COMBINING LIFE AND HEALTH INSURANCE*

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We estimate the benefit of life-extending medical treatments to life insurance companies. Our main insight is that life insurance companies have a direct benefit from such treatments because they lower the insurer's liabilities by pushing the death benefit further into the future and raising future premium income. We apply this insight to immunotherapy, treatments associated with durable gains in survival rates for a growing number of cancer patients. We estimate that the life insurance sector's aggregate benefit from FDA-approved immunotherapies is $9.8 billion a year. Such life-extending treatments are often prohibitively expensive for patients and governments alike. Exploiting this value creation, we explore various ways life insurers could improve stress-free access to treatment. We discuss potential barriers to integration and the long-run implications for the industrial organization of life and health insurance markets, as well as the broader implications for medical innovation and long-term care insurance markets. *JEL* Codes: G22, I13, I31.

I. INTRODUCTION

Rapid medical advances over the past two decades have produced new treatments that result in significant and durable improvements in survival for patients with cancer, hepatitis C, AIDS, and severe heart failure, among other diseases. A major drawback, however, is that many of the new life-extending treatments are expensive.

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Existing solutions to finance life-extending treatments have important shortcomings. First, health insurance plans typically come with copays to limit moral hazard (Zeckhauser 1970). Patients may not be able to afford the copay for the drugs in addition to the cost of medical insurance.[1] For those able to afford the copays, it often comes with significant financial stress that may negatively affect health outcomes.[2] When health care is tied to employment, as is typical in the United States, job loss exposes patients to reclassification risk (Cochrane 1995). For those without employer-provided health insurance, the out-of-pocket cost for treatment under the Affordable Care Act (ACA) often exceeds 30% of pretax income.[3] Facing ever tighter budgets and mounting debt, governments cannot afford the cost of the drugs minus the copay. Second, credit-based solutions have been discussed in the literature (Montazerhodjat, Weinstock, and Lo 2016). But households cannot pledge their future labor income and may default on loans received for medical treatment. Higher earnings uncertainty after treatment further reduces borrowing capacity.

Our main insight is that life insurers experience large benefits from life-extending treatments. We apply this insight to cancer and quantify the benefits from immunotherapy. In the United States, there were 1.6 million new cancer cases and 600,000 cancer deaths in 2017. Over the past decade, exciting breakthroughs in the field of immuno-oncology, and targeted cancer

1. Gupta et al. (2015) find that cancer diagnoses increase default and foreclosure rates, in part due to incomplete insurance coverage. Davidoff et al. (2013) find that the average out-of-pocket expenditure for Medicare beneficiaries with cancer equals $4,727 using data from 1997 to 2007. Many pharmaceutical companies have financial assistance programs that help patients pay for copays. However, such programs are currently under investigation by the U.S. Department of Justice for their involvement in the cases of Medicare patients. Pharmaceutical companies have settled for hundreds of millions of dollars in recent months. Such programs are expected to be smaller in the future (Rockoff 2017).

2. See Zafar et al. (2013) for a discussion of "financial toxicity" in the context of cancer care. Further background information can be found on the website of the National Cancer Institute, https://www.cancer.gov/about-cancer/managing-care/track-care-costs/financial-toxicity-pdq#_AboutThis_1.

3. For example, the Silver plan under the ACA provides health insurance that costs $5,500 a year in premiums in 2018 for a family of four with two children and earning the average U.S. household income of $65,000 a year. The maximum out-of-pocket costs are $14,700. The combined $20,200 amounts to 31% of pretax income. For a household earning $100,000, the insurance premiums are $18,300, and the total cost at the maximum out-of-pocket level are $33,000 or 33% of pretax income.

treatments more broadly, have resulted in significant gains in long-term survival.[4] However, the cost of immunotherapy is often extremely high. The combination of Yervoy (ipilimumab) and Opdivo (nivolumab), state-of-the-art treatment for melanoma, costs $149,011 for a standard 12-week course. The cost of the CAR-T cell therapy Kymriah is $475,000.

In the status quo, we face a future where life-saving treatments are effectively unavailable for a large segment of the population. The conundrum will only get worse as (i) the world population ages and with it the incidence of cancer increases; (ii) immunotherapies become more effective, approved for more cancer sites and increasingly as a first-line therapy, and are applied at earlier stages of the disease; and (iii) the fiscal position of governments all over the world worsens.

An example illustrates our basic insight and the role that life insurers can play. Consider an individual who purchases a life policy at age 30 and is diagnosed with stage 4 melanoma at age 40. Due to the reduced life expectancy and the concomitant reduction in premium payments, the policy now has a value of −$0.95 to the insurer per dollar of death benefit compared to −$0.08 before the diagnosis. Our estimates, based on clinical studies, imply that immunotherapy is successful with a 50% probability in case of stage 4 melanoma. The expected gain in survival raises the value of the life insurance contract to the insurer to −$0.51. The insurer's benefit from immunotherapy is therefore $0.44 per dollar of face value. A policy with a death benefit of $339,000 would generate a benefit that is the same as the entire $149,011 cost of the Yervoy plus Opdivo treatment. A patient would typically face "only" the copay and maximum out-of-pocket costs, about $20,000 for the

4. Immunotherapy refers to a set of treatments that stimulate the body's immune system to attack cancer cells. The American Cancer Society distinguishes between five categories of immunotherapies: (i) monoclonal antibodies, (ii) immune checkpoint inhibitors, (iii) adoptive cell therapies, (iv) cancer vaccines, and (v) cytokines. Over the past five years, the largest number of new drugs were immune checkpoint inhibitors. PD-1/PD-L1 and CTLA-4 are examples of checkpoint proteins that sit on the surface of the cancer cells and tell the T-cells to leave the cancer alone. Immune checkpoint modulators interrupt this signal and unmask the cancer so T-cells recognize it and activate. The 2018 Nobel Prize in Medicine was awarded to immunotherapy researchers who discovered the checkpoint inhibitors. Unlike traditional cytotoxic chemotherapies and radiation, immunotherapies are fairly well tolerated and leave the healthy cells unscathed. They can be repeated, resulting in a more durable response.

typical family covered by the ACA. A life insurance policy with a face value as small as $46,000 generates a benefit of $20,000 to the life insurer, enough to cover the out-of-pocket costs. Most of the $0.44 gain comes from a face value effect: the new therapy (partially) restores life expectancy and pushes the payment of the death benefit back into the future. The remainder comes from a premium effect: by living longer, the insuree will pay more premiums.

Several key parameters determine the benefit to life insurers of a patient diagnosed with a life-threatening disease: the increase in survival probability resulting from treatment, patient demographics, age of diagnosis, and the life insurance premium. Section II provides a model with these ingredients. We apply the model to the case of immunotherapy in Section IV. We provide detailed calculations for the case of metastatic melanoma. Various robustness checks show that the benefit to the life insurer is nearly invariant to interest rates, insurer markups, and lapsation rates (which may in part be driven by job mobility in the case of group life policies), and is proportional to the effectiveness of the treatment. Lapsation is priced into the life insurance contract, with higher lapsation resulting in a lower premium. The losses in case of an unexpected diagnosis are higher with higher lapsation; the face value effect strengthens. The premium effect weakens, leaving the overall benefit nearly unaffected.

We compile evidence that suggests similar benefits for 23 cancer sites and staging with FDA-approved immunotherapies and we compute the aggregate benefit. The aggregate benefit depends crucially on life insurance participation and coverage rates. Importantly, many households have life insurance policies. Among all financial instruments (stocks, bonds, annuities, etc.), life insurance enjoys the highest participation rate in the United States, with 68% of men between age 35 and 54 having life insurance and 63% of women in 2016.[5] The average death benefit for individuals between 35 and 44 years of age is $240,937, far exceeding the minimum necessary benefit of $46,000 in the above example. Our calculations suggest that life insurers' aggregate benefit is $9.8 billion a year, given the incidence of cancer for which immunotherapies are currently available and approved by the FDA.

5. Likewise, Koijen, Van Nieuwerburgh, and Yogo (2016) find life insurance participation rates in the Health and Retirement Study of 70% for term life policies and 35% for whole life policies for households with a head aged 51 to 64.

The total cost of immunotherapy drugs for consumers with life insurance is $12.6 billion, and we estimate patients' aggregate copay to be $4.8 billion. The large benefit to life insurers relative to these two cost measures underscores the potential funding that can be unlocked.

We discuss various ways life insurers can ensure that policy holders have stress-free access to life-extending treatments. Although it will typically not be optimal for life insurers to pay for policy holders who can finance the treatments themselves, they could (i) allow policy holders to borrow against the value of their policy at actuarially fair rates or (ii) pay for their treatment and reduce the policy's death benefit accordingly. These solutions could be offered at no cost to the insurer. The first mechanism introduces a frictionless credit market for life-extending treatments, whereas the second mechanism is akin to an efficient life-settlement market. There exists a life settlement market on which investors buy policies from sick policy holders, but often at deep discounts (Daily, Hendel, and Lizzeri 2008; Fang and Kung 2017; Sachdeva 2017). Traditional life settlements suffer from the additional drawback that the buyer of the policy has a financial incentive for the patient to die as soon as possible, a misalignment of incentives.[6] In our solution, the incentives of the life insurer and the patient remain perfectly aligned. Regardless of the precise mechanism, there would be enormous gains in reputation for life insurance companies from saving lives.

