differences the expenditure provides:

$$dV = \int_{t=0}^{t=\infty} e^{-rt}\,[H(t)u\big(c(t), w(t), l(t)\big) \cdot \Delta S(t) + u\big(c(t), w(t), l(t)\big) \cdot S(t) \cdot \Delta H(t)\,]d(t)$$

In our calculus, we can focus solely on mortality: the value of health, while potentially calculable and substantially impactful, is beyond the scope of the study here.[75] Instead we assume "that consumers receive a constant level of surplus per dollar of full consumption over their lifetime"[76]— θ. Creating a shorthand for consumption, C_f, we see the marginal value of increased longevity as the following:

$$\frac{dV}{\mu} = \int_{t=0}^{t=\infty} e^{-rt}\, \theta C_f \Delta S(t)\, d(t)$$

This equation also measures the value of increasing longevity at age a. In other words, how we "valu[e] changes in death rates at a particular age"[77] is:

$$\frac{dV(a)}{\mu(a)} = \int_{t=a}^{t=\infty} e^{-r(t-a)}\, \theta C_f \frac{S(t)}{S(a)} d(t)$$

This equation demonstrates that utility of life is strictly positive. This makes intuitive sense, as death is normalized to 0 utility—meaning no individual would pay for death[78]—but also that people value longevity differently at different stages of their lives.[79] We can then rewrite the formula to define the value of statistical life, as defined by $\lambda(a) \cdot W(a)$, where $\lambda(a)$ measures the "magnitude of the reduction in the death rate," or "unit change in the probability of death" [80] at age a, and $W(a)$ is value of a statistical life at age a. Thus:

$$\frac{dV(a)}{\mu(a)} = \int_{t=a}^{t=\infty} e^{-r(t-a)}\, \theta C_f \frac{S(t)}{S(a)} d(t) = \lambda(a) \cdot W(a)$$

In this case, neither $\lambda(a)$ nor $W(a)$, then, will be linear; the risk of death is itself a function of myriad factors beyond age, which can be broadly grouped into two categories: widely available medical knowledge and capacity, M, and health expenditures for furthering knowledge, Z.[81] The survival function, therefore, is the negative of the natural log of the λ-mortality function:

$$S(a, t, M, Z) = e^{-\int_a^t \lambda(a, M, Z)}$$

Luckily, exact data on unquantifiable variables such as medical knowledge is not needed, as actuarial tables can serve the framework's needs.

iii. How Do We Apply Mortality Data to Theoretical Curves to Quantify Cost?

[74] Murphy & Topel 2003, *supra* note 8, at 43. Murphy and Topel originally denote *r* as *p*, given that *p* may be flexible. Later in the proof, they hold *p* constant because they assume constant interest rates. Therefore, to cut down on confusion, I've chosen to include the figure as *r* from the initial equation.

[75] For a discussion of this factor as a shortcoming of the model and the overall analysis of the costs and returns of medical research, see infra Section III.v.

[76] Murphy & Topel 2003, *supra* note 8, at 45.

[77] *Id.*

[78] Assuming an economically rational person without the influence of, say, Dr. Kevorkian.

[79] *See generally* Viscusi, *supra* note 70. It is worth noting, however, that "[s]tudies with more restrictive formulations in which age enters linearly have found a negative age-VSL relationship[.]" Joseph E. Aldy & W. Kip Viscussi, *Age Variations in Workers' Value of a Statistical Life* 2 (Harvard John M. Olin Discussion Paper Series, Paper No. 468, 2004), http://www.law.harvard.edu/programs/olin_center/papers/pdf/468.pdf (citing V.K. Smith & W.H. Desvousges, *An Empirical Analysis of the Economic Value of Risk Changes*, 95 J. POL. ECON. 89 (1987); Phaedra S. Corso, James K. Hammitt & John D. Graham, *Valuing Mortality-Risk Reduction: Using Visual Aids to Improve the Validity of Contingent Valuation*, 23 J. RISK & UNCERTAINTY 165 (2001); James K. Hammitt & Jin-Tan Liu, *Effects of Disease Type and Latency on the Value of Mortality Risk*, 28 J. RISK & UNCERTAINTY 73 (2004)).

[80] Murphy & Topel 2003, *supra* note 8, at 5.

[81] This necessarily casts aside the risks of death from non-medical, external incidents, such as car crashes. While those risks are obviously at play in real life, when considering the value of surviving medical incidents, we can disregard them.

A death due to cancer i at age a prevents all consumption that would have otherwise occurred throughout the individual's life after age a. Therefore, the expected cost on the economy of an individual's otherwise-premature death at age a due to cancer, $C_i(a)$ equals:

$$C_i(a) = P(CM_i \mid a\,) \cdot V(a)$$

where $P(\mathrm{CM_i})$ is the probability of mortality from cancer i. Extrapolating that expected cost to all people in a given year t equals:

$$C_i(t) = \sum_{a=0}^{\infty} N(a,t) \cdot P(CM_i \mid a\,) \cdot V(a)$$

where $N(a,t)$ is the total number of people age a in year t. Census data is the best bet for population data.[82] Then multiply the number of people age a by the likelihood that a person age a passes away from cancer i, also known as the cancer's mortality rate by age. The CDC provides mortality rates for a given cancer by age, permitting estimation of the total number of people age a that will pass away from cancer i.[83] Next, multiply that by the person's value of remaining life at age a for the total economic cost for all those age a to cancer i. Finally, to sum the cost of all those lost to cancer i, repeat for all ages, or a=∞.[84]

To derive the value of a change in survivor profiles given a change in medical research—or, as Murphy and Topel term it, "knowledge"—apply the above equation of the expected cost on the economy of an individual's otherwise-premature death to the difference of the reduced cancer rate from improved knowledge, $CM_{i,t=1}$ and the status quo rate, $CM_{i,t=0}$:

$$V_i = \sum_{a=0}^{\infty}\{[N(a) \cdot P\big(CM_{i,t=1} \mid a\,\big) \cdot V(a)] - [N(a) \cdot P\big(CM_{i,t=0} \mid a\,\big) \cdot V(a)\}$$

iv. Model's Age-Based Implication

The inverted-U consumption curve has an important implication: life is valued differently at different ages. Different authors and studies have tried to address the statistical value of life and largely agree that age affects how people value a year.[85] Whether life is valued differently by age has also been addressed in psychological analysis.[86]

Additionally, governments have wrestled with this question. In 2000, the Canadian government adopted a stratified valuation: the value of a statistical life for those over 65 was deemed 25% less than that for someone 65 or younger.[87] The following year, the European Commission recommended that its member countries use a value of statistical life that declines with age.[88] The United States has particularly struggled with age's role in determining life's value. In 2003, the U.S. took up the question when considering the costs of enacting stricter air quality and carbon emissions standards.[89] "[T]he EPA presented sensitivity analyses based on research suggesting that older individuals are willing to pay less for life-saving interventions than younger adults."[90] Specifically, the report demonstrated a "VSL estimate for those age 65 and older that was 37 percent lower than for those aged 18-64. This unit benefit difference, which became known as the

[82] *See American FactFinder*, U.S. CENSUS BUREAU, U.S. DEP'T OF COMMERCE, http://factfinder.census.gov/.
[83] *See United States Cancer Statistics (USCS)*, CENTERS FOR DISEASE CONTROL & PREVENTION, http://www.cdc.gov/cancer/npcr/uscs/download_data.htm.
[84] Due to the model's structural and data limitations, $V(a)$=0 for all a>110.

[85] *See, e.g.*, W. Kip Viscusi & Joseph E. Aldy, *The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World*, 27 J. OF RISK & UNCERTAINTY 1, 5 (2003), http://www.nber.org/papers/w9487; Thomas J. Kniesner, W. Kip Viscusi & James P. Ziliak, *Life-Cycle Consumption and the Age-Adjusted Value of Life*, 5 CONTRIBUTIONS TO ECON. ANALYSIS & POL. 1524, 1524 (2004), https://law.vanderbilt.edu/files/archive/256_Life-Cycle_Consumption.pdf; Magnus Johannesson et al., *On the Value of Changes in Life Expectancy: Blips Versus Parametric Changes*, 15 J. OF RISK & UNCERTAINTY 221, 221–25 (1997). *But see* M.W. JONES-LEE, THE VALUE OF LIFE: AN ECONOMIC ANALYSIS (1976) (suggesting that if life was to be considered a consumption function, life's statistical value should be constantly decreasing); M.W. JONES-LEE, THE ECONOMICS OF SAFETY AND PHYSICAL RISK (1989) (suggesting a similar structure); Alan Krupnick et al., *Age, Health, and the Willingness to Pay for Mortality Risk Reductions: A Contingent Valuation Survey of Ontario Residents,* 24 J. OF RISK & UNCERTAINTY 161, 163 (2002) (finding that the VSL is fairly flat until it lowers around age 70).
[86] *See, e.g.*, Valdiney V. Gouveia et al., *Patterns of Value Change During the Life Span*, 41 PERS. SOC. PSYCHOL. BULL. 1276–90 (2015).
[87] HARA ASSOCIATES INC., BENEFIT/COST ANALYSIS OF PROPOSED TOBACCO PRODUCTS INFORMATION REGULATIONS (2000) (Prepared for Health Canada and Consulting and Audit Canada).
[88] EUROPEAN COMMISSION, RECOMMENDED INTERIM VALUES FOR THE VALUE OF PREVENTING A FATALITY IN DG ENVIRONMENT COST BENEFIT ANALYSIS (2001), http://ec.europa.eu/environment/enveco/others/pdf/recommended_interim_values.pdf. Again, these questions were debated in consideration of air quality standards.
[89] *See Evaluating Climate Policy Options, Costs and Benefits*, U.S. ENVTL. PROTECTION AGENCY, https://www.epa.gov/climatechange/evaluating-climate-policy-options-costs-and-benefits
[90] Lisa A. Robinson, *How US Government Agencies Value Mortality Risk Reductions*, 1 REV. ENVIRON. ECON. POLICY 283, 287 (2007).

