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ABSTRACT

Medical care at the end of life, estimated to contribute up to a quarter of US health care spending, often encounters skepticism from payers and policy makers who question its high cost and often minimal health benefits. However, though many observers have claimed that such spending is often irrational and wasteful, little explicit analysis exists on the incentives that determine end of life health care spending. This paper attempts to provide the first rational and systematic analysis of the incentives behind end of life care. The main argument we make is that existing theoretical and empirical analysis of the value of life do not apply, and often under-values, the value of life near its end and terminal care. We argue that several factors drive up the value of life near its end including the low opportunity cost of medical spending near ones death, the value of hope including living into new innovations, and the potential positive effect of on the value of life from being frail. We calibrate the ex-post value of hope associated with treatments for HIV patients to be as much as four times as high as standard per-capita estimates of treatment effects and as many as two and a half times as high as aggregate values across all cohorts.

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Section 1: Introduction

Medical care at the end of life often encounters skepticism from payers and policy makers who question its high cost and often minimal health benefits. Indeed, many studies have found that about a quarter of overall life-time spending on medical care occurs in an individual's last year of life, regardless of whether that care is privately or publicly financed (Hogan et al. 2000; Lubitz and Riley 1993). It seems generally agreed upon that medical resources are being wasted on excessive end-of-life treatments that often only minimally prolong an already frail life. This excessive care at the end of life affects the overall distribution of health care spending as it is highly skewed, driving up lifetime average spending levels many times. For example, it has estimated that close to half of the overall spending on old individuals in the US stems from the top 5 % of the spending distribution (Garber et al (1998)).

From an economic standpoint, it may seem obvious that much of this extreme end-of-life spending is irrational since the value of a life year is often estimated to be in the range of $100 thousand, but overall spending to extend life a few months near death can be in the millions. It can be argued that this vast misallocation of resources, induced by excessive end of life health care, has important consequences for the overall economy since end-of-life care makes up a substantial share of overall healthcare spending which is approximately 16% of the economy. This alleged over-spending on terminal care also has important implications for the public programs that pay for much of this end of life care, (such as the US's Medicare for the old and Medicaid for the poor), as well funds like Social Security, which must continue paying out over longer, but lower quality, lives.

Even though many observers have claimed that such spending is often futile and wasteful, it persists and is growing in both the private and public sectors. This may indicate that there are some less understood benefits of end-of-life care, and presumably larger than the often discussed costs. Indeed, little explicit and systematic analysis exists on the incentives that determine end-of-life care. We argue that a positive analysis of why and when high levels of terminal care spending occur is a prerequisite before any normative claims can be made or any policy proposals aimed at limiting such care can be justified on an efficiency basis.

In this paper, we attempt to provide a rational choice analysis of the incentives behind end of life care. The main argument we make is that existing theoretical and empirical analyses of the value of a life do not apply to the valuation of life near its end and, therefore, do not apply to the demand for terminal care. In particular, that several forces operate which makes the value of end of life care higher than previously argued.

First, if resources have no value when dead, a self-interested individual would be willing to forego his entire wealth to extend his life when dying, even if only for a few months. A substantial amount of spending on futile care is rational when there is little-to-no value of leaving wealth behind. The desire to spend one's wealth on terminal care is supported by existing evidence that a large share, up to a half, of personal bankruptcies are associated with unforeseen health care spending, often taking place when faced with life-threatening

diseases (Himmelstein (2005)). We argue that living, like other goods, has diminishing marginal utility--the willingness to pay for an additional year of life falls with how many years one has to live. This is in contrast to how the value of a statistical life-year is taught and explained: it is often prefaced with claiming that it is *not* how much people are willing to pay to avoid having a gun put to their head (presumably one's wealth). However, terminal care decisions are often exactly of that nature.

Second, we argue that an important ignored component of spending on end-of-life care is the preservation of hope of living which then raises valuation of life. We define the value of hope explicitly as the *current* consumption of *future* survival. If a patient is given a death sentence in 6 months, he values those 6 months less than if he knew he would live after that. The fear of knowing that the end is near is a bad, as is often revealed by people preferring a quick accidental death. We derive how this value of hope raises the willingness to pay for what appears as futile treatments. Related to such a value of hope is the option value of living to utilize a newly discovered treatment before one dies. Indeed, many celebrities, e.g. Michael J. Fox and the late Christopher Reeve, have invested large shares of their own wealth into speeding up the discovery of a cure for this purpose.

Third, the *social* value of terminal care is often greater than the *private* value of the same treatments. However, existing analysis of the value of a life year mostly consider only private valuation. If the extension of a given person's life has positive external effects on others (family members, tax-payers who do not tolerate letting poor people die), we would estimate and observe more spending than what is privately optimal. Since private willingness to pay for life extension is limited by one's wealth, the mere existence of Medicaid seems inconsistent with a private valuation approach being relevant, as it would be infeasible for those patients to pay for the end-of-life care that they receive. Indeed, most rich countries don't tolerate poor people dying when existing technologies can save them.

Fourth, we argue that the rational level of terminal care for frail patients is often larger than commonly believed. In particular, we show when the value of terminal care may be the same regardless of the "quality" of life experienced by the patient. Therefore, even though a person may be frail and in very poor health, it may still be rational for him to value life-extending terminal care as much as a perfectly healthy person. This differs from a vast health economic literature arguing that there is less value in prolonging a life of lower quality, the driving assumption of "quality-adjusted life-year" (QALY) analysis.

Because of all of these factors, the value of terminal care may exceed the levels currently attributed. To empirically assess the importance of one of these factors, the value of hope, we calibrate the option value of new innovation associated with terminal care for HIV patients in the 1990s. We find that the ex-post value of hope associated with treatments for HIV patients to be as much as four times larger than standard estimates. The option value is largest when treatments enabled patients before the breakthrough of HAART in 1996 to live to see that breakthrough. Although it is clear that the tremendous breakthroughs in HIV may be atypical of medical progress across the board, they still

serve as a useful case to illustrate how one can quantify this value of hope more systematically.

The paper is organized as follows. Section 2 discusses the non-linearity of the value of life. Section 3 discusses how the value of hope raises spending. Section 4 discusses how altruism within and across families affects terminal care. Section 5 discusses the impact of quality of life on rational terminal care. Section 6 considers the unusual aspects of R&D into new terminal care technologies. Section 7 provides our calibrations for HIV. Lastly, section 8 concludes.

Section 2: Rational Terminal Care and the Non-Linearity of the Value of Life

Consider the indirect utility function *V(Y,S)* of an individual with lifetime wealth Y and survival function *S*. For example, this indirect utility function may be the one resulting from a canonical consumption problem of the type

$$V(Y,S) = \max \int_0^\infty \exp(-\rho t) S(t) u(c(t)) dt \qquad (1)$$

subject to

$$Y = \int_0^\infty \exp(-rt) S(t) y(t) dt = \int_0^\infty \exp(-rt) S(t) c(t) dt, \qquad (2)$$

where *y(t)* is income at age *t*, *c(t)* consumption at *t*, *r* and ρ are the interest rate and time-preference and u is the instantaneous utility function, assumed weakly positive ($u \geq 0$).