Our calculations suggest the benefit of combining life insurance with health insurance for life-extending treatments, which we explore in Section V. Life insurance would become a more valuable product to consumers because it would pay for life-enhancing medical treatment. Widespread adoption of this funding model would increase life expectancy in the population, which would lower the cost of life insurance. The life insurance market would grow for all these reasons. A virtuous circle of more life insurance premium revenue, higher life insurance participation rates and coverage, and more payments for treatment would result. A larger drug market would stimulate further development of life-extending treatments, accelerating the virtuous circle.

6. Indeed, the life settlements industry became financially distressed when new life-extending drugs came on the market, after the industry had bought life insurance policies from HIV/AIDS patients in the late 1980s and early 1990s.

Our analysis naturally prompts two questions. First, why might it be optimal for life insurers to cover some of the life-extending medical treatments, when they are not fully covered by health insurers? Second, if the gains from combining life and health insurance are substantial, why do we not see this in the industry already?

To address the first question, we discuss key economic differences between life insurers and traditional health insurers in Section III. First, health insurers cannot condition on preexisting conditions due to the ACA. Life insurers, by contrast, are not subject to this same requirement and it is common practice to medically examine policy holders before underwriting a life insurance policy. Second, health insurance covers treatments that improve both the quantity (that is, life expectancy) and quality (that is, overall well-being) of life. Life insurers care only about insuring the quantity of life. This implies that health and life insurers face different cost-benefit trade-offs. We discuss other institutional and behavioral frictions that may differentially affect coverage decisions of health and life insurers.

Next we explore potential barriers to integration of health and life insurers. This discussion is supported by a survey we conducted among 23 senior executives of the life and health insurance industries. First, because life and health insurance has historically been sold separately, these lines of business developed independently in insurance companies and there are substantial operational frictions to integrate them. This may delay innovation. Second, life and health insurers have historically been subject to different regulatory frameworks, and it is unclear how an integrated product would be regulated and whether life insurers would be able to condition on a policy holder's health status. In addition, there are consumer financial protection issues if policy holders do not fully understand the new combination product. Third, there is uncertainty about the response of health insurers, in terms of legal risk and future coverage decisions. Despite these hurdles, and the fact that many of these treatments are relatively recent, we provide initial evidence that the industry is innovating in the direction outlined in this article via accelerated death benefits and critical illness insurance. We discuss how these products can be modified to improve access to life-extending treatments in Section V.

Section VI concludes with the broader implications for the adoption of life-extending technologies, long-term care insurance, and the incentives for medical innovation.

II. The Benefits to Life Insurers of Life-Extending Treatments

We consider an individual who has a life insurance policy with a life insurance company and a health insurance policy with a health insurance company. The health and life insurance companies operate independently. For reasons discussed in detail in Section III, we assume that the health insurer's optimal coverage rate $c^\star < 1$. Consequently, the health insurer does not fully reimburse the cost of life-extending treatments.

We assume that a life insurance policy has been purchased before the life-extending treatment is discovered. We discuss the long-run implications for life insurance markets in Section V and medical innovation in Section VI. The current value of a life insurance contract bought at age x_0 that pays a death benefit F upon death and collects a premium $\pi(\cdot)$ while alive is given by:

$$L(x, \pi, \mu) = \pi(x_0) \int_0^\tau \exp(-(r+k)s)_s p_x ds - F \int_0^\tau \exp(-(r+k)s)_s p_x \mu(x+s) ds, \tag{1}$$

where x is the policy holder's current age, r is the interest rate, $\mu(x)$ the instantaneous mortality rate at age x, ${}_sp_x$ the probability that an individual of age x survives for another s periods, k the rate of lapsation, and τ the residual maturity of the life insurance policy. Whole life insurance policies correspond to $\tau = \infty$ (large τ). The first term is the discounted value of the premium payments, the second term the discounted value of the death benefit. This policy is underwritten when the individual is in normal health, typically following a medical exam. An actuarially fair policy sets the premium $\pi(x_0)$ such that the policy has 0 value at origination: $L(x_0, \pi(x_0), \mu) = 0$. A policy offers an expected profit to the insurer if $L(x_0, \pi(x_0), \mu) > 0$.

If, at a later date ($x > x_0$), the individual is diagnosed with a disease (D) that reduces longevity, the mortality rate jumps from $\mu(x)$ to $\mu^D(x)$, where $\mu^D(x) > \mu(x)$. The value of the insurance policy to the insurer decreases to $L(x, \pi, \mu^D)$. This decrease stems from

a reduction in expected premium payments (first term) and the closer proximity of the death benefit payout (second term).

Now assume that a life-extending treatment for the disease is available at cost C. This cost could either reflect the out-of-pocket cost to the policy holder, or the entire cost of the treatment (to patient and health insurer). This treatment is successful with probability θ.[7] Conditional on treatment, the value of the life insurance policy increases from $L(x, \pi, \mu^D)$ to $\theta L(x, \pi, \mu) + (1-\theta)L(x, \pi, \mu^D)$.

The life insurer's benefit from a diagnosed policy holder undergoing the life-extending treatment equals

$$\begin{aligned} &\theta L(x,\pi,\mu) + (1-\theta)L(x,\pi,\mu^D) - L(x,\pi,\mu^D) \\ &= \theta\left(L(x,\pi,\mu) - L(x,\pi,\mu^D)\right). \end{aligned} \tag{2}$$

The life insurer's benefit increases in the treatment's effectiveness and in the loss in value due to a loss in life expectancy absent treatment. The benefit to the life insurer, $\theta(L(x, \pi, \mu) - L(x, \pi, \mu^D))$, contains a premium and a face value component:[8]

$$\begin{aligned} &\underbrace{\theta\pi(x_0)\int_0^\tau \exp(-(r+k)s)({}_sp_x - {}_sp_x^D)ds}_{\text{Premium component}} \\ &\underbrace{-\theta F\int_0^\tau \exp(-(r+k)s)({}_sp_x\mu(x+s) - {}_sp_x^D\mu^D(x+s))ds}_{\text{Face value component}}, \end{aligned} \tag{3}$$

where ${}_sp_x^D$ is the survival probability for an individual of age x who is diagnosed with the disease but does not receive the new

7. The assumption that the treatment is successful with some probability is particularly well fitting for immunotherapy. Only a fraction of patients (around 30–50%) responds to the treatment with durable gains in survival and it is typically not possible to determine beforehand who will show positive response. Currently, this idiosyncratic treatment risk is entirely borne by the individual. Standard risk-sharing arguments suggest that patients who recover may be willing to pay more than those who do not. Life insurers (as in our solution), health insurers, or pharmaceutical companies could pool the treatment risk. Such financing arrangements are already available for in vitro fertilization, for example.

8. We assume that the probability of lapsation is independent of an individual's health status. This expression can be generalized easily to allow for health state–dependent lapsation.

treatment. The insurer's benefit in expression (3) is positive because the treatment increases the present value of future premium income, the first term, and reduces the present value of the death benefit, the second term. The premium component is absent in insurance markets in which premiums are prepaid such as annuity markets (Hendel and Lizzeri 2003). The face value component arises because treatment improves survival and pushes the payment of the death benefit farther into the future, compared with the situation without treatment.

III. Incomplete Coverage by Health Insurers

Section IV quantifies the benefits from a particular type of life-saving medical innovation, immunotherapy. But first, we discuss the potential reasons health insurers limit coverage of certain medical treatments, as assumed in the previous section. We argue that these frictions do not (or at least not to the same extent) apply to life insurers. This opens up the possibility for life insurers to get involved in health insurance markets.

In this section, a central observation is that health insurers cover treatments that improve both the quantity and the quality of life. An example of the former is cancer drugs, and examples of the latter include anti-inflammatory drugs and antihistamines. In contrast, life insurers only care about the quantity, not the quality, of life. Life insurers can therefore cover a subset of treatments, while health insurers are restricted to offer a bundle of treatments.

III.A. Preexisting Conditions

Under the 2010 ACA, health insurers cannot discriminate based on preexisting conditions. They must offer insurance to both good and bad health risks. In response, health insurers may decide to offer high-deductible plans to discourage the sick from enrolling (Rothschild and Stiglitz 1976). In the United States, where the majority of health insurance is employer sponsored,[9]

9. According to the latest Census Bureau data for 2016, employment-sponsored health insurance covered 56% of the U.S. population, more than any other type of health insurance. Medicaid covers 19%, Medicare 17%, direct purchase 16%, and military 4.5%; 9% of the population was uninsured. These numbers do not add up to 100% because people who switch insurance types during the year are double counted.

benefit managers may have similar incentives to attract healthy employees. The high deductibles leave gaps in coverage. Handel, Hendel, and Whinston (2015) estimate an insurance equilibrium model to study the trade-off between adverse selection and reclassification risk. When health insurers cannot condition on health status, they find that only a pooling equilibrium is sustainable with high deductibles for all consumers.

Life insurers are allowed to, and do, condition their prices on a policy holder's health status at the moment of underwriting. Medical exams are a standard underwriting tool and the norm for larger policies. Life insurers are allowed to price discriminate against a diabetes or cancer patient who wants to buy life insurance or even deny coverage.