'senior discount' or 'senior death discount,' generated such substantial controversy that EPA eventually abandoned such differentiation in VSL levels for benefit assessment."[91] In response, the following year's appropriations prohibited funding agencies that employed age-based VSL valuations.[92]

v. Model's Shortcomings

The model and its data have a few shortcomings that need to be addressed.

First, there is a lack of granularity for age-specific data. Most of the reported cancer data is only available in buckets instead of specifically delineated by year. Moreover, the Census groups all individuals aged over 100 as simply "100+." These generalizations lead to imperfect calculations regarding the value of remaining life.

Second, the model fails to account for future generations' use of new medical technologies and advancements. Indeed, the model only considers today's population, though future generations will not only utilize our advances, but also build upon them. For this reason, the model dramatically undervalues the value of research.

Third, though calculated in real wages, the value curves used by Murphy and Topel may be outdated because they were calculated years ago. Real wages and consumption patterns may have since changed, which would render the value of a year or remaining life incorrect. Additionally, Murphy and Topel set a return rate of 3.5% to "calibrate the model so as to make the average male indifferent to a uniform 1/10,000 increase in the probability of death on the job (from age 20 to age 65) when compensated by an increase in earnings of $500 per year," per their experimental data.[93] Though there is no particular evidence to change this model at this point in time, that number is subject to change, especially amongst a different population.

Fourth, this article only considered public sector funding of medical research to impact cancer mortality. Needless to say, many non-governmental institutions contributed vast sums of money to the fight against cancer. Therefore, the investment figures are artificially lower and the impact is artificially higher, overvaluing the government's ROI.

Fifth, data shows that some cancers are more fatal today than they were a decade earlier.[94] This phenomenon has not been fully explained. Environmental factors may well be the cause of this rise—such as food preparation or radiation from electronics—as could influences from health care costs affecting screenings.[95] The analysis imperfectly zeroes out any increases in fatality rates.

Sixth, studies that aim to estimate a value of increased life such as this one discard measures of quality of life. This has a multi-dimensional impact: one's quality of life generally affects the value of one's life directly, but also impacts one's consumption. Consequently, "[l]ife years in deteriorating health may be less valuable to the individual than years in good health."[96] Even if discarded for administrability, omitting health and quality of life data may incorrectly estimate consumption and value of life.

vi. What about Darwin?

One question conspicuously looms: what if humans are becoming more immune to cancer naturally? Put another way, what if humans' decreasing mortality and incidence rates are simply due to Darwinistic survival of the fittest and evolution? The short answer: this is extremely unlikely for myriad reasons.

First and foremost is time. Traits change over centuries, if not millennia: not thirty years. More importantly, they require multiple generations to procreate before having an effect on the population's survival probabilities. Even if humans were becoming more immune to cancer via natural selection, such an adaptation would take generations to notice a trend beyond statistical noise. Statistics for incidence and

[91] Joseph E. Aldy & W. Kip Viscussi, *Labor market estimates of the senior discount for the value of statistical life*, 53 J. ENVTL. ECON. & MGMT. 377, 378 (citing Katharine Q. Seelye & John Tierney, *E.P.A. Drops Age-Based Cost Studies*, N.Y. TIMES, May 8, 2003, http://www.nytimes.com/2003/05/08/us/epa-drops-age-based-cost-studies.html?pagewanted=all; Cindy Skrzycki, *Under Fire, EPA Drops the 'Senior Death Discount'*, WASH. POST, May 13, 2003, https://www.washingtonpost.com/archive/business/2003/05/13/under-fire-epa-drops-the-senior-death-discount/e14279ed-9109-40e5-998b-fd3a1620799c/).
[92] Pub. L. No. 108-199, 118 Stat. 3 (2004).
[93] Murphy & Topel 2003, *supra* note 8, at 47.

[94] *See infra* Table 1, Appendix.
[95] *See, e.g.*, EMMETT B. KEELER, EFFECTS OF COST SHARING ON USE OF MEDICAL SERVICES AND HEALTH 3 (1992).
[96] Viscusi, *supra* note 70, at 12.

mortality rates date back through the 1970s,[97] not nearly enough time to discern Darwinistic adaptation.

Time is also at play in relation to when cancer forms and humans' mating habits. Survival of the fittest requires animals select mates with the superior trait. When Darwinism is at play, the superior traits that an animal may select are visible and apparent. The same cannot be definitively said for humans and cancer immunology for multiple reasons. Most people meet their spouses in anywhere from their teens through their thirties,[98] whereas the vast majority of cancers materialize after mating age.[99] Otherwise, that weakness would likely disappear quickly from human physiology.

A second argument against Darwinism and cancer immunology is human mating habits more practically. Though the average person may well consider health as a variable in choosing a mate, intuition tells us that it is unlikely for most to rank cancer immunity—to the extent that it can be quantified—as the determinative choice in mating decisions.

The final argument against natural selection changing cancer incidence baselines is that one's cancer immunity may not be inheritable. Cancer develops randomly via accumulated, independent mutations. For this reason, cancer typically strikes at older ages, after an individual has amassed more mutations. Moreover, cancer is *typically* a disease of the somatic cells, which are not inherited via reproduction, not of the germ cells, which are. And *rarely* does one's susceptibility to cancer impact one's biological ability to mate, meaning the trait would not die out from an inability to pass it on.[100]

Some scientific studies confirm this intuition, but their findings are neither universal to all cancers nor universally agreed upon. For example, in one study, two scientists "proposed that DNA replication errors in stem cells, which occur independently of environmental and inherited factors, could be an important intrinsic source of tumour[sic]-initiating events."[101] The study concluded "that endogenous factors have a much greater influence on cancer risk than previously considered and that random mutagenesis from these endogenous factors cannot be prevented and are thus 'bad luck.'"[102] If true, the value of research would be markedly diminished. But this is extremely unlikely for myriad reasons.

vii. Even Without Darwin, Can All Advances Be Traced to Medical Research?

[97] *See generally* RYERSON, *supra* note 13.

[98] British people, for example, most likely meet their partner at 27 years old. *See* Serina Sandhu, *British people meet life-long partner at 27, study reveals*, INDEPENDENT (Jan. 19, 2016), http://www.independent.co.uk/news/uk/home-news/british-people-meet-life-long-partner-at-27-study-reveals-a6820431.html (citing Press Release, match.com, Secrets of the Six Month Dating Rule Revealed, https://uk.match.com/pages/advice/press-centre/press-releases/secrets-six-month-dating-rule-revealed).

[99] *See* RYERSON, *supra* note 13. While the average age of all women giving birth is just over 28 years old, *see* T.J. MATHEWS & BRADY E. HAMILTON, MEAN AGE OF MOTHERS IS ON THE RISE: UNITED STATES, 2000-2014, 1 (Jan. 2016), http://www.cdc.gov/nchs/data/databriefs/db232.pdf, for argument's sake, we can define mating age at approximately 50, as very few couples over 50 bear children.

[100] Though some inherited traits may impact one's susceptibility to cancer indirectly. For example, the pallor of one's skin impacts the likelihood of developing melanoma and is inheritable. *See Risk Factors for Skin Cancer*, NAT'L COUNCIL ON SKIN CANCER PREVENTION, http://www.skincancerprevention.org/skin-cancer/risk-factors.

[101] Gemma K. Alderton, *Cancer Risk: Debating the Odds*, 16 NATURE REVS. 68, 68 (2016) (citing Cristian Tomasetti & Bert Vogelstein, *Variation in cancer risk among tissues can be explained by the number of stem cell divisions*, 347 SCI. 78, 78–81 (2015)).