For any such indirect utility function, V, consider how much an individual would be willing to pay for a product that changed his survival function from S to S'. If we denote this amount by v(S',S), it satisfies[2]:

$$V(Y\text{-}v(S',S),S') = V(Y,S). \qquad (3)$$

This *infra-marginal* valuation formula[3] differs from the existing value-of-life methodology used in the empirical literature which only considers *marginal* changes in life expectancy. This basic definition has remarkably strong implications for the economic value of raising survival for people who are near the end of their life. In particular, consider the value of a gain in survival to S' for an individual who is near the end of his life, approximated by his existing survival function satisfying S = 0. The value of this survival gain satisfies:

$$v(S',0) = Y \text{ for all } S' \qquad (4)$$

[2] An analogous argument occurs if the individual is asked to value a probability distribution over a set of feasible survival functions induced by treatment.

[3] See Becker et al (2005) for a more elaborate discussion of infra-marginal valuation in a different context.

This extreme implication states that an individual is willing to pay his entire wealth for any gain in survival, *no matter how small the improval*. Put differently, if there is no value of leaving resources behind when dead, an individual is willing to spend all of his wealth to prolong life, even if just briefly. This is an extreme implication induced by the complementarity between consumption and longevity (see Dow et al (1999)); as consumption is worthless without life, all of it would be sacrificed to gain more life.

More generally, there may be inherent *non-linearity* in the valuation of life. The marginal value of an additional life year will likely fall the more life one has left. This implies that the value of big changes in survival cannot be as easily inferred from the value of small changes in survival. There is an implicit linearity assumption when the existing literature aggregates marginal valuations to estimate the value of life-improvements. Consider the common practice of infra-marginal valuation through multiplying life-years gained with a constant marginal value of a life-year, say, $100 thousand. To illustrate simply, consider the canonical consumption problem above in the case of no discounting and a deterministic lifetime. In this case, the indirect utility function is made of T years of consumption of the overall wealth Y split up over the T years as in

$$V(Y,T) = Tu(Y/T) \tag{5}$$

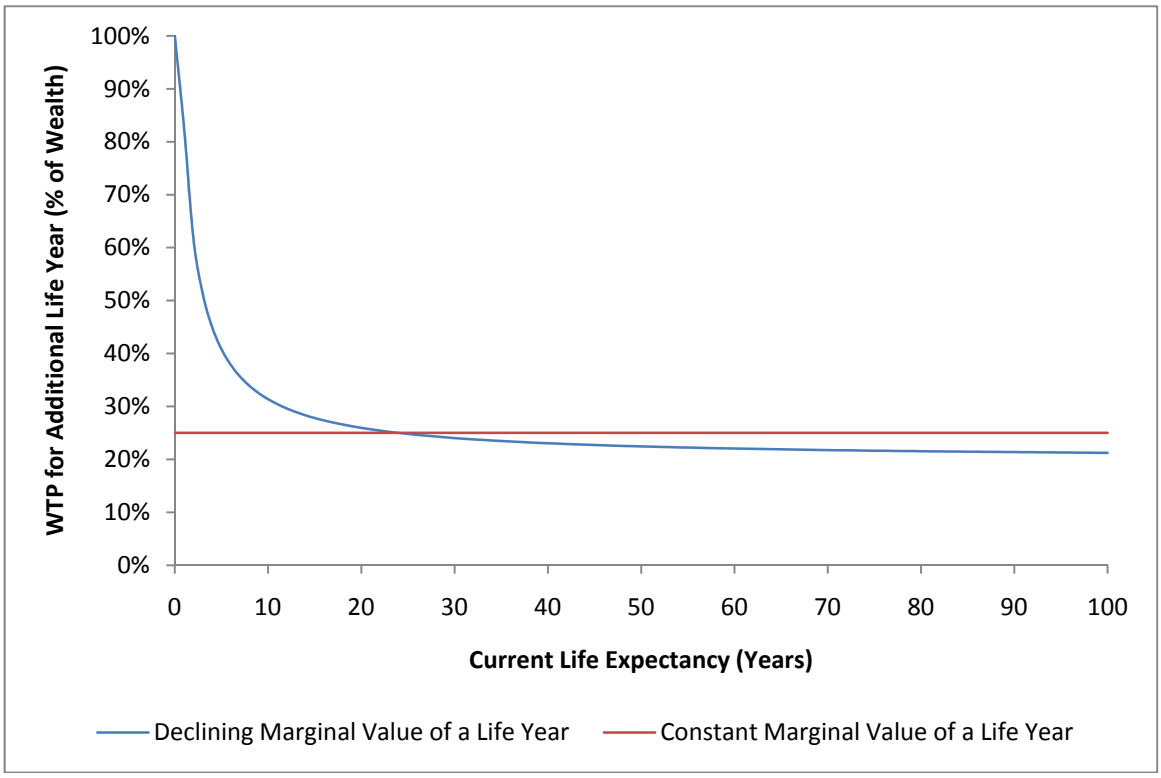
This implies the marginal value of life

$$dY/dT = -V_T/V_Y = c - u/u' \tag{6}$$

This says that if the elasticity of the utility function with respect to consumption is one, then there is no value of life. This is the case when utility is proportional to consumption (u=ac) so that the indirect utility only depends on wealth, V=aY. In this case, the decrease in quality of life due to a longer life equals the gain from increased quantity of life.

As illustrated in Figure 1, the typical pattern of willingness to pay for a life-year will fall with life expectancy. The value of a life year equals total wealth when the alternative is death and decreases as you get further from there. By contrast, traditional valuations typically assume that the value of a life-year is constant.

Figure 1: Declining marginal value of a life-year as a function of life expectancy



In the example above, it can be shown[4] that when u is concave, the marginal value of life falls with longevity:

$$d/dT\ [dY/dT] \leq 0.$$

This is similar to diminishing marginal utility in consumption of traditional goods[5]. The important point is that if the marginal value of life declines with life in this way, the marginal value of life for those who have a lot of it, e.g. workers healthy enough to participate in labor markets, may not reflect the value of terminal care for those who have less life left.

Section 3: The Value of Hope in Terminal Care

Many observers of end-of-life care claim that some notion of "hope" is important for patients to invest time and money into staying alive. The previous analysis indicated that "selling hope" is often easy, not because of the actual health benefits of such treatments, but because of the low opportunity cost, when there is little benefit from leaving wealth behind.

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[4] Differentiating c-u/u' with respect to T yields [-u''u/(u')^2](dc/dT), which is negative.

[5] For example, when the utility function takes the constant elasticity form, $u(c) = c^a$, then the indirect utility function takes the Cobb-Douglas form $V(Y,T) = T^{1-a}Y^a$ which displays the traditional declining marginal rate of substitution with the levels of the two "goods".

However, there is an aspect of hope that seems important to doctors and care-givers. We formalize the value of hope as stemming from the current consumption of future survival: the person values knowing today that there is chance of living tomorrow. If certain death was known to prevail tomorrow, the person would be without hope today and, therefore, enjoy living less. Living life under a death sentence is a "bad" as reflected in many sentiments that people would prefer to die in sudden accidents over living with a terminal cancer diagnosis.