As a result of the exemption from the preexisting condition regulation, life insurers can offer a "quantity of life" insurance contract for the coverage gaps left by health insurance, and they can do so at marginal cost.[10]

III.B. Covering Off-Label and Innovative Treatments

Certain expensive but life-saving treatments are not reimbursed by health insurance. Although no comprehensive data are available on coverage of employer-sponsored insurance, public insurance (Medicare and Medicaid) does not cover certain treatments. For example, off-label use of chemotherapy drugs that are not supported by the National Comprehensive Cancer Network's drugs and biologics compendium is prevalent (16% of chemotherapy spending) and not reimbursed by Medicare and Medicaid.[11] Because many diagnoses occur later in life, with the median age of a cancer diagnosis being 65, public insurance coverage is relevant.

10. Because life insurance contracts tend to be long-term contracts with premiums set up front and constant over the life of the contract, there is no reclassification risk.

11. Conti et al. (2013) studies 10 of the most commonly prescribed anticancer drugs in 2010. The paper finds that 70% of use ($7.3 billion out of a total $12 billion) is "on-label," meaning that the cancer site, stage, and therapy line met the FDA-approved indication. The remaining 30% is "off-label" use, split into 14% ($2 billion) that conformed to National Comprehensive Care Network (NCCN) compendium recommendations, a basis of insurer coverage policies, and 16% ($2.5 billion) that is NCCN-unsupported and not reimbursed. Off-label drug use is common in cancer treatment because clinical research shows that combination chemotherapy is effective in treatment, and the FDA typically does not approve combinations of chemotherapy (National Cancer Institute website).

Also, younger individuals may lose employer-sponsored health insurance if the disease results in job loss, which forces them to go onto publicly provided disability insurance.

Life insurers face a different cost-benefit trade-off for two reasons. First, as discussed already, life insurers only focus on care that improves the quantity of life, while health insurers are required to cover quality and quantity of life. Second, assuming that both health and life insurers act cautiously when faced with uncertainty about the efficacy of a treatment, their trade-off will be different. If the treatment does not work, life insurers will need to pay the death benefit and lose future premium income. Health insurers, by contrast, face no further cost. However, if the treatment is successful, life insurers will face no further cost,[12] or at least not any time soon, while health insurers are likely to face additional costs associated with the quality of life care. Hence, for a cautious health insurer, it may be optimal to decline an experimental treatment, whereas for a cautious life insurer it is optimal to grant access.

III.C. Neglected Risks

An additional reason that demand for health insurance with better coverage for expensive and life-saving treatments may be low is that households underestimate the probability of a major illness that necessitates such treatment or the costs associated with such treatment. Survey evidence indicates that households have difficulty assessing low-probability events (Gennaioli, Shleifer, and Vishny 2015) and that they are often surprised by the cost of health care.[13] Of course, the same friction would generate

12. This is particularly clear for term life insurance, where the life insurer would not need to pay a death benefit if the policy expires while the consumer is still alive due to the treatment.

13. A 2017 survey by HSA bank found that two-thirds of respondents expect to need less than $100,000 for health expenses in retirement, an amount far below average realized outlays. A 2015 survey by the Harvard Chan School of Public Health found that 26% of respondents claimed medical bills caused severe damage to their household's bottom line, and 55% of respondents in a 2017 Amino survey claimed they had at least once received a medical bill they could not afford. Chino et al. (2017) found that 39% of cancer patients report higher than expected financial burden from cancer care. Experiencing higher than expected financial burden from cancer care is associated with high or overwhelming financial distress and with decreased willingness to pay for cancer care.

low demand for critical illness insurance, insurance that provides a payout when a major illness strikes.

Because life insurance combined with critical illness insurance for major illnesses for which an expensive and life-saving treatment exists can be offered at the same cost, or even lower costs, than stand-alone life insurance, there is a potential to overcome risk neglect through product design. The combination product is a form of automatic enrollment, an idea with a proven track record in the realm of consumer finance (e.g., Carroll et al. 2009). But why would households buy life insurance? The awareness problem of caring for one's family is much less severe and there is no evidence that households underestimate the overall risk of death. In fact, subjective beliefs about 10-year survival rates are remarkably accurate (Khwaja, Sloan, and Chung 2007).[14]

III.D. Moral Hazard and the Bundling of Quality and Quantity of Life

Moral hazard necessitates copays and larger copays for treatments where moral hazard is more severe. Even in the case of cancer, there may be a therapy that is FDA approved but for a specific patient has a very limited probability of success. If an insurer covers the treatment, the patient and her doctor may decide to try the treatment despite the limited probability of success.

Because health insurance bundles coverage for quality and quantity of life medical care, copays (including out-of-pocket maximums) cannot be set perfectly to capture each patient's demand for quality and quantity of care. While moral hazard with respect to quantity of life treatments is the same for the life insurer as for the health insurer, unbundling allows life insurers to offer a more attractive contract to people with a strong preference for quantity of life if moral hazard is stronger for quality than for quantity of life treatments. Although this condition seems plausibly satisfied, we are not aware of research that has convincingly established larger moral hazard for quality than quantity of life treatments, so we raise this as only a possibility.

14. For a recent review of behavioral economics in health care markets, see Chandra, Handel, and Schwartzstein (2019).

IV. Quantifying Life Insurers' Benefits from Immunotherapy

We now apply the framework of Section II to the case of immunotherapy. The large benefits to life insurers we find prompt the questions of why life insurers do not offer such contracts and more generally why health and life insurers do not integrate. We take on these questions in Section V.

IV.A. Data

Mortality rates, for the population at large and conditional on a cancer diagnosis, are from the Surveillance, Epidemiology, and End Results (SEER) Program, the comprehensive database for cancer incidence and survival information in the United States. The National Cancer Institute initiated the SEER Program in 1973 with 9 cancer registries across the country and has expanded the coverage to 18 registries representing approximately 28% of the U.S. population.[15] The database is the standard source for academic studies in medicine and health economics.

We collect the expected survival rates without conditioning on a cancer diagnosis by age group (30–34, 35–39, ..., 60–64, 65+), race, and sex. SEER*Stat calculates the expected survival rate using the Annual US Life Tables published by the National Center for Health Statistics. We use the underlying life tables for 2012 for each demographic group.[16]

We also use SEER*Stat to collect the one-year survival rates for patients diagnosed with various cancers conditioning on the stage of the cancer and patient demographics (age, race, and sex).[17] For each cancer site and stage, we restrict the sample

15. The 18 registries are Alaska Native Tumor Registry, Atlanta, Connecticut, Detroit, Greater California, Greater Georgia, Hawaii, Iowa, Kentucky, Los Angeles, Louisiana, New Jersey, New Mexico, San Francisco Oakland, Rural Georgia, San Jose-Monterey, Seattle-Puget Sound, and Utah.

16. Available at https://seer.cancer.gov/expsurvival/US.1970thru2012.individual.years.txt, accessed February 22, 2018. Choosing a different year for mortality rates for the population at large has virtually no effect on our results.

17. The software can be downloaded from https://seer.cancer.gov/seerstat/software/. We used version 8.3.5. This information is from the SEER 18 database submitted in November 2016. We use the Derived AJCC Stage Group, 6th ed. (2004+) variable from the SEER 18 database for all cancer sites other than breast cancer. For breast cancer, we use Breast-Adjusted AJCC 6th Stage (1988+) staging variable. The staging information is widely available for our sample periods. Additional information on cancer staging in SEER is available from https://seer.cancer.gov/seerstat/variables/seer/ajcc-stage/.

period to be the five-year period preceding the year of the first FDA approval of the corresponding immunotherapy (or 2014, which is the last year in the database), to exclude the effect of immunotherapy on survival. We provide further details in Online Appendix A.

We use SEER to collect 2016 incidence rates for all cancer sites for which there exists an FDA-approved immunotherapy. We use staging information in the SEER data if the FDA approval is for a particular stage of the cancer. Online Appendix B provides further details on the construction of our data.

For the cost data, we start from the CMS Medicare Part B data.[18] The downloadable Excel file contains comprehensive data of the spending and utilization of Medicare Part B drugs for 2013 to 2017. We use the 2017 Average Spending per Beneficiary (column AM) in calculating the average cost of treatment options per site. For immunotherapy drugs not appearing in this list, we calculate the costs using the 2017 October Medicare Average Sales Price file[19] and the FDA-approved dosage specified in the drug labels for an average adult weighing 70kg.[20] The dosing regimen is for a 12-week course. This is the Medicare reimbursement amount, which also serves as a yardstick for private health insurers.[21]

Sales data on each drug are obtained from Cortellis Competitive Intelligence database, both for the United States and globally. Life insurance participation rates and average death benefits by age, gender, and income are obtained from LIMRA's 2016 Life Insurance Ownership in Focus. The data combine individual and group policies. We set the lapsation rate to $k = 4.2\%$ a year, based

18. https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Information-on-Prescription-Drugs/MedicarePartB.html.

19. https://www.cms.gov/apps/ama/license.asp?file=/Medicare/Medicare-Fee-for-Service-Part-B-Drugs/McrPartBDrugAvgSalesPrice/Downloads/2017-October-ASP-Pricing-File.zip.

20. https://www.accessdata.fda.gov/scripts/cder/daf/.

21. To benchmark our cost estimates, we also obtained data from FAIR Health Inc., who collect data on the claims experience of the privately insured population, covering over 150 million insured individuals. For the 12 immunotherapy drugs that we have in the FAIR Health data and in the Medicare data, the prices paid by private insurers are on average 2.2 times higher for the former. This suggests that our cost estimates are conservative. These costs do not include the costs of hospitals and doctors, and they do not include the costs of traditional chemotherapy and/or radiotherapy that often accompany immunotherapy when the immunotherapy is a second-line treatment.

on the LIMRA observation report for 2005–2007.[22] We explore robustness of our results to the lapsation rate below.