[102] *Id.*

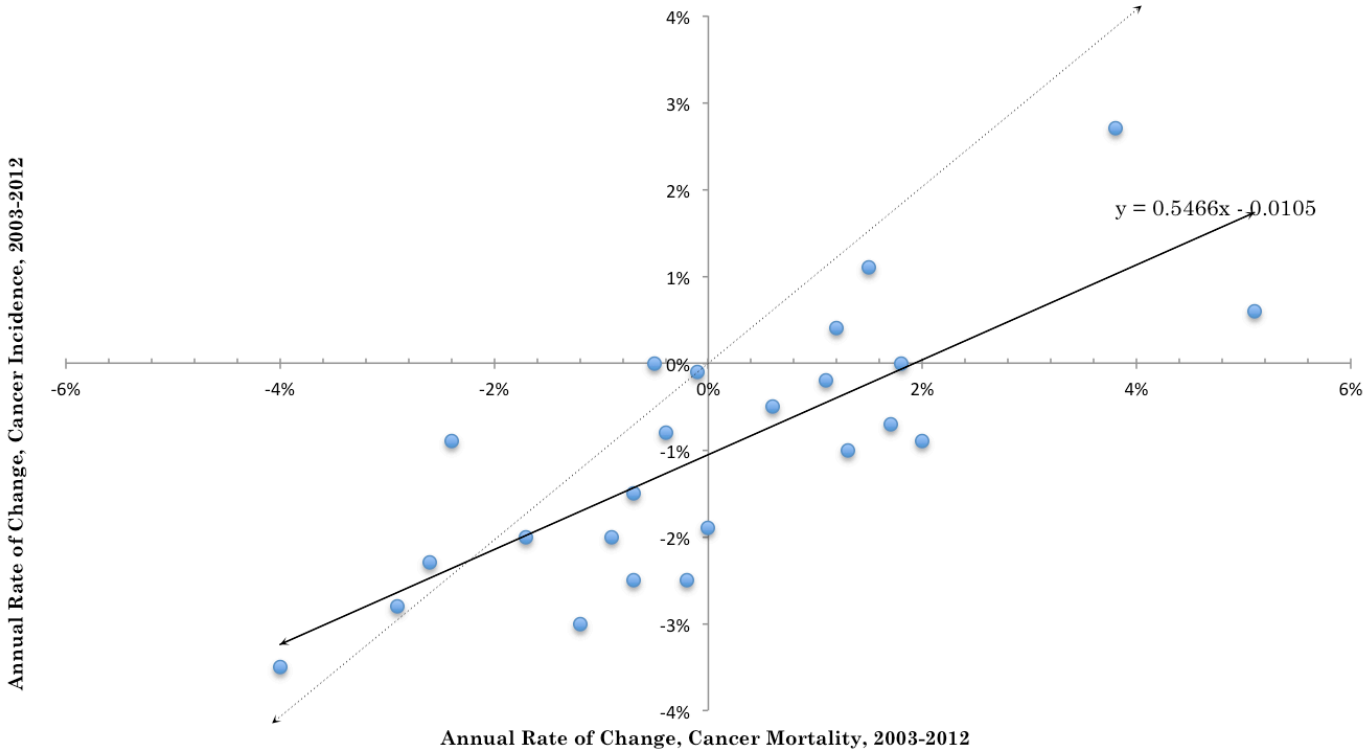


Figure 1. Annual Rates of Change, Cancer Incidence v. Mortality, 2003-2012

Finally, can changes in mortality—and thus economic benefits—be fairly attributed to medical research? Conceptualizing mortality rates as the confluence of three underlying factors—incidence rates, cancer's progression upon detection, and the efficacy of the treatment—shows that to be true. First, look to incidence rates. If not genetics, changes in incidence rates must be linked to external factors, namely the way humans interact with our environment. The history of cigarettes and lung cancer is exemplary; the cigarette changed the way humans interact with their environment, increasing incidence rates. Isaac Adler published the first study linking smoking tobacco and cancer in 1912,[103] and the first half of the century saw tremendous investigation that "confirmed this growing suspicion, that smokers of cigarettes were far more likely to contract lung cancer than non-smokers."[104] Despite the research, smoking-related cancers' incidence rose from 1950-1990 as smoking rose.[105] However, public awareness campaigns throughout the time period and since have lead to decreased smoking, which, in turn, has decreased lung cancer incidence.[106] Without medical research on the topic, smoking rates—and thus, cancer rates—may still be on the rise. Similar narrative arcs can be said for other carcinogenic chemicals like asbestos and its related cancers.[107] Admittedly, some changes in human-environmental interactions are not always due to medical research. For example, one may adopt a vegetarian diet for moral reasons independent of its correlation with reducing one's risk of cancer.[108] But these phenomena occur at such small rates in comparison that it does not ultimately impact the validity of the analysis.

[103] *See generally* ISAAC ADLER, PRIMARY MALIGNANT GROWTHS OF THE LUNGS AND BRONCHI: A PATHOLOGIC AND CLINICAL STUDY (1912).
[104] *See* Robert N. Proctor, *The history of the discovery of the cigarette–lung cancer link: evidentiary traditions, corporate denial, global toll*, 21 TOBACCO CONTROL 87, 87–88 (2012).
[105] Centers for Disease Control, *Mortality Trends for Selected Smoking-Related Cancers and Breast Cancer – United States, 1950-1990*, 42 MORBIDITY & MORTALITY WEEKLY REPORT 857, 863–66 (1993).
[106] *See* S. Jane Henley et al., *Lung Cancer Incidence Trends Among Men and Women — United States, 2005–2009*, 63 MORBIDITY & MORTALITY WEEKLY REPORT 1, 1–3 (2014).
[107] *See, e.g.*, *Asbestos History*, MESOTHELIOMA RES. FOUND. AM., http://www.mesorfa.org/exposure/history.php.
[108] *See generally* Roland L. Phillips, *Role of lifestyle and dietary habits in risk of cancer among Seventh-day Adventists*, 35 CANCER RES. 3513 (1975).

And the other two factors? Because large-scale data is unavailable to isolate detection timing or treatment efficacy, we must look at them in the aggregate by isolating incidence and mortality; in essence, where the two do not match, the intervening cause is the combination thereof. Figure 1 details the differences between incidence and mortality ratings.

For most cancers, incidence has annually decreased from 2003-2012. This is represented by cancers left of the *y* axis, or *x*=0, meaning that Quadrants III & IV respectively—which could be characterized as "lower incidence, lower mortality" and "lower incidence, higher mortality"—are heavily populated.

But the dotted line representing *y=x* tells the powerful tale of how to break down mortality rates between incidence and the other two factors, timing and efficacy of treatment. Cancers falling "below" or "to the right" of that line represent cancers whose drops in mortality have outpaced drops in incidence. Thus, even if not *all* drops in incidence rates are due to medical interventions, then the further drops beyond incidences can only be caused by changes in detection and or efficacy of treatment.

A final criticism may simply be that changes in external factors, primarily costs, have decreased preventative screenings, meaning that while incidence may not be a factor, some simply do not find out until it's too late. If this is the case, research is actually undervalued because some will unfortunately pass from cancer when new medical breakthroughs might have saved them. Where the data is available, it militates towards increased research efficacy. From 2000-2013, the percentage of women 40 years of age or older with an up-to-date mammogram—within the past 2 years—dropped by 5%.[109] That percentage is even more staggering for women 18 years of age or older with an up-to-date Pap test: in 2000, 81.3% of women had a Pap smear within the past 3 years, while 2013 saw that number drop to 70.4%.[110] Again, despite fewer women getting such procedures, cervical and breast cancers' mortality rates have both decreased.

Therefore, it is fair to connect changes in incidence and mortality to medical research at large.

IV. Costs of Cancer and Value Derived From Improved Mortality.

i. Specifics of Recent Developments

Since 1935, cancer—or "malignant neoplasms"—has been among the top 5 leading causes of death every year in the United States.[111] But despite significant research expenditures in that time, cancer remains the second-leading cause of death in the United States, taking 584,881 people in 2013, trailing only heart disease.[112] Thankfully, the past decade has experienced marked improvements in mortality statistics on most cancers. The biggest improvements in mortality rates of cancers afflicting men have been in prostate and colon cancers at 4.0% and 3.0% annual mortality rate reductions, respectively;[113] for women, larynx and colon cancers have experienced the largest reductions in mortality rates at 3.0% and 2.8% annually, respectively.[114] Table 1 of the Appendix offers a list of changes in mortality rates for, as well as when the average individual is likely to be diagnosed with and pass away from, various types of cancers.[115]

Unfortunately, the news is not all good: certain cancers have seen marked increases in incidence and or mortality rates. Specifically, both men and women are falling victim to thyroid and liver or bile duct cancers at an alarmingly higher rate annually, approximately 5% and 3%, respectively.[116] These figures have largely undercut the progress made in other cancers, especially in women, such that the overall risk that women will pass away from any cancer in their lives was unchanged, though the risk of death at a given age changed.[117]

ii. Costs of Cancer, 2012

The incidence and mortality rates have permitted us

[109] NAT'L CTR. FOR HEALTH STATISTICS, U.S. DEP'T OF HEALTH & HUM. SERVICES, HEALTH, UNITED STATES, 2014, 232–33, Table 70, http://www.cdc.gov/nchs/data/hus/hus15.pdf.
[110] *Id.* at 83–84, Table 15.

[111] *See* DONNA L. HOYERT, 75 YEARS OF MORTALITY IN THE UNITED STATES, 1935–2010, 1 (2012).
[112] NAT'L CTR. FOR HEALTH STATISTICS, U.S. DEP'T OF HEALTH & HUM. SERVICES, HEALTH, UNITED STATES, 2014, 97, Table 20, http://www.cdc.gov/nchs/data/hus/hus15.pdf.
[113] *See infra* Table 1, Appendix.
[114] *Id.*
[115] For a complete listing of the data compiled herein, see assorted tables in Ryerson, *supra* note 13.
[116] *Id.*
[117] *Id.*

to study what exactly cancer is costing the American economy from a consumption perspective. In this way, any cancer's cost equals the amount of money an economically rational individual *should* be willing to pay to guarantee protection from that cancer.