This is incorporated into the previous analysis by letting current utility become an increasing function of survival. Consider the case when this takes the linear form

$$u(S,c)=Hu(S) + u(c) \qquad (7)$$

Here, the parameter H reflects hope and specifies how valuable the consumption of future survival is today. For the canonical consumption problem above the present value of expected utility now satisfies

$$V(Y,S;H)= AHu(s)+ V(S,Y) \qquad (8)$$

where A is the value of a life-long annuity and $V(Y,S)$ is the value function without hope (from before). If we denote by $v(H)$ the value of life as a function of the value of hope this satisfies

$$V(Y-v(H),S';H)- V(Y,S;H)=H[Au(S)-A'u(S')] + V(Y-v(H),S')-V(Y,S)$$

The left hand side is simply the implicit definition of the infra-marginal value as a function of the hope parameter. The right hand composes that into a positive term that rises with H and a second term that reflects the traditional value of life without hope. It follows directly that the value of life as a function of hope, $v(H)$, is an increasing function. Whenever future survival is valued in terms of current consumption, future survival gains are "double-counted" survival affects the value of future consumption in a standard manner but also raises the value of being alive presently. This "double counting" may occur more in end of life care decisions than in the labor- or product-market setting where marginal valuations of life are typically estimated.

3.1: Hope and the Option Value of New Innovation

Future survival may not have inherent consumption value but may be valued in non-standard ways by enabling patients to take advantage of future technologies. In other words, there is an option value of terminal care since it may enable the person to live to see future cures.

Consider an uncertain time of arrival of a new discovery A and let G denotes its cdf. If C(t) denotes the higher survival curve associated with the cure and S the survival in absence of a cure, the individual faces the expected survival function denoted S^C defined by

$$S^C(t) = \int_0^\infty S_a(t)dG(a) \tag{10}$$

where $S_a(t)$ the probability of surviving t years if the cure arrives at time a. If s_j is the probability that the patient survives to year *j* conditional on having survived to year *j*-1 in the absence of the cure, and s_j^c is the analogous yearly probability with the cure, this survival curve is given by $S_a(t) = \prod_{j=1}^{t} s_j$ for t≤a and $S_a(t) = S_a(a)\prod_{j=a}^{t} s_j^C$ for t>a. In essence, $S_a(t)$ is the product of the cureless one-year survival probabilities for each year until the arrival of the cure, followed by the product of the one-year survival probabilities with the cure in each year following its introduction.

Now consider v^C, the value of using a given treatment that yields a higher survival, S', with the possibility of a future cure. This value is defined by

$$V\left(Y - v^C, S'^C\right) = V\left(Y, S^C\right) \tag{12}$$

This value reduces to the value v (discussed in previous sections) when there is no possibility of a cure. The difference in value between the traditional willingness to pay for a treatment, v, and the non-standard value, v^C, is the possibility of living to experience a new cure under the treatment[6].

This simple analysis has several direct implications for the demand for terminal care. First, it generally predicts that, holding the effectiveness of current treatments (S'-S) constant, factors that increase the rate of future innovation will also increase the demand for terminal care. One such factor would be a larger, more promising pipeline of treatments being investigated for future market approval. Another may be the size or prevalence of the disease, since increased patient base raises R&D incentives. Also, it seems reasonable to assume that lack of treatment discoveries in the past would lower expectations of immediate discoveries now. Compared to a novel disease, if it has been 40 years without any huge breakthroughs, it would seem less likely that a breakthrough will occur in the next year. This would lead to the prediction that the demand for terminal care treatments would rise in the novelty of the disease, holding the effectiveness of current treatments constant.

Second, the option value would also predict that individuals would be willing to sacrifice quality of life for longer survival. This non-standard impact on the quality-quantity tradeoff of living is predicted because living a frail life to see a new cure is more valuable than a shorter healthier life.

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[6] It is worthwhile noting that this option value implies that randomized clinical trials where future treatments are not incorporated yield biased estimates of the full treatment effect. That is, $S'_C - S_C \neq S' - S$.

Third, the option value of future cures may also lead one to predict a *risk-loving* behavior when deciding between treatments with different survival distributions. This occurs if the loss in the left-hand side is outweighed by the gain in survival in the right-hand tail, made more valuable due to expected future innovations. Having a 10 percent chance of living 10 years and 90 percent chance dying immediately may be more valuable than living 1 year for certain. In other words, treatments with the same mean survival or treatment effect may differ in value since larger variances raise the chance of living into a cure.

In general, these demand predictions may occur on the extensive margin (number of patients treated) or on the intensive margin (compliance). For example, one would predict that as breakthrough drugs enter the last phases of the FDA approval process, both uptake and compliance on current marginal drugs would increase due to patients hoping to see the marketing of new drugs.

Section 4: The Quality of Life and the Value of Extending It

It is often argued that life-extension should be allocated towards individuals in good health rather than those in poor health. In this section we analyze the value of life as a function of the level of health or "quality" of life. We find that terminal care is often more rational for frail patients than commonly believed. Even though a person may be frail and in very poor health, it may still be rational for him to value life-extension as much as a perfectly healthy person. An extreme case of this is the analysis above where a person is willing to spend his entire wealth for extra life, regardless of whether that individual is frail or healthy.

More precisely, consider when the annual utility function, *U(c,q)*, is extended to depend positively on both consumption *c* and quality of life *q*. For a given quality of life, consider the indirect utility with full consumption smoothing:

$$V(Y,S) = AU(Y/A,q) \tag{16}$$

The infra-marginal value of life *v(q)* for a given level of quality *q* is then defined by

$$A'U(Y/A' - v(q),q) = AU(Y/A,q) \tag{17}$$

This has the direct implication that quality of life has two *offsetting* effects on the value of life (see also Murphy and Topel (2003)). First, quality raises the value of life (left-hand side) by raising the level of utility under the improved survival, A', since living longer is enjoyed more when the quality of that life is higher. However, as a second effect, it also raises the value of the remaining life at the lower survival (right-hand side). Therefore, a higher quality of life means the new life is enjoyed more but also means the old life is better as well. The second effect is due to quality increasing the amount of foregone consumption needed to finance life extension. Depending on the cross partial of U and the complementarity between consumption and quality of life, the value of life,

v(q), may be falling or rising in the quality of life. As the quality of life has indeterminate effect on the value of its extension, frail individuals may have the same incentives to extend life as health individuals.

Section 5: The Social vs Private Value of Life

The previous sections considered a self-interested individual in isolation. This section considers altruism within families where the social value of life can make it more valuable than the private levels analyzed above.

5.1 Altruism within Families

Altruism within families affects the social value of a life in two ways. First, altruism of a dying person towards his children reduces the value of life due to bequest motives, as the dying person still values resources left behind. Second, altruism towards the dying person, e.g. parents saving their child, raises the value of life since people, other than the dying patient, value his survival.