We set the baseline interest rate to $r = 3\%$ a year, close to the average yield on a 10-year nominal Treasury bond over our sample period 2004–17 (3.17%).

IV.B. New Immunotherapies and Improvements in Survival

1. Immunotherapies: Approvals, Incidence, and Cost. Table I illustrates the rapid expansion of FDA-approved immunotherapies. Each row corresponds to an FDA approval event; the approval dates in the first column are listed in chronological order. The second column reports the drug's brand name. The third column reports the cancer site. The fourth column reports the cancer stage (or NS if the approval pertains to all stages). The fifth column reports the number of new annual cases from SEER; the incidence is specific to the cancer site, subtype, and stage to which the immunotherapy pertains. For example, the 2011.Q1 approval of Yervoy (ipilumab) pertains to metastatic (stage 4) melanoma. The incidence number also pertains to stage 4 melanoma. The sixth column reports the drug cost as described in Section IV.A.

The table makes three main points. First, the number of immunotherapies has expanded rapidly since the first major approval of Herceptin (trastuzumab) in 1998. The growth in approvals is particularly pronounced since 2011, when a series of new checkpoint inhibitors came on the market. Adoptive cell therapies, such as CAR-T cell therapy, and oncolytic virus therapies have been approved even more recently.

Second, immunotherapies are becoming available for ever more cancer sites and site subtypes. Immunotherapies are increasingly used for earlier-stage cancers and as first-line therapies (instead of chemotherapy) rather than second-line therapies (in combination with chemotherapy). Immunotherapy drugs are increasingly used in combination, which further escalates the cost. As the incidence numbers in the fifth column indicate, current therapies are applicable to hundreds of thousands of cases in the United States alone.

22. The subsequent, and more recent, observation report based on data from 2007–2009 reports a lapsation rate of $k = 4.5\%$, where the slightly higher lapsation rate is likely due to the financial crisis. We therefore choose to use the lapsation rate from the observation report 2005–2007.

TABLE I

FDA-APPROVED IMMUNOTHERAPIES: 1998–2019

FDA approval	Drug	Site	Stage	Incidence	Costs
1998 Q3	Herceptin	Breast (HER2+)	S4	3,148	38,094
2001 Q2	Campath	Leukemia (CLL)	NS	15,748	NA
2002 Q1	Zevalin	Lymphoma (NHL; FL)	S4	4,323	53,816
2003 Q2	Bexxar	Lymphoma (NHL; FL)	S4	4,323	NA
2004 Q1	Erbitux	Colorectal	S4	27,418	28,913
2004 Q1	Avastin	Colorectal	S4	27,418	4,859
2006 Q3	Vectibix	Colorectal	S4	27,418	33,614
2006 Q4	Avastin	Lung (NSCLC nonsquamous)	S4	70,711	4,859
2006 Q4	Herceptin	Breast (HER2+)	S1–S4	34,719	38,094
2009 Q2	Avastin	Brain (glioblastoma)	NS	11,404	4,859
2009 Q3	Avastin	Kidney (RCC)	S4	8,770	4,859
2009 Q3	Zevalin	Lymphoma (NHL; FL)	S4	4,323	53,816
2009 Q4	Arzerra	Leukemia (CLL)	NS	15,748	38,642
2010 Q2	Provenge	Prostate cancer	S4	19,725	105,133
2010 Q4	Herceptin	Gastric or gastroesophageal junction (GEJ) (HER2+)	S4	1,964	38,094
2011 Q1	Yervoy	Melanoma	S4	3,155	98,436
2011 Q3	Adcetris	Lymphoma (HL, ALCL)	S4	1,852	86,149
2011 Q3	Zelboraf	Melanoma	S4	1,262	36,010
2011 Q4	Erbitux	Head and neck	S4	23,544	28,913
2011 Q4	Sylatron	Melanoma	NS	small	45,433
2013 Q4	Gazyva	Leukemia (CLL)	NS	15,748	28,026
2014 Q2	Cyramza	Gastric or gastroesophageal junction (GEJ)	S4	13,091	34,228
2014 Q3	Avastin	Cervical	S4	2,071	4,859
2014 Q3	Keytruda	Melanoma	S4	3,155	47,383
2014 Q4	Avastin	Ovarian	S4	5,643	4,859
2014 Q4	Blincyto	Leukemia (ALL)	NS	5,747	105,795
2014 Q4	Cyramza	Lung (NSCLC)	S4	85,711	34,228
2014 Q4	Cyramza	Gastric or gastroesophageal junction (GEJ)	S4	13,091	34,228
2014 Q4	Opdivo	Melanoma	S4	3,155	50,575
2015 Q1	Opdivo	Lung (NSCLC squamous)	S4	15,001	50,575
2015 Q2	Cyramza	Colorectal	S4	27,418	34,228
2015 Q4	Darzalex	Multiple myeloma	NS	24,625	58,349
2015 Q4	Empliciti	Multiple myeloma	NS	24,625	46,464
2015 Q4	Imlygic	Melanoma	S3–S4	8,712	10,209
2015 Q4	Keytruda	Melanoma	S4	3,155	47,383
2015 Q4	Keytruda	Lung (NSCLC)	S4	85,711	47,383
2015 Q4	Opdivo	Kidney (RCC)	S4	8,770	50,575
2015 Q4	Opdivo	Lung (NSCLC nonsquamous)	S4	70,711	50,575
2015 Q4	Opdivo + Yervoy	Melanoma	S4	315.5	149,011
2015 Q4	Yervoy	Melanoma	S3–S4	8,712	98,436

TABLE I
(CONTINUED)

FDA approval	Drug	Site	Stage	Incidence	Costs
2016 Q1	Arzerra	Leukemia (CLL)	NS	15,748	38,642
2016 Q1	Gazyva	Lymphoma (NHL; FL)	S4	4,323	28,026
2016 Q1	Opdivo + Yervoy	Melanoma	S4	1,578	149,011
2016 Q2	Opdivo	Lymphoma (cHL)	S4	1,852	50,575
2016 Q2	Tecentriq	Bladder	S3–S4	8,041	38,466
2016 Q3	Arzerra	Leukemia (CLL)	NS	15,748	38,642
2016 Q3	Keytruda	Head and neck	S4	23,544	47,383
2016 Q4	Avastin	Ovarian	S4	5,643	4,859
2016 Q4	Darzalex	Multiple myeloma	NS	24,625	58,349
2016 Q4	Keytruda	Lung (NSCLC)	S4	85,711	47,383
2016 Q4	Lartruvo	Soft tissue sarcoma	S4	1,737	44,475
2016 Q4	Opdivo	Head and neck	S4	23,544	50,575
2016 Q4	Tecentriq	Lung (NSCLC)	S4	85,711	38,466
2017 Q1	Bavencio	Skin cancer (MCC)	S4	208	35,336
2017 Q1	Keytruda	Lymphoma (cHL)	S4	1,852	47,383
2017 Q1	Opdivo	Bladder	S3–S4	8,041	50,575
2017 Q2	Bavencio	Bladder	S3–S4	8,041	35,336
2017 Q2	Darzalex	Multiple myeloma	NS	24,625	58,349
2017 Q2	Imfinzi	Bladder	S3–S4	8,041	41,550
2017 Q2	Keytruda	Lung (NSCLC nonsquamous)	S4	70,711	47,383
2017 Q2	Keytruda	Bladder	S3–S4	8,041	47,383
2017 Q2	Keytruda	MSI-H or DMMR (mostly colorectal)	S4	27,418	47,383
2017 Q2	Rituxan Hycela	Lymphoma (FL, DLBCL) and leukemia (CLL)	NS	51,631	21,445
2017 Q2	Vectibix	Colorectal	S4	27,418	33,614
2017 Q3	Blincyto	Leukemia (ALL)	NS	5,747	105,795
2017 Q3	Keytruda	Gastric or gastroesophageal junction (GEJ)	S3–S4	20,181	47,383
2017 Q3	Kymriah	Leukemia (ALL)	NS	3,100	475,000
2017 Q3	Mylotarg	Leukemia (AML)	NS	12,557	45,250
2017 Q3	Opdivo	Colorectal (MSI-H)	S4	27,418	50,575
2017 Q3	Opdivo	Liver (HCC)	S4	4,139	50,575
2017 Q3	Yervoy	Melanoma	S4	3,155	98,436
2017 Q4	Adcetris	Lymphoma (pcALCL, CD-30 MF)	NS	small	86,149
2017 Q4	Gazyva	Lymphoma (NHL; FL)	S2–S4	8,287	28,026
2017 Q4	Opdivo	Melanoma	S3–S4	8,712	50,575
2017 Q4	Yescarta	Lymphoma (NHL; DLBCL)	S4	7,206	373,000
2017 Q4	Zelboraf	ECD	NS	small	36,010
2018 Q1	Imfinzi	Lung (NSCLC)	S3–S4	119,615	41,550
2018 Q1	Adcetris	Lymphoma (cHL)	S3–S4	3,496	86,149
2018 Q1	Blincyto	Leukemia (ALL)	NS	5,747	105,795
2018 Q2	Avastin	Ovarian	S3–S4	12,032	4,859
2018 Q2	Opdivo + Yervoy	Kidney (RCC)	S4	8,770	149,011
2018 Q2	Kymriah	Lymphoma (NHL; DLBCL)	S4	7,206	475,000