Cancer cost the American economy $1.38 trillion in 2012, and $1.35 trillion annually from 2008-2012. It may seem odd that costs rose while mortality is, on the whole, falling slightly. But that can be traced back to changes in our population: despite falling rates, rising overall population drive that cost significantly. Of the 23 specific cancer sites or types studied, the highest costing cancers are of the lung and bronchus.[118] The costs of each of these 23 cancers are listed in Table 2 of the Appendix.[119]

Because the costs of cancer are principally driven by the likelihood of incidence, the mortality of those afflicted, and when they are afflicted, it is unsurprising that three of the six lowest costing cancers are single-sex cancers—uterine, cervical and testicular—because the cost can only come to bear on half the population.

iii. Costs Saved, 2002-2012

Performing the same analyses of cancers' costs using the changes in incidence rates from 2002-2012 derives the costs saved over this time. Said another way, we examine the difference between what 2012 cancer mortality statistics *would* have been without research via 2002 mortality rates versus the rates actually experienced. Those differences (and their corresponding value in dollars) account for the costs saved due to such research. In total, the United States saved $255 billion in 2012 alone from improvements in cancer's mortality. The biggest changes were in lung and bronchial cancers as well as colorectal cancers. The costs saved for each cancer is represented in Table 3 of the Appendix.[120]

iv. Return on Investment

The next question that needs be asked is that of a return on investment: we know how much we've *gained*, but how much have we lost? This article assumes the amount lost is the cost of investment. During Fiscal Years 2002 through 2011, the NCI invested just under $48 billion in current U.S. dollars, or $56 billion in 2015 dollars.[121] Given the $255 billion in returns found by the consumption there is an approximate 355%, or 431%, ROI in 2015 dollars and current dollars, respectively. These effects are even more pronounced under a time-lag theory: assuming a delay of approximately 15 years, the ROI would be even more biased towards further investment. Not bad for government work.

v. Breakeven Analysis

The final analysis to be performed is breakeven analysis: what returns—in the form of decreases in mortality rates—taxpayers should demand for a given investment. Because changes in mortality rates are valued differently by age, breakeven analysis is only viable at a macro level, i.e. measuring the dollars invested overall versus a constant change in mortality rates across all ages. Holding population constant, one need only set the change in mortality rate to a constant to see how much value would be recouped by such a change in rate using the framework above. If the money invested is lower than the value recouped, the research yields positive returns. Table 4 in the Appendix offers the breakeven point for a 1% reduction of mortality rate by cancer. A total investment of $13.8 billion USD should produce the reduction rate desired. Therefore, research that can achieve the 1% reduction in mortality rate at lesser costs or research costing $13.8 billion and can achieve better returns should be funded.

V. Policy Recommendations and Ethical Underpinnings

Medical investment shows tremendous positive returns on investment. Be it morally or economically, it appears to be objectively good policy to increase funding for our nation's laboratories and scientists

[118] *See supra* notes 103–107 and accompanying text.

[119] For population information, see *American FactFinder*, U.S. Census Bureau, http://factfinder.census.gov/. For incidence and mortality information, see *United States Cancer Statistics (USCS)*, Ctrs. for Disease Control & Prevention, http://www.cdc.gov/cancer/npcr/uscs/download_data.htm.

[120] For population information, see *American FactFinder*, U.S. Census Bureau, http://factfinder.census.gov/. For incidence and mortality information, see *United States Cancer Statistics (USCS)*, Ctrs. for Disease Control & Prevention, http://www.cdc.gov/cancer/npcr/uscs/download_data.htm.

[121] *See Appropriations*, NAT'L INSTS. HEALTH, http://www.nih.gov/about-nih/what-we-do/nih-almanac/appropriations-section-1.

doggedly working to neutralize this millennia-old disease.[122] The question, though, is how: one could easily devise myriad dissemination schemes. This section begins by explaining and reviewing possible schemes. Then, having shown targeted investment using cost-benefit analysis to be, at worst, acceptable, the article addresses specific ethical concerns.

i. Ethical Considerations In Adopting Cost-Benefit Analysis

There are many ways to distribute limited resources. In asking the same rationing question for public defendants' limited legal resources, Professor Glenn Cohen breaks down possible schemes into the following categories[123]:

> First-come, first-serve: those who arrive first in the door receive priority, regardless of how many man-hours their cases demand
>
> Random/lottery: leave it to lady luck as to who receives care
>
> Priority to the worst-off: those in the worst position get the most help
>
> Age-weighted: youth prioritized, as they have more life left to live
>
> Outcome-determinative: those who have the best chance of success should be prioritized
>
> Aggregation of desired outcomes: aggregate the number of people saved or benefits conferred
>
> Instrumental: what was the defendant's alleged role in the events causing him to now need legal assistance

Cohen endorses or rejects different potential arrangements within each category after lengthy discussions of each.[124]

There are certainly significant differences between legal services and medical research that prevent wholesale adoption of Cohen's recommendations here, but they are nevertheless instructive. As Cohen did, the scientific community can outright reject the first-come, first-serve option because it does not lend itself to the scheduling and structure of congressional appropriations at regular intervals: experiments take different times and are on different schedules, so a temporal driver would frustrate funding. And again similar to Cohen, the lottery also seems less than ideal because those with objectively lesser needs may be grossly disproportionate benefactors under such a system.

Of the remaining approaches, Cohen endorses some wholesale, endorses others with qualifications, and outright rejects others.[125] As he makes clear, though, there may well be no correct answer: only that, as "institutions responsible to the taxpayers," such organizations "must be open about their decisions on these issues and provide reasons why they have chosen the rationing principles they have."[126] The same could likely be said about medical research. So maybe asking whether cost-benefit analysis is the *correct* distribution is the wrong question: rather ask if it is defensible. And it is.

In a way, cost-benefit analysis is an amalgamation of the endorsed systems above: it has a flavor of many of the endorsed approaches, as it accounts for age, outcome determinations, the worst off and aggregate values. But, more foundationally, cost-benefit maximizes taxpayers' utility in the form of economic return. Put another way, cost-benefit analysis minimizes the money wasted. It is therefore logical for a government, which exists to serve *all* citizens, to utilize cost-benefit analysis.

There are obvious policy pitfalls to this suggestion, chiefly the appearance of the government "branding" one disease less important than another. But empirics tell us that that is, in fact, the case. Given medical research and knowledge, we already know which cancers are the deadliest. Ask a patient battling Hodgkin's lymphoma if she'd rather have pancreatic cancer, the deadliest cancer based on five-year survival rates.[127] The former, "one of the most curable

[122] Cancer was first described in Ancient Egypt around 3,000 B.C. *See* SIDDHARTHA MUKHERJEE, EMPEROR OF ALL MALADIES: A BIOGRAPHY OF CANCER 40–41 (2011); *Early History of Cancer*, AM. CANCER SOC'Y, http://www.cancer.org/cancer/cancerbasics/thehistoryofcancer/the-history-of-cancer-what-is-cancer.

[123] *See generally* I. Glenn Cohen, *Rationing Legal Services*, 5 J. LEGAL ANALYSIS 221, 244–84 (2013) (offering multiple varieties of possible schemes within each category).

[124] *Id.* at 245–46.

[125] *Id.*

[126] *Id.* at 284.

[127] *See* AM. CANCER SOC'Y, CANCER FACTS AND FIGURES 2015, 17 (2015),

forms of cancer,"[128] boasts a survival rate of around 88%, while the latter is closer to 7%.[129] All else equal, curing pancreatic cancer creates a demonstratively larger economic impact than does curing Hodgkin's disease; proclaiming that fact is not a referendum on those fighting for their lives against Hodgkin's disease, but rather a way to maximize the utility of each dollar put into a laboratory.

1. Gender Concerns Pass Muster

Arguably the thorniest implication of employing cost-benefit analysis for appropriations decisions would be the disparate impact it may have on genders. "The gender difference in cancer susceptibility is one of the most consistent findings in cancer epidemiology."[130] A 2011 study "suggests that while some small fraction of the mortality disparity can be explained by survival differences after diagnosis, almost all of the disparity arises from the fact that men are more likely than women to develop cancers in the first place."[131] The cause or causes behind these differences in incidence rates by gender have not been crystallized.[132] But what we know is this:

> Cancer mortality was much higher in males relative to females for a majority of cancer types . . . . Cancer survival was generally similar between the sexes; even when differences were observed, these sex disparities were relatively modest. Disparities of cancer mortality have largely paralleled those of cancer incidence. . . . [Thus,] sex disparities in cancer mortality arise from the sex differences in cancer incidence.[133]

Given the disparities, a policy driven by cost-benefit analysis that has an unintended gender discrimination disbursement could contribute to the narrative of sexism in today's America in a particularly ironic and perverse way. Thus, it is worth pausing to once again take stock of whether cost-benefit analysis is the correct *modus operandi*. If we equate moral standards to legal standards—maybe not a perfect analogue, but not a bad one, either—the answer remains yes. When a law overtly calls for gender classifications, it's viewed with substantial, or in legal parlance, "intermediate scrutiny."[134] But,

> [w]hen a statute gender-neutral on its face is challenged on the ground that its effects upon women are disproportionably adverse, a twofold inquiry is thus appropriate. The first question is whether the statutory classification is indeed neutral in the sense that it is not gender-based. If the classification itself, covert or overt, is not based upon gender, the second question is whether the adverse effect reflects invidious gender-based discrimination.[135]

In light of the facially neutral foundation of the regime and the genuine, altruistic aims of the cancer research programs, a cost-benefit analysis is permissible. Therefore, while the gender distinctions are concerning, they do not merit discarding cost-benefit analysis entirely to distribute research funds appropriately.