More precisely, consider when a parent is terminally ill but now both the parent and the child share the payment that shifts the parent's survival to *S'* rather than death, *S=0*. Let the infra-marginal value of the parents life *v* be split between the parent and the child according to the shares *(s,1-s)*. Let $V^p\left(Y^p,S\right)$ and $V^C\left(Y^C\right)$ be the indirect utility functions of the parent and child, with the latter ignoring the child's survival prospects which are assumed to remain constant. The infra-marginal value of the parent's life, *v*, is then defined by

$$\left(1+a^c\right)V^p\left(Y^p-sv,S'\right)+\left(1+a^p\right)V^c\left(Y^c-\left(1-s\right)v\right)=\left(1+a^p\right)V^c\left(Y^p+Y^c\right) \quad (12)$$

where a^c is the altruism of the child towards the parent and a^p the altruism of the parent towards the child. The right hand side is the child's welfare when no treatment is undertaken for the parent: the parent dies and all of the parent's wealth is left as bequest. The left hand side is the joint welfare of the two when the increased survival, and its cost, is shared. This can be rewritten as

$$\left(1+a^c\right)V^p\left(Y^p-sv,S'\right)=\left(1+a^p\right)\left[V^c\left(Y^p+Y^c\right)-V^c\left(Y^c-\left(1-s\right)v\right)\right] \quad (13)$$

This simply equates the gain in welfare of the parent surviving with the foregone consumption of the child. Clearly, with large enough altruism in the child and low enough altruism of the parent, we can have a larger willingness to pay than the previously considered self-interested level made up solely of the parent's wealth

$$v > Y^p \quad (14)$$

Conversely, for low enough altruism in the child and high enough altruism of the parent, we can observe willingness to pay lower than the self-interested level

$$v < Y^p \tag{15}$$

If altruistic spending rises with income, the two-sided nature of altruism may even raise spending above wealth levels of the sick individuals, especially if the healthy are richer than the ill. For example, terminal care for a child, financed by his parents, is likely to be far greater than the self-interested levels determined by the wealth level of the child.

5.2 Altruism across Families and Public Pay-As-You-Go (PAYG) Health Care

Clearly an important contributor to the high level of spending on terminal care is the public subsidization of demand (in the United States, mostly through Medicare and Medicaid). To consider the determinants of the size of public subsidies, consider the public pay-as-you-go (PAYG) insurance that finances most health care spending in the developed world. Particularly for the poor, the demand subsidy through third-party financing is clearly an important factor in determining the high level of terminal care spending. This is a natural extension of the analysis above, but now each parent is being subsidized by the average child in the economy as opposed to their own child.

The classic effects of any demand subsidies are, of course, to raise the supply-price, lower the demand-price, and increase quantity. Consequently, terminal care spending, the product of supply-price and quantity, will be positively affected by demand subsidies[7].

However, we argue here that there exists evidence suggesting that, even in the absence of demand subsidies, the level of terminal care spending would be higher than accounted for by existing value-of-life estimates. Indeed, there is a large literature in health economics, the most prominent early study being the RAND Health Insurance Experiment[8], which attempted to estimate the effect of co-pays on health care spending. Interpreting co-pays as unsubsidized care, this literature has implications for the counterfactual spending that would take place in absence of demand subsidies[9]. In general, if it is estimated that non-subsidized care is a certain percent of subsidized care, then terminal care spending would be predicted to be the same percentage of observed subsidized levels. But even when discounting spending due to subsidies in this manner, it appears that terminal care spending is larger than common estimates of the value of a life. For example, even if we

[7] Demand subsidies for health care in many countries, including Medicare and Medicaid in the US, differ from classic demand subsidies in that they also involve third-party (administrative) pricing.

[8] Other more recent studies on the effect of public demand subsidies include Card, et al (2004), Finkelstein et al (2005). The RAND experiment is not well suited to study the effects of public subsidies on terminal care, as it had caps on out of pocket spending that were likely met for expensive terminal care.

[9] Indeed, The RAND Health Insurance Experiment was ideally suited to studying public subsidization as premiums were never collected by participants, mimicking the effects of differentially generous tax-financed plans. The experiment offers less evidence on the demand for insurance, but rather the demand for ex-post care given a randomly determined insurance policy.

assume that for every 100 thousand dollars spent on publicly funded terminal care, 50 thousand would be spent without public subsidies, spending levels on terminal care are many times higher than existing value of life estimates. Therefore, this suggests that using standard co-pay estimates to predict unsubsidized demand may not alter our basic argument. This is particularly true if, as often is estimated, acute hospital inpatient care is less elastic to co-pays than is other forms of care, perhaps for exactly the reasons discussed in this paper.

The overall analysis of PAYG insured terminal care is analogous to multiple children and parents who exhibit heterogeneous altruism towards each others, where presumably within-family altruism is stronger than across-family altruism. Therefore, such altruistic and PAYG financed terminal care have many analogous features to the analysis of a single family before. Again, it is the relative altruism of the old relative to the young that determine whether a PAYG-financed health care program has a larger value of saving an patient from dying than the patient himself. If younger generations care more about using state of the art terminal care to save the old than the older generations care about public deficits, then optimal spending levels may be well beyond the average wealth of the dying generation.

5.3 Insurance and Terminal Care

The social aspect of terminal care is related to the sharing of the costs with a pool of other individuals through insurance. The previous analysis considered the ex-post allocation problem of terminal care conditional upon a disease occurring. We here consider the ex-ante allocation problem of deciding how much wealth to allocate towards a potential future disease occurrence involving expensive terminal care. This will determine the willingness to pay for an insurance policy that covers terminal care if it is necessary in the future. Efficient insurance of terminal care does not tradeoff living against dying. Rather, it trades off current consumption against terminal care in the future and, therefore, may limit spending compared to uninsured spending. This is a non-standard effect due to changes in the opportunity costs of spending.

To illustrate this non-standard effect, let f be the probability of a terminal illness occurring, in which case, the person faces death unless treated. Assume for ease of exposition that the person is untreated if uninsured but if insured he is treated and his survival prospects are S' as before. If the individual does not develop the disease he faces the survival S. The willingness to pay for such coverage, v, is determined by how much wealth the individual is willing to give up ex-ante in order to obtain the survival S' if the terminal illness would occur in the future:

$$fV(Y-v,S')+(1-f)V(Y-v,S)=fV(Y,0)+(1-f)V(Y,S) \qquad (18)$$

If the individual was willing to give up all his present wealth for terminal care when needed in the future, the left-hand side would be zero and the right-hand side positive. Therefore, as opposed to the case for the ex-post willingness to pay, the ex-ante willingness to pay for terminal care is not equal to the individual's level of wealth ($v < Y$).

This is of course because the individual trades off other uses of wealth when making an ex-ante decision. In particular, he must consider consuming the wealth if the individual does not become terminally ill. Indeed, the willingness to pay for coverage is only equal to one's wealth if illness will occur with certainty, a special case of the previous analysis[10].

Section 6: R&D into Terminal Care Technologies

Our analysis above analyzes the high value of terminal care given the existence of technologies to extend life when it is threatened. This section considers the incentives for medical R&D to bring such technologies to market in the first place. The major issue we will discuss is how the presence of altruism affects optimal R&D into life-saving technologies[11].

We have previously discussed the difference between the social and private value of life, given the existence of a technology. There is an important aspect of the altruistic nature of care for life-threatening conditions which concerns the desire to avoid denying treatments to dying patients. This is certainly one of several reasons that such high levels of terminal care spending exist. Indeed, doctors often express concerns that it is "unethical" to deny any patient the use of existing technology in life-threatening situations, which has led to sharp disagreements between doctors and economists on appropriate levels of care. Terminal care is perhaps the starkest example of this issue. We here stress that such preferences may easily be incorporated into classical utility analysis but have unrecognized implications for the appropriate speed of technological change over time and, hence, for the appropriate change in health care spending over time.