TABLE I
(CONTINUED)

FDA approval	Drug	Site	Stage	Incidence	Costs
2018 Q2	Keytruda	Cervical	S4	2,071	47,383
2018 Q2	Keytruda	Lymphoma (NHL; PMBCL)	S4	721	47,383
2018 Q3	Opdivo + Yervoy	MSI-H or DMMR (mostly colorectal)	S4	27,418	149,011
2018 Q3	Opdivo	Lung (SCLC)	S4	16,552	50,575
2018 Q3	Libtayo	Skin (CSCC)	S3–S4	small	36,400
2018 Q4	Keytruda	Lung (NSCLC squamous)	S4	15,001	47,383
2018 Q4	Keytruda	Liver (HCC)	S4	4,139	47,383
2018 Q4	Adcetris	Lymphoma (sALCL, PTCL)	NS	small	86,149
2018 Q4	Tecentriq + Avastin	Lung (NSCLC nonsquamous)	S4	70,711	43,325
2018 Q4	Keytruda	Skin (MCC)	S3–S4	826	47,383
2019 Q1	Keytruda	Melanoma	S3–S4	8,712	47,383
2019 Q1	Tecentriq	Breast cancer (triple-negative)	S3–S4	4,785	38,466
2019 Q1	Tecentriq	Lung (SCLC)	S4	16,552	38,466
2019 Q2	Keytruda	Lung (NSCLC)	S3–S4	92,166	47,383
2019 Q2	Keytruda	Kidney (RCC)	S4	8,770	47,383

Third, the cost of these drugs is high, often on the order of annual median U.S. household income and sometimes a multiple thereof.

2. Survival Improvements. Figure I illustrates the improvements in survival for recently approved immunotherapies for stage 3–4 melanoma (Panel A), leukemia (Panel B), lung cancer (Panel C), and breast cancer (Panel D). The graphs are taken from the randomized control trials (RCTs).[23] While the improvements in survival vary across cancer sites, immunotherapies improve survival rates substantially and durably. In the case of late-stage melanoma, the one-year survival rate jumps from 40% without to 70% with immunotherapy.

The fairly short patient follow-up period is a drawback of these studies, which makes precise inference on long-run survival rates difficult.[24] This is partly due to the recent nature of

23. The figures are reproduced with permission from Robert et al. (2015), Goede et al. (2014), Brahmer et al. (2015), and Perez et al. (2014), respectively.

24. As discussed in Section III.B, even a cautious life insurer may be inclined to facilitate access to new treatments because, without receiving the treatment, the patient has a high probability of dying in a short period of time.

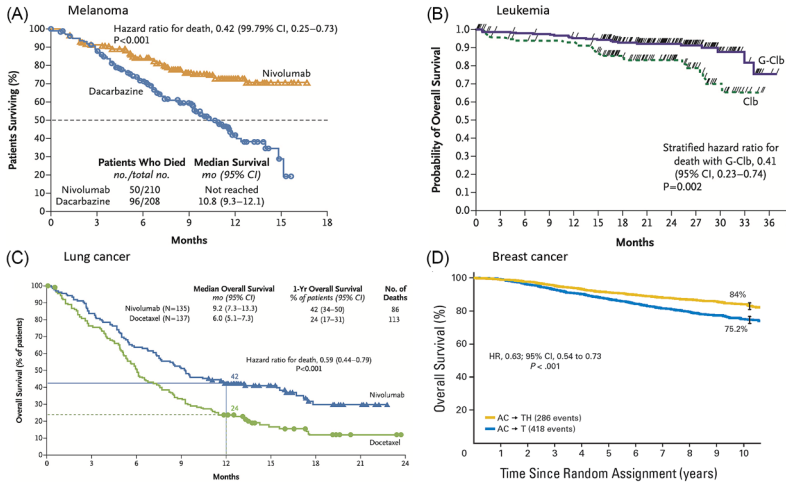

FIGURE I

Improvements in Survival in Randomized Control Trials

The four graphs illustrate the improvements in survival rates for melanoma (Panel A), leukemia (Panel B), lung cancer (Panel C), and breast cancer (Panel D). Panel A is from The New England Journal of Medicine, Robert et al., "Nivolumab in Previously Untreated Melanoma without *BRAF* Mutation," 372(4), 320–330. Copyright © (2015) Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society. Panel B is from The New England Journal of Medicine, Goede et al., "Obinutuzumab plus Chlorambucil in Patients with CLL and Coexisting Conditions," 370(12), 1101–1110. Copyright © (2014) Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society. Panel C is from The New England Journal of Medicine, Brahmer et al., "Nivolumab versus Docetaxel in Advanced Squamous-Cell–Non Small-Cell Lung Cancer," 373(2), 123–135. Copyright © (2015) Massachusetts Medical Society. Reprinted with permission from Massachusetts Medical Society. Panel D is from "Trastuzumab Plus Adjuvant Chemotherapy for Human Epidermal Growth Factor Receptor 2-Positive Breast Cancer: Planned Joint Analysis of Overall Survival From NSABP B-31 and NCCTG N9831," Perez, E. et al: Journal of Clinical Oncology, 32(33), 2014, 3744–3752. Reprinted with permission.

the medical advances. In part, it is due to early termination of successful clinical studies in an effort to make the drugs available sooner to the population at large.[25] Hundreds of ongoing and future clinical trial studies will remedy this problem. Nevertheless, the early evidence on survival gains is encouraging. Also, important advantages relative to traditional cancer therapies are that immunotherapies are fairly well tolerated, leave the healthy

25. In some clinical studies, patients in the control group are allowed to switch to the treatment arm, biasing downward the estimated treatment effects.

cells unscathed, and can be repeated. These advantages improve the likelihood of durable survival. As one illustration of the long-term benefits, Panel D reports the improvement in survival from Herceptin, the first FDA-approved immunotherapy in our sample. For this case, a 10-year follow-up study is already available. The 10-year survival rate is lifted from 75% without to 84% with immunotherapy.

IV.C. Modeling Survival Gains

To assess the impact of a cancer diagnosis on a life insurer's liabilities, we estimate survival models for individuals with and without a cancer diagnosis. We use the Gompertz-Makeham mortality model in which the instantaneous mortality rate of an individual, without a cancer diagnosis, of age x with demographics z (gender and race) is modeled as

$$\mu(x;z) = \alpha(z)\exp(\beta(z)x) + \gamma(z). \tag{4}$$

We estimate the model separately for households with different demographics z. Next, we estimate the mortality model conditional on a cancer diagnosis, which may include the cancer stage. We refer to these mortality curves as $\mu^D(x;z)$.

To estimate the parameters $\xi \equiv \{\alpha, \beta, \gamma\}$, we compute the one-year survival probability implied by the model:

$${}_1p_x^{model}(z) = \exp\left(-\int_0^1 \mu(x+u;z)du\right), \tag{5}$$

and minimize the summed squared distance between survival probabilities in the data and the model:

$$\widehat{\xi} = \arg\min_{\xi} \sum_x \left[\log(-\log({}_1p_x^{data})) - \log(-\log({}_1p_x^{model}))\right]^2.$$

For each demographic group, we estimate one set of parameters $\widehat{\xi}$ for healthy individuals and one set for individuals diagnosed with cancer. In case of melanoma, we have detailed data on the age, gender, and cancer stage from both SEER and the RCT (Robert et al. 2015). We use the SEER survival data five years prior to the FDA approval date to provide the closest possible match to the timing of the RCT and to avoid having a control group contaminated by immunotherapy. The survival curves for the control

group in the RCT are a close match to the stage 4 melanoma survival curves in SEER. For leukemia, lung cancer, and breast cancer, the information disclosed in the clinical studies is too limited to afford a close match, and we therefore focus on melanoma for our main calculations.[26] We focus on white men and women, because melanoma is rare for black individuals. We then combine men and women in the same proportion as in the RCT by Robert et al. (2015).

We use the information in Figure I, Panel A to estimate θ, the likelihood of success of the immunotherapy. Specifically, we estimate θ to match the one-year survival rate conditional on treatment in Robert et al. (2015), ${}_1p_x^T(z)$, as:

$$ {}_1p_x^T(z) = {}_1p_x(z)\theta + {}_1p_x^D(z)(1-\theta). $$

We use the mixed survival curves by gender for age 65, the median age of patients in the clinical study.[27] In the case of melanoma, we find that $\widehat{\theta} = 0.51$ closely fits the survival curves conditional on immunotherapy treatment. This indicates that the treatment is effective for half of the patients.

IV.D. A Life Insurer's Benefit from Immunotherapy for Melanoma

Table II reports the life insurer's benefit from immunotherapy in melanoma patients: $\theta(L(x, \pi, \mu) - L(x, \pi, \mu^D))$. The benefit is for the same gender composition as in the RCT by Robert et al. (2015) and it pertains to a policy with a \$1 death benefit. In the rows, we report the age at which the life insurance policy was purchased and in the columns the age at which the individual is diagnosed with melanoma. We set the interest rate at 3% and the insurer's markup at 10% (Mitchell et al. 1999) to determine the insurance premium π. The table also breaks down the benefit into the premium and face value components as in equation (3).