2. So, Too, Do Age Discrimination Considerations

Again taking from Cohen's work, there are two categories of justifying age-weighting: quantity and quality of life. The former is premised on two ideas: first, that "everybody should as much possible have the opportunity to live a 'complete' life . . . and therefore those who are older and have had more of their share of life years ought to get less priority than the younger who have not."[136] Second, "that the young are more productive and therefore giving them priority 'grows the pie.'"[137] The second justification is in lock step with the central premise of cost-benefit analysis and thus in line with this essay's pivotal idea

http://www.cancer.org/acs/groups/content/@editorial/documents/document/acspc-044552.pdf.

[128] *Hodgkin Lymphoma*, N.Y. TIMES: HEALTH GUIDE, http://www.nytimes.com/health/guides/disease/hodgkins-lymphoma/prognosis.html.

[129] *See* AM. CANCER SOC'Y, *supra* note 127.

[130] *See generally* M. Tevfik Dorak & Ebru Karpuzoglu, *Gender differences in cancer susceptibility: an inadequately addressed issue*, 3 FRONT. GENE. 268 (2012).

[131] Laura Blue, *Almost Every Type of Cancer Kills More Men Than Women, Study Shows*, TIME, Jul. 13, 2011, http://healthland.time.com/2011/07/13/almost-every-type-of-cancer-kills-more-men-than-women-study-shows/.

[132] *See e.g.*, Jean McCann, *Gender Differences in Cancer That Don't Make Sense—Or Do They?*, 92 J. NAT'L CANCER INST. 1560, 1560–62 (2000) (claiming that in some cases, genetic factors seem more like, in others, behavioral factors are a better fit, but "[f]or some cancers, there is no ready explanation for differences between the sexes.").

[133] Michael B. Cook et al., *Sex Disparities in Cancer Mortality and Survival*, 20 CANCER EPIDEMIOLOGY, BIOMARKERS & PREVENTION 1629, 1633 (2011).

[134] Craig v. Boren, 429 U.S. 190, 210 (1976).

[135] Personnel Adm'r of Mass. v. Feeney, 442 US 256, 274 (1979).

[136] Cohen, *supra* note 123, at 255.

[137] *Id.*

of putting resources where they can effectuate the most change.

But we cannot sidestep the first justification altogether: fundamentally, is age-weighting too discriminatory and thus untenable? Some argue that age-weighting cannot be discriminatory because *everyone* will experience an age, regardless of immutable characteristics (such as anatomical sex, race, religion or sexual identity),[138] though this is far from unanimous.[139] But, again, if we equate legality with morality—even as an outer bound of permissibility—age-weighting also very likely passes constitutional muster. "[O]ld age does not define a 'discrete and insular' group, in need of 'extraordinary protection from the majoritarian political process.'"[140] Thus, statutes that effectively discriminate by age are scrutinized under a rational basis test: namely, does the law in question "rest[] upon some rational basis within the knowledge and experience of the legislators"[141]? The rational basis test is far more lenient than intermediate scrutiny generally and in all likelihood met.

Here, there is a legitimate government interest in maximizing research's efficacy. Therefore, any discriminatory effects concerns are not prohibitive.

3. Racial Data Can—And Should—Be Discarded

Cost-benefit analysis may also have a disparate impact on cancers that affect different races or ethnicities differently. The data underlying the analysis tracks race and ethnicity, including: White (overall), White Hispanic, White Non-Hispanic, Black, Asian/Pacific Islander, American Indian/Alaska Native (which in some cases is even further broken down by whether or not individuals are in Contract Health Service Delivery Area counties), and Hispanic.[142] To avoid even the appearance of impropriety, let alone legal challenges to the disbursement structure, however, that data can and should be discarded in the cost-benefit analysis context.[143] The Supreme Court "ha[s] not embraced the proposition that a law or other official act, without regard to whether it reflects a racially discriminatory purpose, is unconstitutional Solely because it has a racially disproportionate impact."[144] By discarding data relating to ethnic and racial demographics of cancer, the disbursement structure would in no way be intentionally racially discriminatory, where intent is required to challenge a regulation or law.[145]

But intent to discriminate may be proven using statistical measures and or grossly disproportionate application of a facially neutral statute.[146] In the first law the Supreme Court rule was facially race-neutral but administered prejudicially, the Court struck down a San Francisco city ordinance relating to safety regulations and licensing for clothes launderers because the ordinance effectively targeted the Chinese citizens that owned and operated over 90 percent of the city's laundry facilities.[147] Overall, the available data does not bear out such drastic racially-distinct differences. The only cause for concern may be skin cancer—black people are *far* less likely to develop melanoma of the skin than white people.[148] However, this isolated instance of dramatic racial differences unlikely survives a challenge for applied discriminatory intent for two reasons: *First*, skin cancer is one of hundreds of cancers to be addressed and has a very low mortality rating overall; thus, research devoted to it makes up a fraction of the total,

[138] *See* Govind Persad, Alan Wertheimer & Ezekiel J. Emanuel, *Principles for allocation of scarce medical interventions*, LANCET, Jan. 31, 2009, at 425 (citing NORMAN DANIELS, AM I MY PARENTS' KEEPER? AN ESSAY ON JUSTICE BETWEEN THE YOUNG AND THE OLD (1988)).
[139] *See* Samuel Kerstein & Greg Bognar, *Complete Lives in the Balance*, AM. J. BIOETHICS, APR. 7, 2010, at 41 (arguing that an elderly individual who, as a younger person, "enjoyed (or would have enjoyed if she had been in need) the benefits of an arrangement that gives priority to the young . . . , she has no legitimate complaint that she is denied a life-saving resource" later in life.).
[140] Mass. Bd. of Retirement v. Murgia, 427 U.S. 307, 313 (1976) (citing United States v. Carolene Products Co., 304 U.S. 144, 152–53, n.4 (1938)).
[141] 304 U.S. at 152.
[142] *See, e.g.*, RYERSON, *supra* note 13, Table 2.15.
[143] What's more, the ability to discard such data displays yet another advantage of cost-benefit analysis: nimble flexibility.
[144] Washington v. Davis, 426 U.S. 229, 239 (1976).
[145] There is also a substantial case to be made that, even beyond the jurisprudential, today's political climate offers sufficient reason to go above and beyond to avoid any disparate impact by funding appropriations if at all possible. Discarding cancer's related racial data—at least in this context, as it could serve to help other contexts—is an overt move that to calm political uneasiness surrounding such a move.
[146] *See, e.g.*, Akins v. Texas, 325 U.S. 398, 403–04 (1945) ("A purpose to discriminate must be present which may be proven by systematic exclusion of eligible jurymen of the proscribed race or by unequal application of the law to such an extent as to show intentional discrimination").
[147] *See generally* Yick Wo v. Hopkins, 118 U.S. 356 (1886).
[148] *See* RYERSON, *supra* note 13, at Table 3.

yielding negligible differences in effect between races. Conversely, in many cases, caucasians are *less* likely to develop certain cancers. In this scheme, just as often as some racial or ethnic classes may be comparatively advantaged, they are elsewhere comparatively disadvantaged, undermining the idea that the law is discriminatory to only one such class of people. *Second*, in cases like *Yick Wo*, the administration of the regulation includes an element of choice. In that case, a Board of Supervisors who discretionarily issued permits stating that a laundry facility met certain regulations.[149] On the other hand, there would be no element of discretion if adhering to strict numerical analysis in cases like skin cancer, so the racially distinct adjudication is not in itself discriminatory. Therefore, it seems unlikely that a cost-benefit framework is struck down for racial discrimination implicit in its administration.

ii. Specific Policy Recommendations: Incorporating Cost-Benefit Analysis into Medical Research Investment Decisions

The NCI should employ cost-benefit analysis into their decision-making for grants and trials. More, the funding structures and processes should be altered to enable more satisfactory grants to get funded. Finally, the government should also expand its partnership with other funding sources—not simply because curing cancer is collaborative, but also because it would further maximize federal dollars.

1. Weight Grant Applications by Cost of the Cancer Being Addressed

When possible, funding decisions should incorporate cost-benefit analysis. As discussed above, the government is responsible for doing the most it can with its limited resources. For those grants with a narrow purpose, questions of analytical weighting by disease profile are often foreclosed. But what about unbounded grants that could fund a broad number of cancer types? In these applications, the cost of a given cancer—and thus its potential savings upon the discovery of a cure—should be central in a grant's application. How an approval committee could implement this vision is admittedly difficult to figure out. For example, how heavy an analytical weight ought to be is up for debate. Perfect, though, cannot be the enemy of progress: the NCI should nevertheless push to weigh their grant approvals using cost-benefit analysis.