Consider when an altruist prefers a dying patient not to receive care in the *absence* of a technology over denying the same care in the *presence* of a technology. This may be due to higher levels of consumed "guilt" when denying care in presence of a technology. In particular, let W^1 be the social surplus when using the developed technology and W^0 when not using the developed technology. Now let N denote the social surplus when the technology is not developed at all (and cannot be denied to patients). We assume that there is a social surplus from using the technology if it gets developed: $W^1 > W^0$. This surplus that occurs once the technology is out there may come from patients themselves or from altruistic payers of that care. Under standard preferences, it would be the case that not using a developed technology or not having it developed would entail the same ex-post surplus($W^0 = N$). The terminally ill patient would be indifferent because he

[10] Note that survival of the person absence the occurrence of terminal illness, *S*, has an indeterminate effect on the willingness to pay for terminal care insurance. This is because better health in absence of the illness occurring raises both the expected utility of being uninsured and insured.

[11] See Philipson et al (2006) for a general discussion of altruism and R&D.

obtained the same health and the altruists would be indifferent because their wealth would be unchanged and the health and wealth of the patient would be as well. However, when guilt is consumed from denial of care, the willingness to pay for care by altruists interacts with the presence of a new technology and this equality may not hold. In particular, if altruists consume guilt when denying care then $N > W^0$,so that not having a technology is better than denying it and inducing guilt[12].

In this case, the surplus conditional on developing the technology does not correspond, in a standard manner, to the value of R&D investments needed to generate the technology in the first place. In particular, let $P(R)$ be the probability of discovery of the technology given R&D investment *R*. The expected surplus of developing the technology is then

$$\max_R P(R)W^1 + (1 - P(R))N - R \tag{19}$$

This has the necessary first-order condition that balances the expected gain in social surplus with marginal R&D costs

$$P_R(W^1 - N) = 1 \tag{20}$$

The difference between efficient use when developed not having the technology developed at all, $W^1 - N$, defines socially efficient R&D. However, the difference $W^1 - W^0$ is usually how the value of a new technology is assessed, by assuming that the pre-innovation surplus W^0 is the welfare for which the price is sufficiently high to make the demand for the innovation vanish[13]. However, the difference, $N - W^0$, driven by the extent to which denial of care leads to guilt, determines how socially efficient R&D, quite different from traditionally discussed efficient levels of R&D. Thus, when there is no guilt from denying care, $N = W^0$, then the ex-post surplus guides optimal R&D investment in a standard manner. At the other extreme, guilt consumed could be so large that optimal use of the technology when developed is actually dominated by no use of an undeveloped technology($N > W^1 > W^0$). In that case, even though the technology is demanded ex-post and may generate a traditional surplus above the level of R&D undertaken, that R&D may be inefficient. In the intermediary case, consumption of guilt when denying care lowers the value of R&D. Put simply: what appears as valuable ex-post usage of expensive terminal care technologies does not necessarily warrant more R&D to develop them. The consumption of guilt when denying care implies that an innovation does not merely result in a price reduction, as commonly perceived by economists, but also represents a *shift* in the social demand curve.

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[12] This separates denial aversion from the aversion to deny care due to tort law, so called defensive medicine. Denial aversion concerns states with different technology as opposed to defensive medicine that concerns different care given the existence of a technology.

[13] For a canonical illustration of treating innovations as merely price reductions, see e.g. Hausman (2000))

Indeed, this aspect of technological change has important implications for the worldwide incidence of R&D. For example, in the area of drug development, the US makes up more than half of world sales, even though US is only about a fifth of world output. This fact is often used to argue that US markets drive drug R&D spending in the US or elsewhere and therefore subsidize other nations where markets for medical technologies are more regulated. However, when denial of care induces consumption of guilt, countries outside of the US may actually be hurt by such technological change. This occurs if they are better off not providing care in absence of a technology than they are denying care in its presence. In other words, there may be negative, as opposed to positive, external effects of US-driven technological change.

In addition, the guilt consumed when denying care is related to the rising push towards more insurance coverage in the US, despite the fact that both private and public coverage has been rising over time. The greater lack of insurance in the 1970s or 1980s was not as unacceptable as today because there was less denied care back then. Now with more technological change and the feasibility to deny existing technologies for the uninsured, the public outcry and guilt over un-insurance has risen.

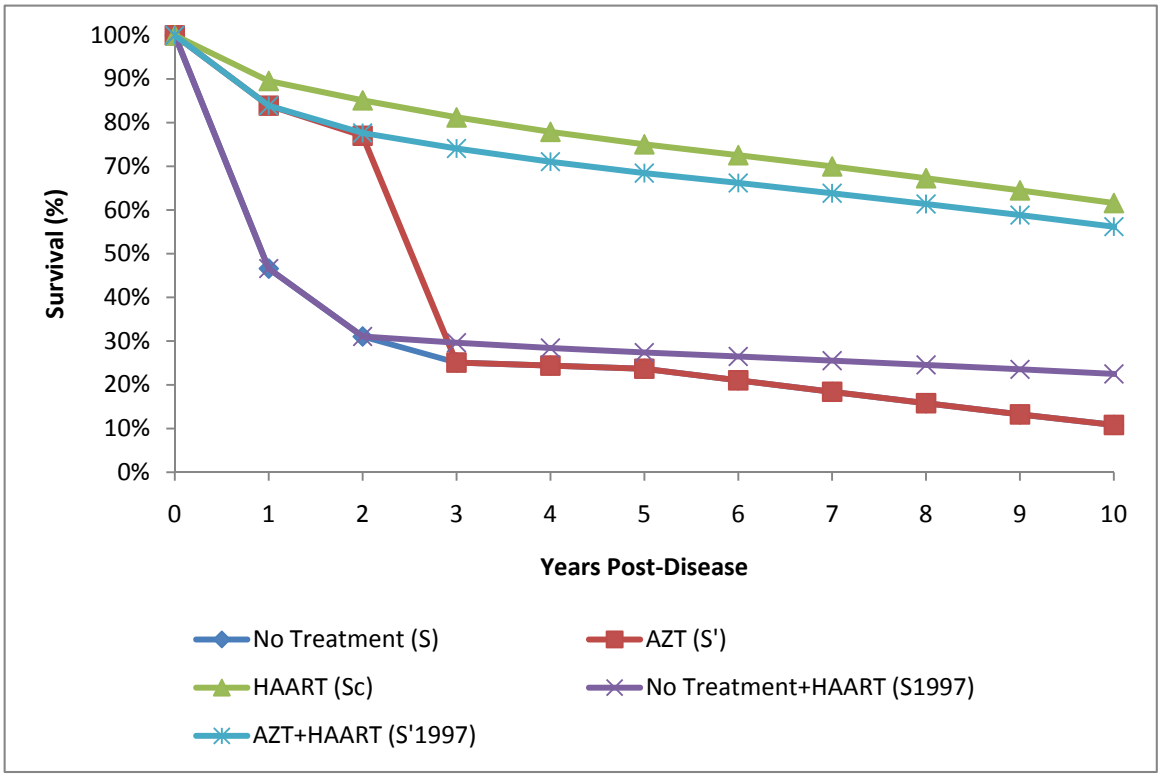
Section 7: Calibrating the ex-post value of hope due HIV innovation

In this section, we estimate the value of hope from living into future innovation. We consider patients with HIV before the new break through medicines were developed in the 1990s. Before these breakthroughs occurred, we show that there was a significant value of receiving terminal care that only marginally improved survival as this enabled patients to live long enough to see breakthrough treatments that came on the market in 1997. Our major finding is that the ex-post option value was as much as 400% of the traditionally determined value of the marginal therapies used. The great breakthroughs in HIV may be atypical of medical progress generally, but they serve as a useful case to illustrate how one can quantify the discussed benefits of terminal care more systematically.