The main insight of Table II is that the life insurer experiences large benefits from immunotherapy treatment of stage 4 melanoma. For a person who purchased life insurance at age 30 and is diagnosed at age 40, the benefit is \$0.44 per dollar of death

26. In unreported results, we have matched the demographics of the control group in RCTs for leukemia, lung cancer, breast cancer, and colorectal cancer as well as possible and have found that the SEER survival rates neither systematically under- or overstate the RCT survival rates.

27. We assume that θ does not vary by age and gender. As more detailed data become available from ongoing clinical studies, this assumption can be relaxed.

TABLE II

THE INSURER'S BENEFIT FROM IMMUNOTHERAPY FOR MELANOMA PER DOLLAR OF FACE VALUE

Age of purchase	Insurer's benefit Age of diagnosis					Premium effect Age of diagnosis					Face value effect Age of diagnosis				
	30	40	50	60	70	30	40	50	60	70	30	40	50	60	70
30	0.46	0.44	0.41	0.36	0.29	0.03	0.02	0.02	0.02	0.02	0.43	0.41	0.38	0.34	0.27
40		0.46	0.43	0.37	0.30		0.04	0.04	0.04	0.03		0.41	0.38	0.34	0.27
50			0.46	0.40	0.33			0.08	0.07	0.05			0.38	0.34	0.27
60				0.46	0.38				0.13	0.10				0.34	0.27
70					0.47					0.20					0.27

Notes. The table reports the insurer's benefit and the breakdown in the premium and face value effect (see equation (3)). In the rows, we report the age at which the policy was purchased and in the columns the age at which the individual is diagnosed with melanoma.

benefit (face value). A policy with a death benefit of $339,000 would be sufficient to cover the entire $149,011 cost of the Yervoy plus Opdivo treatment for a 12-week treatment course. The patient would typically face "only" the copay and maximum out-of-pocket costs, about $20,000 for the typical family under the ACA. A life insurance policy with a face value as small as $46,000 would generate a large enough benefit to cover the copay.

If we decompose the benefit into the premium and the face value components, we find that the former accounts for $0.02 and the latter for $0.41 in the example. The face value component is invariant to the age of purchase and declines with the age of diagnosis. The premium component increases with the purchase age as life insurance purchased later in life is more expensive. It also declines with age of diagnosis. When a young person is diagnosed with cancer, the benefits of restoring them to full health are largest, holding constant the age of purchase. The individual with restored health will pay life insurance premiums for longer, and the death benefit will be pushed out further into the future. The lowest benefit is for older individuals who purchased their policy early in life. They face a shorter period of lower premiums, and there is only so much room to push the death benefit into the future. However, even for a 70-year-old who purchased her policy at age 30, the benefit is 29 cents per dollar of face value. A policy with a $70,000 death benefit would suffice to cover a typical $20,000 copay.

In Table III, we explore the sensitivity of our estimates to the interest rate, the markup, the effectiveness of immunotherapy, and the lapsation rate. We assume that the interest rate is the same when the policy is purchased and when the individual is diagnosed with cancer. We find that the benefit is not much affected by the level of interest rates.

If the market for life insurance is perfectly competitive, that is, if markups are 0, then the benefit declines because the premium effect declines. It is more valuable for the insurance company to preserve policies with high profit margins. However, these effects are again small for reasonable variations in markups because the premium effect is small.

The effectiveness of immunotherapy has a first-order effect on the insurer's benefit; the benefit is linear in θ. Taking again an individual diagnosed at 40 who purchased her policy at age 30, the benefit increases from $0.44 in our benchmark calculations with $\theta = 0.51$ to $0.66 when $\theta = 0.75$. Conversely, a lower value of $\theta = 0.25$ would reduce the benefit to $0.22.

TABLE III

THE INSURER'S BENEFIT FROM IMMUNOTHERAPY FOR MELANOMA: ROBUSTNESS

Age of purchase	$r = 1\%$ Age of diagnosis					Markup $= 0\%$ Age of diagnosis				
	30	40	50	60	70	30	40	50	60	70
30	0.47	0.44	0.40	0.34	0.26	0.45	0.44	0.41	0.36	0.29
40		0.47	0.42	0.36	0.28		0.45	0.42	0.37	0.30
50			0.47	0.40	0.31			0.45	0.40	0.32
60				0.48	0.37				0.45	0.37
70					0.48					0.45
	$\theta = 0.75$					$k = 6\%$				
30	0.69	0.66	0.61	0.54	0.44	0.45	0.44	0.41	0.37	0.31
40		0.69	0.64	0.56	0.45		0.45	0.42	0.38	0.32
50			0.69	0.61	0.49			0.45	0.41	0.34
60				0.70	0.56				0.45	0.38
70					0.70					0.46

Notes. The table reports the insurer's benefit if we change the interest rate from 3% to 1%, if insurance markets are perfectly competitive (markup = 0%), if immunotherapy is more effective and $\theta = 0.75$, and if lapsation is higher and $k = 6\%$. In the rows, we report the age at which the policy was purchased and in the columns the age at which the individual is diagnosed with melanoma.

Last, we vary the lapsation rate from $k = 4.2\%$ to $k = 6.0\%$. The former is the observed average lapsation rate, and the latter is close to the lapsation observed for group policies (5.9%). We find that lapsation does not affect the benefit much. This may be surprising at first, as a shorter effective maturity of the policy due to lapsation makes it less likely that the insurer has to pay out the face value. However, insurers price in lapsation (Koijen and Yogo 2015), and premiums are lower as a result. Conditional on being diagnosed, the increase in the insurer's liability is larger the higher the lapsation rate. The composition of the benefit therefore shifts if the lapsation rate is higher, reducing the premium component while increasing the face value component. The changes approximately cancel and the overall benefit is ultimately not much affected by lapsation. This lapsation result implies that job mobility, one important driver of lapsation for group life policies in the data, does not affect the (group) life insurer's benefit from life-extending medical innovation. As such there is no reason to treat individual and group life insurance differently when it comes to calculating the benefit.

IV.E. Life Insurance Coverage

Our insight applies broadly as life insurance ownership is prevalent. Table IV reports ownership rates of life insurance and average death benefits by age and gender in the top panel and by income and gender in the bottom panel. If we focus on the age group between 35 and 44 as an example, the average ownership rate is 67% for men and 62% for women. The average death benefit is \$257k for men and \$219k for women. Using the numbers from Table II, and the same gender ratio as in the clinical trial, a life insurance company would experience a benefit of \$106k for a representative 40-year-old who purchased their policy at age 30.

If we condition on income, then we find that ownership rates increase with income, as expected. However, importantly, even among consumers with income levels between \$35k and \$50k, ownership rates are as high as 66% for men and 70% for women. The average death benefit for this group is \$154k for men and \$145k for women. This translates into a benefit of \$66k for a representative 40-year-old who purchased their policy at age 30. These amounts are more than large enough to cover the typical copay associated with immunotherapy, also for households with income levels below the median.

TABLE IV
OWNERSHIP RATES AND COVERAGE BY AGE, GENDER, AND INCOME

	Ownership rate (%)		Mean death benefit ($)	
	Men	Women	Men	Women
Age (years)				
18–24	48	37	135,153	101,077
25–34	63	59	168,021	145,554
35–44	67	62	257,054	219,448
45–54	68	63	277,639	218,539
55–64	62	58	217,947	141,076
65 and older	62	51	121,371	87,556
Income				
Under $35k	45	48	77,613	91,282
$35k–$50k	66	70	153,633	144,911
$50k–$75k	74	73	170,645	198,706
$75k–$100k	81	74	258,193	212,691
Over $100k	83	72	378,548	340,108

Notes. The table reports the ownership rates and average death benefit by age and gender in the top panel and by income and gender in the bottom panel. The data are obtained from LIMRA's 2016 Life Insurance Ownership in Focus.

IV.F. The Aggregate Benefit of Immunotherapy to Life Insurers

We estimate the aggregate benefit for life insurers as a result of immunotherapies in a given year. Let i denote a cancer site for which the FDA has approved an immunotherapy, j a demographic group (gender interacted with age groups), Inc_{ij} the incidence or number of new cases in a year of that cancer i in group j, $LIpart_j$ the life insurance participation rate of group j, $LIamt_j$ the average death benefit of the demographic group's life insurance policy, and b_{ij} the life insurance company's benefit per dollar of death benefit, which depends on patient demographics and cancer site. The aggregate benefit in a given year across all 23 cancer sites (defined to include staging information) and demographic groups is:

$$Funded = \sum_i \sum_j Inc_{ij} LIpart_j LIamt_j b_{ij}. \tag{6}$$

Insurance participation rates, $LIpart_j$, and average death benefit, $LIamt_j$, by demographic group j (age bucket and gender) are from LIMRA and given in Table IV. The incidence data by demographic group for each cancer site and stage, Inc_{ij}, are from

SEER. The costs of immunotherapy for each cancer site, C_i, were given in Table I. When multiple immunotherapies are available for a site-stage combination, we use the average cost across all immunotherapies available for that site.