2. Increase Number of Grants Funded and Create a Revolving Fund

This essay has sought to promote increasing aid in medical research and, if done, using cost-benefit analysis to use it efficiently. What remains unanswered, though, is *how much* the increase should be. Luckily, the NCI Budget Justifications offer a bit of insight, helpfully converting budget outlays and requests into approximately how many grants they will cover and could cover, respectively.

As noted earlier, "[m]any more grants are approved by the NCAB than can be financed from the NCI budget."[150] While this data is not released, the NCI should examine how many grants were rejected or cut substantially for budgetary reasons, that have been otherwise funded fully. Funding increases should be matched to these "good-rejects" year-to-year: any science that can survive the rigorous vetting process and stands to make an impact deserves to be funded to the maximum extent the country can afford.

Finally, it is important to note that the money allocated for these grants, if permitted, need not always be completely consumed in a given calendar year. Indeed if the federal government increases funding, yet the NCAB does not field enough worthy and scientifically promising grant applications whose net costs, if approved, amount to the sum allocated, the NCI could do one of two things: increase the funding amount of the satisfactory grants or pool its leftover funds into a separate revolving fund. The former may not be wise, as it creates perverse incentives for laboratory waste.[151] The latter, however, would permit more flexibility if, in a future year, even more grants are scientifically meritorious.

A revolving fund should do the trick. When appropriated funds go unused—such as when fewer than normal grants are granted—they are to be

[149] 118 U.S. at 366.

[150] ORIENTATION BOOK, *supra* note 19, at 52.

[151] This is not to say that increasing funding for grants could not be extraordinarily beneficial. From personal experience, many of the scientists in a lab whose names do not appear atop the grant application are woefully underpaid. To critics who would say this, I would ask then that increased salaries ought be folded into the applications appropriately *ex anti* instead of asking for more money after it's been approved.

returned to the Treasury. Monies appropriated in revolving funds, however, stay at the agency's disposal if unspent in a given year.[152] What's more, establishing a revolving fund is quite simple. The appropriations language need only include one of two provisions: "any remaining funds are available without fiscal year limitations"; or, "there is to be established a revolving fund."[153] Thus, Congress should appropriate all cancer research funds into a revolving fund—operating and administrative funds need not be included—such that the NCI can hold on to excess funds in comparatively leaner years and approve more meritorious grants when appropriate.

3. Convert Discretionary to Mandatory Spending

In FY2016, the NIH was appropriated approximately $31.4 billion as purely discretionary budget authority.[154] The only mandatory spending on the NIH at large is for Public Health Service Evaluation financing—$780 million[155]—and specialized type 1 diabetes research—$150 million.[156] In other words, the NCI and its cancer research are funded through *nearly entirely* discretionary funds.

Because the NCI's budget is purely discretionary, the Budget Control Act of 2011[157] has, and could again, substantially impact the Institute during budget crisis. The operative provision of the Act states that if budgets do not sufficiently curtail spending, automatic spending cuts are triggered across discretionary accounts.[158] The amount by which these discretionary accounts are cut is determined by spreading the budget's shortfall across all accounts, including the NIH.[159] Obviously for the cancer research community—not to mention those affected by the dreaded disease—that is far from ideal. For this reason, the President's moonshot proposed the cancer research funding be converted from discretionary to mandatory[160], ensuring its isolation from these sorts of politics.

The mandatory-discretionary distinction also matters a great deal during government shutdowns. During shutdowns, "[e]ssential services continue to function, as do *mandatory spending programs*."[161] Discretionary programs, however, are subject to agency plans.[162] The NIH's procedures during the 2013 government process are instructive. During the 2013 shutdown, only a small portion of NIH operations were funded and permitted to continue. Specifically, scientists operating under grants were permitted to continue their research.[163] Other NIH—and therefore NCI—functions, though, were cut: peer review and advisory council meetings, administrative support, and reporting administration were all cut off.[164] These functions, including certain ones that are time-specific, were only resumed when a deal was struck under detailed guidelines.[165]

For that very reason, appropriations for the NCI should be converted from discretionary to

[152] *See* Brooke Stanley & Amy Hinz, *Budgeting for Gift Accounts and Revolving Funds* 9–10 (Harvard Law Sch. Federal Budget Policy Briefing Paper Grp., Paper No. 60, 2016) https://wiki.harvard.edu/confluence/download/attachments/204380235/STANLEY%20-%20Briefing%20Paper%20No.%2060.pdf?api=v2.
[153] *Id.* at 10.
[154] Consolidated Appropriations Act, 2016, Pub. L. No. 114-113 (2016).
[155] Protecting Access to Medicare Act of 2014, Pub. L. No. 113-93, 128 Stat. 1040, U.S.C. § 1305. For more information regarding the PHS evaluations, see C. STEPHEN REDHEAD & AGATA DABROWSKA, PUBLIC HEALTH SERVICE AGENCIES: OVERVIEW AND FUNDING (FY2010-FY2016) (2015).
[156] Medicare Access and CHIP Reauthorization Act of 2015, Pub. L. No. 114-10, 129 Stat. 87 (2015).
[157] Pub. L. No. 112-25, 125 Stat. 240 (2011).
[158] *Id.* § 302.
[159] *Id.* For more information on the Budget Control Act, see BILL HENIFF JR., ELIZABETH RYBICKI, & SHANNON M. MAHAN, THE BUDGET CONTROL ACT OF 2011 (2011).
[160] *See* Press Release, *supra* note 3
[161] COMMITTEE FOR A RESPONSIBLE FEDERAL BUDGET, Q&A: EVERYTHING YOU SHOULD KNOW ABOUT GOVERNMENT SHUTDOWNS UPDATED DECEMBER 7, 2015, 1 (2015), http://crfb.org/sites/default/files/documents/update_shutdown_qa_2015.pdf.
[162] *Id.* at 1–2.
[163] Press Release, National Institutes of Health, Information for the NIH Extramural Grantee Community During the Lapse of Federal Government Funding (Oct. 1, 2013), http://grants.nih.gov/grants/guide/notice-files/NOT-OD-13-126.html.
[164] *Id.* Though not directly related to the NCI, one of the bigger problems with government shutdowns is the NIH's hospital facilities. During the 2013 crisis, NIH was turning away hundreds of patients a day for regular hospital procedures. *See NIH, CDC feeling government shutdown's effects*, CBS NEWS (Oct. 1, 2013), http://www.cbsnews.com/news/nih-cdc-feeling-government-shutdowns-effects/.
[165] Press Release, National Institutes of Health, Revised Guidance on Resumption of NIH Extramural Activities Following the Recent Lapse in Appropriations (Oct. 22, 2013), http://grants.nih.gov/grants/guide/notice-files/NOT-OD-14-007.html; Press Release, National Institutes of Health, Guidance on Resumption of NIH Extramural Activities Following the Recent Lapse in Appropriations (Oct. 18, 2013), http://grants.nih.gov/grants/guide/notice-files/NOT-OD-14-003.html.

mandatory, thereby largely preventing the halting of vital researching and research-supporting activities in light of the national political climate.[166] The President's FY2017 budget proposal requested $680 million in mandatory appropriations for "Cancer Initiative Mandatory Financing"[167]: this would represent a huge step forward, but it is only 13% of the NCI's budget. For context, the Department of Veterans Affairs and Department of Transportation 2016 budgets were approximately 56%[168] and 79%[169] mandatory, respectively. (On the other hand, the more politically controversial Department of Energy was not mandatorily appropriated, either.[170]) The recent enactment of the 21st Century Cares Act[171] is a good start, but instructive of what's left. The Act reauthorizes the NIH funding through 2020[172] and establishes a new "NIH Innovation Account"—named on behalf of Beau Biden, Vice President Biden's son who passed away from brain cancer in 2015—but it again is discretionary.[173] Much more spending needs to become mandatory to withstand future instability.

4. Expand Partnerships with Public and Private Institutions

In March of 2016, the NIH launched the Online Partnership to Accelerate Research ("OnPAR"),[174] which "lets researchers upload rejected NIH proposals to an online portal where potential funders can review the scores received from reviewers, and decide whether to put up cash."[175] "OnPAR's growing list of private funders currently includes the Juvenile Diabetes Research Foundation, National Alopecia Areata Foundation, Children's Tumor Foundation, Adenoid Cystic Carcinoma Research Foundation, Breast Cancer Research Foundation, Melanoma Research Alliance, and Parent Project Muscular Dystrophy."[176] These efforts can permit worthy scientific exploration to continue unabated while minimizing waste and unnecessarily repeated experimentation. What's more, expansion would aid in funding research should these budgetary constraints not be rolled back. Therefore, the government must expand cooperation in cancer research to permit worthy scientific exploration to receiving funding when the NCI cannot itself afford it.

But cancer's deadly mutations are not contained within the United States, nor are all scientists equipped and trained to cure it U.S.-based. The U.S. government should do anything and everything it can to coordinate research efforts with other nations' state-sponsored and non-government sponsored efforts so that no laboratories waste even a dollar on unnecessary, duplicative experiments.[177] Many hands make light work.