Before there was any therapies developed, HIV patients had very little time left to live once diagnosed with AIDS. In April 1987, mono-therapy zidovudine (AZT) was licensed and soon became widely available as the first antiretroviral drug that improved survival (Fischl et al. 1987; McLeod and Hammer 1992). However, the improvement was marginal, ranging from several months to 1.6 years (Lemp et al. 1990; Moore et al. 1991; Vella et al. 1992). Nine years later, in 1997, HAART (highly active antiretroviral therapy) emerged as a major breakthrough for AIDS treatment and has improved life expectancy of AIDS patients markedly, by around 10 years (Walensky et al. 2006; The Antiretroviral Therapy Cohort Collaboration 2008). Any AIDS patients who were diagnosed between April 1987 and 1997 had a choice of whether to receive AZT or not. We consider how much the improved likelihood of living to see HAART in the future increases the true value of receiving AZT from its traditional value.

Figure 1 illustrates the data used on US cohorts diagnosed with AIDS. As an illustration, it contains the cohort of AIDS patients diagnosed in 1995 and their survival prospects for various treatment regimens prior to the arrival of HAART in 1997.

Figure 1: The option value of taking AZT for patients diagnosed with AIDS in 1995



The figure shows five counterfactual survival curves for patients diagnosed with AIDS in 1995 corresponding to the theoretical discussion of the option value in section 3.1. The first survival curve S is for patients who received no treatment for their disease. This survival curve is the lowest of the five with only 47% of patients surviving their first year. The next curve, *S'*, shows the survival of patients who were received AZT therapy. As we will discuss later, these patients faced markedly higher survival in the first two years of the disease, with 84% surviving the first year and 78% surviving to the second year. As discussed in the Appendix, past these first two years their yearly (but not cumulative) survival is the same as that for patients receiving no treatment. The third curve, S^C, represents the survival patients would have faced if they had received HAART from the beginning of their disease. As shown in the figure, these patients would have experienced markedly increased survival, with nearly 90% of patients surviving their first year.

The value of moving from *S* to *S'* represents the traditionally measured value of AZT. However, as discussed in section 3.1, the total value of AZT should also reflect the fact that patients who received AZT had an increased probability of surviving long enough to receive more effective therapies such as HAART. The total value of AZT can be

explained through two additional curves shown in Figure 1. The first, S_{1997}, represents the survival for patients diagnosed in 1995 who received no treatment for their disease until the introduction of HAART in 1997. This curve mirrors the no treatment curve for the first two years and then diverges, reflecting the higher survival prospect these patients faced after 1997. S'_{1997} is similar, except that it represents the survival of patients who initially received AZT for two years, followed by HAART. We consider two ways of measuring the total value of AZT. The first is simply the value of moving from S_{1997} to S'_{1997} , which captures the full survival improvement from AZT, assuming those who started with no treatment *were* healthy enough to benefit from HAART. Hence, this reflects the increase in the probability patients would survive long enough to receive HAART. The second is the value of moving from S to S'_{1997}, which is the total survival improvement from HAART assuming that those not on AZT *were not* healthy enough to benefit from HAART when it occurred. . Figure 1 shows that in either case, the total value of AZT is large, given the vast survival improvement in moving from S_{1997} to S'_{1997} and S to S'_{1997}.Since AIDS is rapidly fatal in the absence of treatment, the short term survival benefit from AZT was extremely valuable for patients diagnosed in this cohort of 1995, as it markedly increased the probability that they would survive to receive HAART.

In the Appendix, we explain how we estimated these survival functions and how we calibrated the willingness to pay for the option value of care. Using these estimates, Table 2 shows the estimated life expectancy for each year under alternative treatment regimens. Our estimates suggest that AZT alone raised life expectancy for AIDS patients from 3.6 to 4.4 years, which is in line with prior estimates suggesting that AZT increased life expectancy anywhere from a few months to 1.6 years (Lemp et al. 1990; Moore et al. 1991; Vella et al. 1992). For HIV patients who progressed into AIDS between 1988 and 1994, our results show that receiving AZT followed by HAART increased life expectancy by slightly less than a year compared to receiving no treatment followed by HAART. However, for AIDS patients whose disease developed in 1995 or 1996, receiving AZT followed by HAART nearly doubled life expectancy relative to receiving no treatment followed by HAART. These results are line with the basic finding that AZT primarily impacts survival in the first two years of the disease(discussed in the Appendix). It is also useful to note that between 1995 and 1996, life expectancy for patients receiving no treatment followed by HAART (S_{1997}) increased by roughly 1.75 years, while life expectancy for patients receiving AZT+HAART increased by slightly less than 0.1 year. The reason for this, as explained in detail in the Appendix, is because in the first two years of disease, the difference between receiving no treatment and AZT is much greater than the difference between AZT and HAART.

Table 1 – Life expectancy for AIDS patients under alternative treatment scenarios, 1988-1996

	LIFE EXPECTANCY (YEARS)			
Year	No Drug (S)	AZT Only	No Drug+ HAART	AZT + HAART

		(S')	(S_{1997})	(S'_{1997})
1988	3.59	4.43	4.46	5.30
1989	3.59	4.43	4.66	5.50
1990	3.59	4.43	4.87	5.71
1991	3.59	4.43	5.09	5.93
1992	3.59	4.43	5.32	6.16
1993	3.59	4.43	5.32	6.16
1994	3.59	4.43	5.33	6.16
1995	3.59	4.43	5.97	13.09
1996	3.59	4.43	7.76	13.17

The calibrated willingness to pay for AZT and the option value of AZT is presented on a per-capita basis in Table 2. As shown in table 3A, we estimate the value of moving from no treatment (*S*) to AZT only (*S'*) to be worth $212,595 on a lifetime basis, which represents the traditional value of AZT. However, the full value of AZT must reflect the fact that the drug helped patients survive to the introduction of more definitive therapies such as HAART (moving from S_{1997} to S'_{1997}). As shown in Table 2, we find that differences between the traditional and full value are small for patients diagnosed between 1988 and 1994, which is not surprising, given the slight differences in life expectancy for these two groups, as seen in Table 1. However, for patients diagnosed in 1995 and 1996, we find that the full value is roughly four times larger than the traditional value. The option value is particularly large for these two cohorts because AZT has its largest effects on survival in the first two years post-disease. Therefore, for these two cohorts, it greatly increased the probability that these patients would survive long enough to receive HAART. Intriguingly, the full value of AZT fell slightly between 1995 to 1996, from $912,082 to $836,370. Since the full value of AZT represent movement from S_{1997} to S'_{1997}, whether the full value increases from year to year depends on the relative change in S_{1997} versus the change in S'_{1997}. As previously discussed, between 1995 and 1996, life expectancy with no treatment plus HAART increased far more than life expectancy with AZT plus HAART (Table 1). This large increase in S_{1997}coupled with a modest gain in S'_{1997}, is why the full value of AZT falls slightly between 1995 and 1996.