The most difficult to estimate is the insurer's benefit per dollar of death benefit for each site and demographic group, b_{ij} in equation (6). We need the one-year survival probability, conditional on diagnosis. In theory, we could estimate a separate set of parameters ξ for every cancer site and demographic group, but the available data are too limited to do so. We therefore assume that a cancer diagnosis triggers a shift in the mortality rate from $\mu(j)$ to $\mu^D(i, j)$, where the shifter χ_{ij} depends on the cancer site and the demographic group,

$$\mu^D(i, j) = \mu(j) + \chi_{ij}.$$

Then the s-year survival probability of a person of age x diagnosed with cancer i is

$$\begin{aligned} {}_sp_x^D(i, j) &= \exp\left(-\int_0^s \mu^D(x+u; i, j)du\right) \\ &= \exp\left(-s\chi_{ij}\right)\exp\left(-\int_0^s \mu(x+u; j)du\right) \\ &= \exp\left(-s\chi_{ij}\right)_s p_x(j). \end{aligned}$$

In other words, χ_{ij} measures the percentage change in the one-year survival probability for cancer site i and demographic group j when going from healthy to diagnosed,

$$\chi_{ij} = \log({}_1p_x(j)) - \log({}_1p_x^D(j)).$$

Because we observe ${}_1p_x$ and ${}_1p_x^D$ for each demographic group (gender and age group) and for each cancer site from SEER, we observe χ_{ij}. We average χ_{ij} across age groups, weighted by incidence, separately for men and women and for each cancer site.[28]

28. The reason for an age-invariant χ is that otherwise we would have to integrate out future changes in χ in the calculation of the value of the life insurance contract. Because we find that χ_{ij} does not vary much with age in the data, this is a reasonable assumption. We use data for white males and white females because incidence rates for blacks are lower, which makes statistical inference more difficult. We apply the same χ_{ij} to blacks and verify that this is an accurate approximation.

Calculating the b_{ij} also requires an estimate of θ, measuring the effectiveness of immunotherapy. For the four cancer sites displayed in Figure I, we calculate an effectiveness parameter,

$$\theta = \frac{{}_1p_x^T - {}_1p_x^D}{{}_1p_x - {}_1p_x^D},$$

where the survival probabilities conditional on treatment and no treatment and the demographics are taken from the respective clinical studies. This delivers an estimate of θ of 0.51 for melanoma, as discussed before, 0.55 for leukemia, 0.24 for NSCLC, and 0.61 for breast cancer. The latter number is based on 10-year survival rates, the others on 1-year survival rates. The average θ across these four cancer sites is 0.48. Based on these estimates, we use $\theta = 0.5$ for all cancer sites.

Table V shows the incidence rate of cancer for the sites for which the FDA has approved at least one immunotherapy. If the FDA has approved an immunotherapy for stage 4 melanoma but not stage 3 melanoma, then the incidence refers to stage 4 melanoma. Current immunotherapies affect nearly 400,000 new cases per year. The table reports the per capita cost and lists the copay, which we set to a $20,000 maximum out-of-pocket cost that the patient shoulders, or the cost of treatment if the cost is lower than the copay.

Table V reports the aggregate benefit and the aggregate cost and copay for consumers with life insurance. The aggregate benefit across the 23 cancer sites amounts to $9.78 billion a year. Using a 3% interest rate to discount the annual life insurance benefit flow corresponds to a $326 billion value. To put this $9.78 billion flow number in perspective, the net income of the combined life and health insurance sectors was $39.42 billion in 2017, which highlights the significance of the benefits of immunotherapy.[29]

The total cost of providing immunotherapy to all 400,000 consumers with life insurance amounts to $12.65 billion, implying that the insurer's benefit corresponds to 77% of the total cost. Accounting for the fact that consumers only pay the copay, the $9.78 billion benefit to the life insurance sector well exceeds the out-of-pocket costs to consumers of $4.83 billion.

29. Source: Annual report of the Federal Insurance Office at the U.S. Department of Treasury.

TABLE V

AGGREGATE BENEFIT, COSTS, AND COPAYS

Cancer site	Incidence	Costs PC ($)	Copay PC ($)	Benefit A ($)	Costs A ($)	Copay A ($)	Benefit/costs A/A (%)	Benefit/copay A/A (%)
Lung NSCLC	119,615	42,110	20,000	3,150	3,259	1,548	97	204
Breast HER2+	34,719	38,218	20,000	320	852	446	38	72
Colorectal	27,418	47,775	20,000	903	845	354	107	255
Myeloma	24,625	55,378	20,000	525	881	318	60	165
Head and neck	23,544	42,290	20,000	702	634	300	111	234
Gastric and GEJ	20,181	38,483	20,000	643	495	257	130	250
Prostate	19,725	105,133	20,000	387	1,293	246	30	158
Leukemia CLL	15,748	33,079	20,000	158	336	203	47	78
Lung SCLC	13,522	42,110	20,000	377	367	175	103	216
Leukemia AML	12,557	45,250	20,000	351	348	154	101	228
Ovarian	12,032	4,859	4,859	270	38	38	706	706
Brain	11,404	4,859	4,859	372	35	35	1,055	1,055
Kidney	8,770	62,957	20,000	277	354	112	78	246
Melanoma	8,712	71,406	20,000	191	392	110	49	174
Lymphoma NHL/FL	8,287	37,026	20,000	193	195	105	99	183
Bladder	8,041	42,662	20,000	197	220	103	90	191
Lymphoma NHL/DLBCL	7,206	289,815	20,000	177	1,328	92	13	194
Leukemia ALL	5,747	198,096	20,000	98	317	32	31	307
Breast TNBC	4,785	38,218	20,000	117	118	62	99	189
Liver	4,139	48,979	20,000	150	128	52	117	288
Lymphoma HL	3,496	67,564	20,000	97	132	39	74	248
Cervical	2,071	26,121	20,000	74	34	26	215	281
STS	1,737	44,475	20,000	52	43	19	122	271
Total	398,081	51,397	19,109	9,781	12,645	4,827	77	203

Notes. The first column lists the cancer site for which the FDA has approved at least one immunotherapy. The second column reports the annual number of cases, or incidence, of that cancer site and stage for which the therapy is approved (summed across stages if therapies are approved for multiple stages). The third column reports the per capita (PC) cost of immunotherapy in dollars; this is the average cost if multiple immunotherapies are available for a given site. The fourth column reports the copay we use in our calculation, which is the minimum of $20,000 and the cost in the third column. The next three columns report the insurer's aggregate (A) benefit as well as the aggregate cost and copay for consumers with insurance. The last two columns compare the insurers' benefit to the total cost and the total copay.

1. Robustness: Clinical Trials and Real-World Effectiveness. In our calculations so far, we have assumed that the improvement in mortality documented in the immunotherapy RCT studies extends to the entire population of patients diagnosed with the corresponding type of cancer. Recent work by Lakdawalla et al. (2017) estimates the real-world effectiveness for various cancer treatments, some of which are immunotherapies. The paper uses SEER Medicare data, implying that the estimates are based on the elderly population. They conclude that the real-world overall survival is similar to what has been observed in RCTs. The overall survival adjustment differs by cancer site. As a robustness check, we use their estimated adjustment factors of 13.7% for breast cancer, 5.8% for lung cancer, and their average 0.6% adjustment factor for melanoma and leukemia, which they do not separately investigate (see Lakdawalla et al. 2017, figure I). The interpretation of these adjustment factors is that the clinical trials overestimate the improvement in mortality for lung cancer, for instance, by 5.8% compared to real-world mortality.

Averaged over the four cancer sites, these adjustments imply a value for $\theta = 0.43$, which we apply to all cancer sites instead of $\theta = 0.50$ in the benchmark calculations. Table VI shows that using the adjusted success rates reduces the aggregate benefit to life insurers from \$9.78 billion to \$8.61 billion.

2. Robustness: Exclusion Criteria. Upon approving a new drug, the FDA may add exclusion criteria that can limit the group of cancer patients that can receive immunotherapies. In this section, we assess the role of exclusion criteria.

In Online Appendix E, we provide a case study of the exclusion criteria for non-small cell lung cancer (NSCLC), the cancer with the greatest incidence (see Table V). For NSCLC, five new drugs have been approved by the FDA since 2014.Q4 based on 11 clinical trials. For each of the 11 clinical trials, we report the exclusion criteria, see Online Appendix Table A.3. The intersection of these criteria turns out to be very limited, which shows that these treatments are available for a large fraction of NSCLC patients.

We also collect sales data of immunotherapy drugs, in the United States and globally, based on annual reports of pharmaceutical companies, see Online Appendix Table A.2. In the last three columns of the table, we use our cost estimates to estimate the number of patients receiving some form of immunotherapy. We find that the number of patients is similar to the number

TABLE VI

AGGREGATE BENEFIT, COSTS, AND COPAYS: ROBUSTNESS

Cancer site	Incidence	Costs PC ($)	Copay PC ($)	Benefit A ($)	Costs A ($)	Copay A ($)	Benefit/costs A/A (%)	Benefit/copay A/A (%)
Lung NSCLC	119,615	42,110	20,000	2,773	3,259	1,548	85	179
Breast HER2+	34,719	38,218	20,000	281	852	446	33	63
Colorectal	27,418	47,775	20,000	794	845	354	94	224
Myeloma	24,625	55,378	20,000	462	881	318	52	145
Head and neck	23,544	42,290	20,000	618	634	300	97	206
Gastric and GEJ	20,181	38,483	20,000	566	495	257	114	220
Prostate	19,725	105,133	20,000	341	1,293	246	26	139
Leukemia CLL	15,748	33,079	20,000	139	336	203	41	68
Lung SCLC	13,522	42,110	20,000	332	367	175	90	190
Leukemia AML	12,557	45,250	20,000	309	348	154	89	201
Ovarian	12,032	4,859	4,859	238	38	38	621	621
Brain	11,404	4,859	4,859	327	35	35	929	929
Kidney	8,770	62,957	20,000	243	354	112	69	217
Melanoma	8,712	71,406	20,000	168	392	110	43	153
Lymphoma NHL/FL	8,287	37,026	20,000	169	195	105	87	161
Bladder	8,041	42,662	20,000	174	220	103	79	168
Lymphoma NHL/DLBCL	7,206	289,815	20,000	156	1,328	92	12	170
Leukemia ALL	5,747	198,096	20,000	86	317	32	27	270
Breast TNBC	4,785	38,218	20,000	103	118	62	87	166
Liver	4,139	48,979	20,000	132	128	52	103	253
Lymphoma HL	3,496	67,564	20,000	86	132	39	65	219
Cervical	2,071	26,121	20,000	65	34	26	190	248
STS	1,737	44,475	20,000	46	43	19	107	238
Total	398,081	51,397	19,109	8,608	12,645	4,827	68	178