5. Further Study for Increased Accuracy

Further analysis is needed to demonstrate what research areas are most cost effective along the monumental undertaking that is curing cancer. The data used above is the most granular readily available to the public.[178] More detailed information on the cancer type and site as well as the patient should be sought and made accessible for further analysis. Consider data on breast cancer. The data groups all breast cancers, when there are as many as five sub-

[166] Admittedly, this conversion may not be perfect. Indeed, the devil is in the details, as "some services associated with mandatory programs may be diminished if there is a discretionary component to their funding." COMMITTEE, *supra* note 161, at 2.
[167] *See* Jocelyn Kaiser, *White House wants $1 billion for Vice President Biden's cancer moonshot. Where will it come from?*, SCI. (Feb. 2, 2016), http://www.sciencemag.org/news/2016/02/white-house-wants-1-billion-vice-president-biden-s-cancer-moonshot-where-will-it-come.
[168] U.S. DEP'T OF VETERANS AFFAIRS, BUDGET IN BRIEF 13 (2016), http://www.va.gov/budget/docs/summary/Fy2017-BudgetInBrief.pdf.
[169] U.S. DEP'T OF TRANSPORTATION, TRANSFORMING COMMUNITIES IN THE 21ST CENTURY 60, https://www.transportation.gov/sites/dot.gov/files/docs/DOT_BH2017_508%5B2%5D.pdf.
[170] U.S. DEP'T OF ENERGY, FY2017 CONGRESSIONAL BUDGET REQUEST: BUDGET IN BRIEF 28, http://energy.gov/sites/prod/files/2016/02/f29/FY2017BudgetinBrief_0.pdf.
[171] Pub. L. No. 114-255 (2016).
[172] *Id.* § 2001.
[173] *Id.* § 1001.
[174] Michael Lauer, *A Pilot Partnership to Find Private Support for Unfunded Applications*, NIH: OPEN MIKE (Mar. 23, 2016), https://nexus.od.nih.gov/all/2016/03/23/a-pilot-partnership-to-find-private-support-for-unfunded-applications/.
[175] Kelly Servick, *New funding matchmaker will cater to NIH rejects*, SCIENCE: NEWS (Mar. 23, 2016, 2:00 P.M.), http://www.sciencemag.org/news/2016/03/new-funding-matchmaker-will-cater-nih-rejects
[176] Lauer, *supra* note 174.
[177] This is not to say that scientists shouldn't confirm data; far from it. It is worth noting that this goal may be unrealistic to achieve fully, it is certainly an ideal worth striving for.
[178] It is possible that, via Freedom of Information Act (FOIA) requests and intense scouring of published grants, more granular data is in fact "available to the public." Such requests, beyond being notoriously time-consuming—meaning the lag prevents any nimble, quick-reaction analysis to funding on a year-to-year basis—requires expert knowledge to digest and categorize for the type of analysis one may want to perform on it.

types of breast cancer and further divisions within each subtype.[179] Thus, analyzing the costs and successes of "curing breast cancer" does not portray the whole picture. The current dataset does not permit such nuanced yet necessary analysis.

Lastly, increased understanding of the real costs of treatment by cancer type and age would present a treasure trove of new information by which to process how to distribute research funding. Such costs would not simply include the costs of the relevant medications and treatments, but real costs of how debilitating the cancer and its treatment are with respect to workforce participation, hospital requirements, etc. For example, consider cancers A and B. Both frequently manifest at the same age but are rarely fatal. However, to treat A requires only one pill a month and the patient maintains an otherwise regular life. Cancer B, however, requires months of energy-sapping chemotherapy, leaving the patient unable to function in her day-to-day life. Therefore, while neither hypothetical cancer "costs" anything in the calculus above because both are cured, they unquestionably have different real costs, from medical care costs to and man-hours opportunity cost.

Each of these areas could help maximize the benefits of implementing cost-benefit analysis in cancer research appropriations decision-making.

VI. Conclusion

In its preamble, the Constitution tells us that the government's role is to "promote the general Welfare."[180] The Founders doubled down on this principle; in articulating Congress's power, the powers that be gave the legislature the "[p]ower To lay and collect Taxes, Duties, Imposts and Excises, to pay the Debts and provide for the common Defence[sic] and general Welfare of the United States[.]"[181] Shortly after our country's founding, Congress decided that promoting the general welfare included caring for its citizens, including curing what ails them. Since beginning that undertaking, the mission has become quite the research regime. Now on the precipice of further expansion, it is the perfect moment to question how, exactly, we can tailor that investment to maximize our results. Because while 'curing cancer' may at first blush seem like a singular goal, it is, in fact, the culmination of a different cures for each of cancers' two hundred plus varieties.

With limited money, the government should be delibarate of whom it decides to fund and under what conditions. Since cancers occur at different ages and amongst different populations, no two incur the same economic strains. Those that affect more people and at a younger age do more economic damage. That's where cost-benefit analysis comes in. As we march along the journey to curing all cancers, we ought to be investing in where we feel the biggest harms first.

In light of this thinking, this article has gone through the incidence and mortality rates by age and sex of some of the largest and most prevalent types or sites of cancers to calculate the total costs each of these horrendous diseases place on our national economy. Some of these cancers make significantly larger dents in our economy than others; lung and bronchus, colon and rectum, pancreatic and breast cancers are among the 'costliest' cancers, while testicular, thyroid, Hodgkin's Lymphoma and larynx cancers are among the 'cheapest.' Further, using historical data, we can see which cancers have become more or less costly. That list is similar, though not identical, to the list of how costly a cancer is. And though dollars increased does not *necessarily* yield results that will have a long-term effect on decreasing cancer's mortality, our investments should nevertheless be guided by the hopes that they will, especially in light of the extremely positive return on investment we see under both time-lag and instantaneous thinking.

It is also worth ensuring that such a driving principle abides by our core moral and legal standards. Having demonstrated that, at the very least, cost-benefit analysis is a morally acceptable method, in part because there is no unanimous *right* choice regarding how to allocate funds, we next ask if it withstood specific criticisms. While gender-, age, and race-based discrimination claims are worth scrutinizing, they are likely insufficient to bar cost-benefit analysis

[179] *Types of Breast Cancer*, BREASTCANCER.ORG, http://www.breastcancer.org/symptoms/types.
[180] U.S. CONST. pmbl. ("We the People of the United States, in Order to form a more perfect Union, establish Justice, insure domestic Tranquility, provide for the common defence, promote the general Welfare, and secure the Blessings of Liberty to ourselves and our Posterity, do ordain and establish this Constitution for the United States of America.").
[181] U.S. CONST. art. 1, § 8, cl. 1.

as our underlying guiding principle.

From this position, a few policy recommendations follow. First, where possible, use cost-benefit analysis and weight investment by potential impact, particularly so for open-ended grants. The cost of a given cancer such a program or grant seeks to positively impact should therefore place a substantial, if not determinative, role in its approval. What's more, we can and should consider rearranging the mechanisms we use to fund such research, seeking to categorize the programs funded by the type of cancer they seek to address such that more detailed analysis can better inform the next generation's decision-making. Finally, we must improve cooperation and data collection to allow for more detailed analysis using more scientists to make future experimentation maximally efficient and effective.

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Appendix

Table 1. Changes in Cancer Mortality Demographics by Age, Cancer Site

Cancer Site	2003-12 Annual Mortality Rate of Change (%), Men	2003-12 Annual Mortality Rate of Change (%), Women	2008-12 Annual Mortality Rate of Change (%), Men	2008-12 Annual Mortality Rate of Change (%), Women	2008-12 Patient's Median Age, Diagnosis (Years), Men	2008-12 Patient's Median Age, Diagnosis (Years), Women	2008-12 Patient's Median Age, Death (Years), Men	2008-12 Patient's Median Age, Death (Years), Women
All sites, Men	-1.4	N/A	-2.5	N/A	66.0	N/A	72.0	N/A
All sites, Women	N/A	0.0	N/A	0.0	N/A	65.0	N/A	73.0
Prostate	-4.0	N/A	-6.6	N/A	66.0	N/A	80.0	N/A
Lung and Bronchus	-2.4	-1.1	-3.0	-1.9	70.0	71.0	71.0	72.0
Colon and Rectum	-3.0	-2.8	-3.6	-3.8	66.0	70.0	71.0	76.0
Urinary Bladder	-0.6	-1.0	-1.2	-1.1	72.0	73.0	78.0	80.0
Skin Melanoma	2.0	0.9	2.0	9.5	65.0	58.0	69.0	69.0
N-H Lymphoma	-0.1	-0.2	-1.1	-0.4	65.0	68.0	74.0	78.0
Kidney and Renal Pelvis	1.7	1.5	-0.1	-0.1	63.0	65.0	69.0	74.0
Leukemia	1.3	0.7	1.8	0.7	66.0	67.0	74.0	76.0
Pancreas	1.2	1.1	1.2	1.1	68.0	73.0	70.0	75.0
Liver / Bile Duct	3.7	3.0	3.7	3.0	62.0	68.0	64.0	73.0
Stomach	-1.7	-0.6	-1.7	-0.6	68.0	71.0	70.0	75.0
Esophagus	-0.2	-1.2	-0.2	-1.2	66.0	71.0	68.0	74.0
Brain/Nervous	-0.2	0.0	-0.2	0.0	57.0	59.0	63.0	66.0
Myeloma	2.1	0.7	3.0	0.7	68.0	69.0	74.0	76.0
Thyroid	5.3	5.2	5.3	3.0	54.0	49.0	70.0	76.0
Larynx	-1.7	-3.0	-1.7	-3.0	65.0	63.0	68.0	69.0
Breast	(not provided)	0.0	(not provided)	0.3	68.0	61.0	70.0	68.0
Corpus and Uterus, NOS	N/A	1.5	N/A	2.3	N/A	65	N/A	71
Ovary	N/A	-0.9	N/A	-0.9	N/A	70.0	N/A	70.0
Cervix Uteri	N/A	-2.4	N/A	-2.4	N/A	57.0	N/A	57.0
Oral Cavity, Pharynx	0.8	0.1	0.8	0.5	61.0	64.0	65.0	73.0
Myeloma	2.1	0.7	3.0	0.7	68.0	69.0	74.0	76.0