Table 2: Willingness to Pay for AZT: Per-Capita Values by Cohort

YEAR	WTP ($)		
	Standard Value of AZT *S* vs *S'*	Full value of AZT S_{1997} vs S'_{1997}	Full Value of AZT S vs S'_{1997}
1988	$212,595	$219,284 (103%)	$307,330 (145%)
1989	$212,595	$220,774 (104%)	$328,613 (155%)

1990	$212,595	$222,293 (105%)	$350,540 (165%)
1991	$212,595	$223,821 (105%)	$372,892 (175%)
1992	$212,595	$225,364 (106%)	$395,845 (186%)
1993	$212,595	$225,385 (106%)	$396,160 (186%)
1994	$212,595	$225,408 (106%)	$396,507 (187%)
1995	$212,595	$912,082 (430%)	$972,960 (458%)
1996	$212,595	$836,370 (393%)	$996,225 (469%)
Notes: Values shown are lifetime values, representing the present discounted sum of annual willingness to pay, assuming a full income of $100,000 per year. Percentages shown in parentheses are the ratio of full value to traditional value.			

The last column in Table 2 also shows the full value of AZT assuming that patients must receive it in order to benefit from HAART. This option value is determined by the value of moving from no treatment at all to AZT followed by HAART (S vs S'_{1997}). Given the poor survival prospects facing patients who receive no treatment at all, it is not surprising that under this method, the full value of AZT is much larger than the traditional value, increasing from 145% of the traditional value in 1988 to 469% in 1996. By contrast with the previous method of calculating full value, under this method, the full value is monotonically increasing. This is because changes in the full value of AZT are driven by changes in S, which is constant, versus changes in S'_{1997}, which is increasing.

In the Appendix, we also compute the traditional and option values of AZT on an aggregate basis, by multiplying the per-capita values shown in Table 2 above by yearly estimates of AIDS incidence. We find that the aggregate traditional value of AZT to be $111 billion, compared to an aggregate full value of AZT to be $211 billion using the movement from S_{1997} to S'_{1997} or $283 billion using the movement from S to S'_{1997}. In other words, aggregating across all cohorts, the full value of AZT is either 189 percent or 255 percent of the traditionally calculated value of AZT (depending on which of the two definitions of the full value of the drug.)

Section 8: Concluding Remarks

Though the high spending on medical care at the end of life often encounters skepticism from payers and policy makers, few explanations have been offered as to its benefits and why it persists and is rising. We analyzed the incentives fueling spending levels on terminal care that are larger than the existing theoretical and empirical analysis of the value of life suggests. We stressed the low opportunity cost of spending near death, the importance of hope, the social value of a life, as well as why frailty does not diminish the

value of a life. We found that incorporating the value of hope for future innovation, in the case of HIV, raised valuations up to four times above standard valuations of marginal treatments.

Our claim that the value of life may be much higher near its end than traditionally argued of course needs more careful empirical examination in future research. There are some existing estimates suggesting that the value of life near its end may be relatively high. Peter Neumann and colleagues (2006) have found that new oncology treatments at the end of life are valued at about $300 thousand per life year, nearly three times the most commonly cited values of a life year of $100 thousand. Moreover, the rapid uptake of new and expensive end-of-life treatments by patients suggests that they are highly valued. Goldman et al (2007) provides evidence on the elasticity of the demand for specialty drugs as a function of the co-pays of patients. They find that the demand for specialty drugs and end-of-life biologics is less elastic to co-pays than other drugs. This may not only explain the high prices charged by patent monopolies but also may have important implications for the gross consumer surplus generated by these treatments.

Although our analysis was mainly positive, it has important normative implications as well. In particular, it has strong implications for using traditional methods of cost-effectiveness, cost-utility, or cost-benefit criteria when making coverage decisions at private and public health plans[14]. CE analysis has been the major method proposed to evaluate new medical inventions and has been argued to be central in managing new technologies, their adoption, and their impact on health care spending. Such valuation schemes are often *linear* valuation methods, which contrasts with our claim that there is an important non-linearity in the valuation of life.

Also, much more analysis is needed on the optimal life-cycle behavior with respect to insuring terminal care as it occur ex-post and how it is insured ex-ante. The fact that so many bankruptcies occurs surrounding life-threatening disease indicates that many people are willing to spend down their wealth. However, if more fully insured this wealth may have been better enjoyed in a healthy state prior to the sickness. The commitment devices that currently exist, such as e.g. advance directives, needs to be analyzed in conjunction with such insurance. The unexpected nature of life-threatening disease needs to be better incorporated into future analysis.

In addition, for purposes of insurance coverage, it is important to learn more about the elasticity of demand for terminal care in as much as it induces optimal benefit design. The basic argument is that there is a tradeoff between risk-sharing (which favors no co-pays) and appropriate incentives (which favors cost-based co pays) in providing insurance that effects medical care use (Mark V, Pauly 1968; Richard Zeckhauser 1970;). This logic implies that if the estimates suggesting an inelastic demand for specialty drugs or biologics generalize to other forms of terminal care, terminal care should be highly

[14] The literature is vast, but for examples, see Weinstein and Stason (1977), Johanneson and Weinstein (1993), Gold et al. (1996), Drummond et al. (1997), Garber and Phelps (1997), Garber (2000), and Cutler (2005).

insured. The common argument that insured terminal care is wasted on people going to their grave may ignore that the demand for this type of care is very inelastic and, hence, should be insured.

To conclude, the general argument we make is that existing theoretical and empirical analysis of the value of life do not apply, and often understates the value of terminal care and life near its end. The different incentives that are present when fighting life-threatening diseases are not well-understood, and deserve much more attention by economists. This is particularly pressing given the large shares of GDPs across countries that are used up in this fight.

APPENDIX

This appendix explains how the survival curves were computed and the calibration performed for the calculation of the optional value of AZT in section 7.

A.1 Estimating AIDS survival curves under alternative therapy regimens

To estimate the option value of AZT, one would ideally want survival curves that cover the entire life spans of AIDS patients under the various combinations of antiretroviral therapies needed to estimate the survival curves described above. However, there are several obstacles. First, most clinical trials and observational data do not follow patients for more than 2, and only sometimes 5, years so it is necessary to extrapolate long term survival probabilities. Moreover, since AZT was available in 1988 and HAART was available in 1997, to varying extents, some of the curves of interest are counter-factual. For example, it is difficult to estimate S_{1997} , the survival of patients who received no therapy for a period of time followed by HAART therapy, based on the direct experience of AIDS patients, because there are very few patients who received no treatment for their disease, followed by HAART. Therefore, it is necessary to find some way to use observed AIDS survival data to construct survival curves under the each of the therapy scenarios outlined above.

As a starting point, our analysis begins with the AIDS survival curves by year of infection estimated by Philipson and Jena (2006)[15] for each year between 1979 and 2000. We then combine these curves to obtain the survival curves of interest as follows. Since AZT was introduced in 1988 and the data from Philipson and Jena (2006) suggest that less than 15% of AIDS patients diagnosed in 1979 survived at least 9 years, we used the survival of 1979 AIDS patients to estimate *S*, the survival curve for AIDS patients who received no therapy. Since HAART was introduced in 1997, we used the survival curves for patient diagnosed in 1997 to estimate S^C , the survival of patients who received HAART from the onset of their disease.