Table 2. Cancer's Economic Costs, 2008-2012

Cancer Site / Type	Cancer's Cost In Total, 2008-2012 (USD Billions)	Cancer's Cost Men, 2008-2012 (USD Billions)	Cancer's Cost Women, 2008-2012 (USD Billions)	Costs Per Tax Payer, Total (USD)
ll Sites	$1,380.97	$705.55	$675.42	$4,396.42
Lung and Bronchus	352.92	195.39	157.52	2219.44
Colon and Rectum	118.47	65.66	52.81	745.04
Breast	114.93	(Data unavailable)	114.93	722.81
Pancreas	85.73	47.10	38.63	539.15
Liver and Bile Duct	61.60	44.63	16.97	387.39
Leukemia	51.51	30.04	21.48	323.95
Brain and Other Nervous System	48.58	28.18	20.41	305.53
Non-Hodgkin's Lymphoma	41.01	24.33	16.68	257.92
Ovary	36.34	-	36.34	228.56
Prostate	38.32	38.32	-	240.99
Esophagus	37.25	31.05	6.21	234.28
Kidney and Renal Pelvis	30.89	21.15	9.74	194.26
Stomach	27.72	16.89	10.83	174.34

Urinary Bladder	25.43	17.74	7.69	159.92
Oral Cavity and Phraynx	24.26	17.97	6.29	152.57
Melanoma of the Skin	24.07	15.22	8.86	151.40
Myeloma	23.25	12.89	10.36	146.22
Corpus Uteri	21.64	-	21.64	136.08
Cervix Uteri	16.58	-	16.58	104.24
Larynx	9.17	7.34	1.83	57.65
Hodgkin's Lymphoma	3.55	2.04	1.50	22.30
Thyroid	3.42	1.67	1.75	21.54
Testis	2.07	2.07	-	13.03

Table 3. Value Saved from Cancer Mortality Drops in 2012 Via Incidence/Mortality Rates 2002 Versus 2012

Cancer Cite / Type	Real Dollars Saved, 2012 (USD Billions)	Real Dollars Saved, 2012, Men (USD Billions)	Real Dollars Saved, 2012, Women (USD Billions)	Savings Per Tax Payer (USD)
All Sites	$255.41	$151.16	$104.25	$813.11
Lung and Bronchus	113.93	78.60	35.33	716.47
Colon and Rectum	30.94	17.67	13.27	194.56
Breast	26.43	(Data unavailable)	26.43	166.23
Pancreas	-2.17	-0.83	-1.34	-13.67
Liver and Bile Duct	-16.72	-12.59	-4.13	-105.16
Leukemia	9.82	5.39	4.43	61.79
Brain and Other Nervous System	2.43	1.19	1.24	15.28
Non-Hodgkin's Lymphoma	18.44	10.28	8.16	115.94
Ovary	9.52	-	9.52	59.88
Prostate	14.04	14.04	-	88.27
Esophagus	3.47	2.27	1.2	21.85
Kidney and Renal Pelvis	6.28	4.01	2.27	39.51
Stomach	6.42	4.60	1.82	40.40
Urinary Bladder	1.15	1.15	-	7.22
Oral Cavity and Phraynx	1.97	1.31	0.66	12.37
Melanoma of the Skin	2.81	2.14	0.67	17.67
Myeloma	4.69	2.67	2.02	29.47
Corpus Uteri	-2.44	-	-2.44	-15.32
Cervix Uteri	1.53	-	1.53	9.61
Larynx	3.01	2.52	0.49	18.92
Hodgkin's Lymphoma	2.03	1.16	0.87	12.80
Thyroid	0.06	-0.03	0.09	0.35
Testis	0.02	0.02	-	0.14

Table 4. Breakeven Analysis for 1% Reduction in Mortality Rate, By Cancer

Cancer Site / Type	Breakeven Investment (USD Millions)
All Sites	13,809.67
Lung and Bronchus	3,529.15
Colon and Rectum	1,184.69
Breast	1,149.40
Pancreas	857.30
Liver and Bile Duct	616.00
Leukemia	515.12
Brain and Other Nervous System	485.83
Non-Hodgkin's Lymphoma	410.13
Prostate	383.20
Esophagus	372.52
Ovary	363.44

Kidney and Renal Pelvis	308.92
Stomach	277.22
Urinary Bladder	254.29
Oral Cavity and Phraynx	242.59
Melanoma of the Skin	240.74
Myeloma	232.50
Corpus Uteri	216.39
Cervix Uteri	165.75
Larynx	91.66
Hodgkin's Lymphoma	35.45
Thyroid	34.24
Testis	20.72

Table 5. National Cancer Institute Annual Budget[182]

Year	NCI Budget (Millions, Current USD)	NCI Budget (Millions, 2015 USD)	% of Fed. Budget
1938	0.4	6.7	0.006%
1939	0.4	6.8	0.004%
1940	0.6	9.7	0.006%
1941	0.6	9.2	0.004%
1942	0.6	8.2	0.002%
1943	0.5	7.3	0.001%
1944	0.5	7.1	0.001%
1945	0.6	7.4	0.001%
1946	0.5	6.7	0.001%
1947	1.8	19.4	0.005%
1948	14.5	142.6	0.049%
1949	14.0	139.4	0.036%
1950	18.9	185.9	0.044%
1951	20.1	183.1	0.044%
1952	19.7	175.8	0.029%
1953	17.9	158.8	0.024%
1954	20.2	178.3	0.029%
1955	21.7	192.2	0.032%
1956	25.0	217.7	0.035%
1957	48.4	408.5	0.063%
1958	56.4	462.6	0.068%
1959	75.3	613.1	0.082%
1960	91.3	730.7	0.099%
1961	111.0	879.9	0.114%
1962	142.8	1121.0	0.134%
1963	155.7	1206.4	0.140%
1964	144.3	1103.6	0.122%
1965	150.0	1128.7	0.127%
1966	163.8	1198.0	0.122%
1967	175.7	1246.5	0.112%
1968	183.4	1248.8	0.103%
1969	185.2	1195.7	0.101%
1970	181.5	1108.5	0.093%
1971	233.2	1364.5	0.111%
1972	378.8	2147.8	0.164%
1973	492.2	2627.4	0.200%
1974	527.5	2536.2	0.196%
1975	691.7	3047.5	0.208%
1976	761.7	3173.4	0.205%
1977	815.0	3187.5	0.199%
1978	872.4	3171.1	0.190%
1979	937.1	3059.7	0.186%
1980	999.9	2875.6	0.169%
1981	989.4	2579.2	0.146%
1982	986.6	2423.1	0.132%

[182] *See generally Appropriations*, NAT'L INSTS. OF HEALTH, http://www.nih.gov/about-nih/what-we-do/nih-almanac/appropriations-section-1; OFFICE OF MGMT. & BUDGET, EXEC. OFFICE OF THE PRESIDENT, FISCAL YEAR 2016: HISTORICAL TABLES, https://www.whitehouse.gov/sites/default/files/omb/budget/fy2016/assets/hist.pdf.

1983	987.6	2350.6	0.122%
1984	1081.6	2467.1	0.127%
1985	1183.8	2607.9	0.125%
1986	1203.4	2602.9	0.122%
1987	1402.8	2926.3	0.140%
1988	1469.3	2944.5	0.138%
1989	1570.3	3000.9	0.137%
1990	1634.3	2963.0	0.130%
1991	1714.8	2983.7	0.129%
1992	1962.6	3314.8	0.142%
1993	1981.4	3249.4	0.141%
1994	2082.3	3329.5	0.142%
1995	1913.8	2976.0	0.126%
1996	2248.0	3396.7	0.144%
1997	2381.1	3517.0	0.149%
1998	2547.3	3703.8	0.154%
1999	2925.2	4162.6	0.172%
2000	3314.6	4560.8	0.185%
2001	3754.5	5027.2	0.202%
2002	4181.2	5506.7	0.208%
2003	4592.3	5914.9	0.213%
2004	4739.3	5947.8	0.207%
2005	4825.3	5857.9	0.195%
2006	4793.4	5636.6	0.181%
2007	4797.6	5483.7	0.176%
2008	4830.6	5318.5	0.162%
2009	4969.0	5490.7	0.141%
2010	5103.4	5547.4	0.148%
2011	5058.6	5331.7	0.140%
2012	5072.2	5234.5	0.143%
2013	4807.5	4889.2	0.139%
2014	4923.2	4928.2	0.140%
2015	4931.0	4931.0	0.134%