To estimate $S^{'}$, the survival for patients who received AZT only, we used the medical literature on the randomized clinical trials effects of AZT (Swanson et al., 1989; Lemp et al., 1990; Moore et al., 1991; Vella et al., 1992; Lundgren et al., 1994). These studies primarily examined the effect of AZT on the probability that AIDS patients survived to 2 years following their disease. Across these studies, AZT increased the probability of surviving to one year by 180% and the probability of surviving to two years by 275%. We therefore assumed that AZT increased the probability of surviving one year and two years by 180% and 275% respectively, compared to no treatment, but we assumed that AZT had no effect on survival to three years and beyond. We made this assumption for two reasons. First is that it provides an extremely conservative lower bound on the effect of AZT. Second, this assumption is in line with the literature, as Lundgren et al. (1994)

[15] We adopt these estimated survival curves because they avoid problems intrinsic to extrapolating parametric models such as exponential, Weibull, or Gompertz. (See Appendix of Philipson and Jena (2006))

find that AZT increased survival for the first two years relative to no treatment, but that patient receiving AZT actually experienced lower survival probabilities in subsequent years, so that the probability of surviving to five years was similar for both groups.

Table A1 shows survival probabilities for patients receiving no treatment $\left(s_j\right)$, AZT $\left(s_j^{'}\right)$, or HAART $\left(s_j^{c}\right)$.[16] The probabilities shown are the probability of surviving to the *j* years post disease, conditional on having survived *j-1* years. As previously discussed, the diagnosis of AIDS carried a particularly grim prognosis, as the probability of surviving the first year for patients receiving no treatment is 47%. AZT increases the yearly probability of surviving in the first and second years to 84% and 93% respectively. As stated earlier, we assumed that AZT only impacted overall survival probabilities for the first two years. Not surprisingly then, the conditional probability for surviving to the third year is lower for AZT patients relative to patients who received no treatment, and the conditional probabilities are the same for both groups in each year thereafter.

The introduction of HAART dramatically increased survival, as 90% of HAART patients survived their first year with the disease. Table A1 shows that HAART is clearly superior to receiving no treatment, as the one year survival probabilities with HAART dominate the survival probabilities with no treatment at all years shown. It is useful to note that the one year probabilities with no treatment at years three onwards (ranging from 81%-97%) are close to the HAART probabilities (95-97%), again based on the clinical literature reporting clinical trial effects. However, as discussed in equation (10), overall survival probabilities represent the product of the one year probabilities shown in Table A1. Therefore, while patients receiving no treatment have similar survival probabilities in year 3 and onwards compared to patients receiving HAART, their low survival prospects overall are driven by the extremely unfavorable probabilities of surviving in years 1 and 2. Similarly, the year 1 and 2 conditional survival probabilities under AZT (84% and 93% respectively) are similar to year 1 and 2 probabilities under HAART equivalents (90% and 95%) . The year 3 probability for AZT patients is 32% however, compared to 95% for HAART, so that overall survival probabilities for AZT patients will be markedly lower than for HAART patients after this time.

Table A1: Survival for patients receiving no treatment, AZT, and HAART

YEAR POST HIV INFECTION (j)	NO TREATMENT $\left(s_j\right)$	AZT $\left(s_j^{'}\right)$	HAART $\left(s_j^{c}\right)$
1	47%	84%	90%
2	67%	93%	95%
3	81%	32%	95%
4	97%	97%	97%
5	97%	97%	97%
6	89%	89%	97%
7	88%	88%	96%

[16] The table shows survival up to 10 years post disease, complete tables showing additional years are available from the authors on request.

8	86%	86%	96%
9	84%	84%	96%
10	82%	82%	96%

For each year between 1988 and 1997, we then calculated the survival curves for patients receiving no treatment or AZT, followed by HAART, using the definition of $S_a(t)$ with a=1997 from section 3.1. To illustrate this method, consider the case of patients who were diagnosed with the disease in 1995 and who received no treatment until the introduction of the drug in 1997. Since they receive no treatment for the first two years, their one year survival probabilities during this time frame are given by s_j in Table A1. For year 2 post disease and onwards, their one survival probabilities then switch to s_j^c as shown in Table A1. Similarly, for patients diagnosed in 1995 who received AZT followed by HAART, their one year survival probabilities are given by $s_j^{'}$ for the first two years, followed by s_j^c for the remaining years. The overall probabilities of surviving to a given year are then calculated by the appropriate product of the one year survival probabilities, as defined for $S_a(t)$in section 3.1. We repeated this method for each year between 1988 and 1997 to obtain counterfactual survival curves for patients diagnosed in these years who received no treatment or AZT until the introduction of HAART in 1997.

A.2 Calibrating the Willingness to Pay for Option Value

To calibrate the willingness to pay for survival improvements, consider when patients have an indirect utility function over annual income *y* and survival *S* given by *V(S,y)*. The annual willingness to pay for improved survival is the value of *v* which satisfies

$V(S,y)=V(S',y-v)$

Following Becker, Philipson, and Soares (2005), we assume that the instantaneous utility function adopts the following form:

$$u(c) = \frac{c^{1-(1/\gamma)}}{1-(1/\gamma)} + \alpha$$

The parameter α is a normalization factor that determines the level of consumption at which the individual would be indifferent between being alive or dead (at which point utility equals zero), and γ is the inter-temporal elasticity of substitution assumed at γ = 1.25 and α = -14.97.[17] The lifetime indirect utility for an individual is given by:

$V(S,y) = u(y)A(S)$

where *A(S)* is the value of an annuity that pays $1 in perpetuity under a given survival curve. Given these expressions, it is straightforward to show that the annualized value of survival improvements is given by

$$v = y - \left[\left(\frac{1}{1-\gamma}\right)\left(\frac{A(S)}{A(S')}\cdot u(y) - \alpha\right)\right]^{\gamma/(\gamma-1)}$$

This value v represents the annual willingness to pay for survival improvements; the lifetime willingness to pay is simply the present value of this annuitized $A(s)v$. In our

[17] For further justification of these parameter assumptions, see Becker, Philipson, and Soares (2005).

calculations, we assume an annual income of y=$100,000 to match a common level used in the value of a life year used in the literature.

A.3 Aggregating Per-Capita values over Cohorts

Using the AIDS incidence numbers discussed in Philipson and Jena (2006), the aggregate values of AZT by cohort and aggregated across all cohorts are reported in the table below. The full value of AZT is computed both in $Billions and as percent of standard value.

Table A2: Willingness to Pay for AZT: Aggregate Values

Year	AIDS Incidence	Standard Value of AZT $Billions	Full Value of AZT $Billions (% of Standard)	
		S vs S'	S_{1997} vs S'_{1997}	S vs S'_{1997}
1988	29,134	6.19	6.39 (103%)	8.95 (145%)
1989	36,146	7.68	7.98 (104%)	11.9 (155%)
1990	43,541	9.26	9.68 (105%)	15.3 (165%)
1991	49,629	10.6	11.1 (105%)	18.5 (175%)
1992	60,638	12.9	13.7 (106%)	24.0 (186%)
1993	79,754	17.0	18.0 (106%)	31.6 (186%)
1994	79,965	17.0	18.0 (106%)	31.7 (187%)
1995	73,569	15.6	67.1 (430%)	71.6 (458%)
1996	70,056	14.9	58.6 (393%)	69.8 (469%)
Total	522,432	111	211 (189%)	283 (255%)

Notes: Values shown are aggregate values, given by multiplying the per-capita values shown in table 2 by the annual incidence. Percentages shown in parentheses are the ratio of full value to traditional value.

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