Notes. The first column lists the cancer site for which the FDA has approved at least one immunotherapy. The second column reports the annual number of cases, or incidence, of that cancer site and stage for which the therapy is approved (summed across stages if therapies are approved for multiple stages). The third column reports the per capita (PC) cost of immunotherapy in dollars; this is the average cost if multiple immunotherapies are available for a given site. The fourth column reports the copay we use in our calculation, which is the minimum of $20,000 and the cost in the third column. The next three columns report the insurer's aggregate (A) benefit as well as the aggregate cost and copay for consumers with insurance. The last two columns compare the insurers' benefit to the total cost and the total copay. We use the adjustments of Lakdawalla et al. (2017) to adjust the overall survival estimates of the clinical trials to estimate the real-world effectiveness.

of people diagnosed with cancer for which there exists an FDA-approved immunotherapy. This does not mean that all patients diagnosed with cancer receive immunotherapies, as some may receive multiple or combination treatments, but it illustrates that these treatments are widely used. In addition, the table illustrates that the trend in sales is steep.

We conclude that eligibility restrictions have been shrinking rapidly and that uptake of immunotherapies has been rising. The evidence underscores the pace at which the medical frontier in this area is shifting out, as also illustrated by Table I.

IV.G. Using the Aggregate Benefit to Improve Access to Immunotherapy

The large benefit can be used in the short run to improve access to these therapies. While many consumers may be able to pay for the out-of-pocket costs of the treatments, there is strong evidence that cancer diagnoses are accompanied by significant financial stress, with further adverse effects on health outcomes (Zafar et al. 2013, and Chino et al. 2017). Life insurers can use the accrued benefit to mitigate the financial toxicity of life-extending treatments. Short of paying for the treatment outright, possibly after means testing, there are at least two zero-cost ways life insurers could improve access to care.

First, they could allow the consumer to tap into the death benefit to pay for immunotherapy and associated medical expenditures. The policy's death benefit would be reduced by the cost of the therapy. This is equivalent to a perfectly efficient life settlement market. Both policy holder and life insurer benefit from this access. Conditional on survival, this arrangement exposes the patient to reclassification risk in the life insurance market if the patient wants to restore the death benefit to prediagnosis levels. Conditional on failure of the treatment, the policy holder loses part of the death benefit and the financial protection it offers to their dependents.

Second, life insurers could offer a loan to pay for treatment. The loan would be collateralized by the life insurer's benefit,[30] to deal with the reduced ability to repay conditional on survival. This is equivalent to a perfectly efficient credit market. Standard

30. The collateral is the market value, not the cash value, of the life insurance policy. As documented, the market value of the life insurance to the policy holder greatly increases after a cancer diagnosis.

credit market solutions have been discussed in the literature (see Montazerhodjat, Weinstock, and Lo 2016). But when offered outside the life insurance context, collateral is limited because households cannot pledge their future labor income and may default on loans received for medical treatment. Higher earnings uncertainty after treatment further reduces borrowing capacity. By unlocking the unused collateral tied up in life insurance contracts, credit market solutions could become feasible for a much larger group of consumers.

By improving access to life-extending treatments, insofar as is optimal from a private cost benefit analysis, the marginal cost of providing life insurance declines. In a competitive market place, life insurers would pass through at least some of the benefits to consumers. In addition, life insurance policies would become more valuable to consumers by partially completing health insurance markets with critical illness cover. Price- and non–price-based demand for life insurance would increase. Lower insurance premiums would result in a larger fraction of the population with life insurance, providing benefits not only when an expensive life-saving treatment is needed but in any other adversity that leads to the death of the breadwinner. The higher demand for life-saving drugs, possibly augmented by the dynamic effects on innovation discussed in Section VI.C, would result in improved longevity. Higher life expectancy would allow life insurers to further lower insurance premiums, increasing participation and coverage rates in life insurance. A virtuous win-win circle emerges.

V. Integrating Life and Health Insurance

The previous section discussed the large windfall that has befallen life insurers in the wake of the adoption of immunotherapy. The same logic applies to any other life-extending medical innovations. We provide examples in Section VI. These gains are expected to rise as advances in personalized medicine accelerate. These developments raise questions about the long-run industrial organization of insurance markets, in particular whether the current separation between health and life insurance is sustainable going forward. In this section, we discuss the basic economics of integrating health and life insurers (Section V.A). We then discuss the potential frictions that may slow or limit such integration in practice (Section V.B). Although the frictions are substantial,

innovation at the boundary of health and life insurance is beginning to take place (Section V.C).

V.A. *The Benefits of Integration*

Consider an independent health insurance company that faces a demand curve $Q^H(p_H, c)$ that decreases in price (insurance premium), p_H, and increases in the coverage rate, $c \in [0, 1]$, and a marginal cost curve, $m(c)$, with $m_c > 0$. The health insurer sets prices and coverage to maximize profits,

$$(p_H^\star, c^\star) = \arg\max_{p_H, c} Q^H(p_H, c)(p_H - m(c)), \tag{7}$$

where $c^\star$ solves

$$Q_c^H(p_H - m(c^\star)) = Q^H m_c.$$

Depending on the coverage rate, a fraction $\lambda(c)$ of consumers can afford to pay for life-extending medical treatment on their own without support of the life insurer, with $\lambda_c > 0$. An integrated health and life insurance company sets the coverage rate to maximize the sum of the profits of the health insurance company, equation (7), and the benefit of the life insurance company, equation (2):

$$(p_{H,I}^\star, c_I^\star) = \arg\max_{p_H, c} Q^H(p_H, c)(p_H - m(c)) + L(x, \pi, \mu^D) + \lambda(c)\theta\left(L(x, \pi, \mu) - L(x, \pi, \mu^D)\right),$$

where $c_I^\star$ solves

$$Q_c^H(p_H - m(c_I^\star)) = Q^H m_c - \theta\lambda_c\left(L(x, \pi, \mu) - L(x, \pi, \mu^D)\right).$$

The first-order condition implies that $c_I^\star > c^\star$ because $\lambda_c > 0$ and $L(x, \pi, \mu) > L(x, \pi, \mu^D)$. The marginal benefit of higher coverage is higher for the integrated insurer than for the stand-alone health insurer. Intuitively, at the optimal coverage level of the independent health insurer $c^\star$, a marginal increase in coverage does not affect the health insurer's profits but raises the profits of the life insurer. Better health care coverage has positive effects on the life insurer because it enables more individuals to pay for life-extending treatments out of pocket, raising their life expectancy

and delaying the payout of the death benefit. There are gains from trade from internalizing the externality between life and health insurers that so far operate independently.

V.B. Frictions to Integration of Health and Life Insurers

Why does the combination of health and life insurance plans not exist in practice? This pertains to the question of why life insurers do not improve access to life-extending medical treatments such as immunotherapy drugs, as discussed in Section IV.G, and to the question of why we do not see health and life insurance companies merge, as suggested by Section V.A.

To answer this question, we designed and administered a survey to poll experts in the life and health insurance industry, including some of the largest insurance and reinsurance companies. We received 23 responses, all from senior executives, including multiple chief executive officers, a chief growth officer, a chief medical officer, a chief science officer, a chief actuary, and a chief underwriter. We provide further details of the survey, including the survey questions and more detailed responses, in Online Appendix C.

One possible answer is that medical advances that are both life-extending and expensive are a recent phenomenon. For example, although there have been advances in cancer care and gradual gains in survival for a long time, immunotherapy's gains have been more rapid, substantial, and durable. In another break from the past, the cost of these new life-extending therapies is very high. More generally, the price of specialized drugs has increased rapidly over the past 5–10 years. It may simply be too early to see the insurance industry's response to these new developments. Thirty percent of survey respondents mention the recency as one of the reasons we have not yet seen combination products.

In addition, there are frictions to integration, which we discuss in order of importance.

1. Operational Frictions. Operational considerations impede integration and innovation. Life and health insurers are very different businesses that have historically developed separately. They employ people with different skill sets, their products have different contract horizons, and their funding cost and capital requirements are different. Moreover, even data sharing is usually prohibitively expensive due to legacy IT systems that cannot communicate with each other. These regulatory and

operational frictions explain why companies such as Aetna, Cigna, and United Healthcare not only legally structure their health and life insurance business units as separated subsidiaries but run them as siloed operations.

The top answer, with 70% of respondents, to the survey question "What are the potential barriers to innovation explaining why life and health insurance combination products have not yet been introduced?" is that "combination products cut across lines of business that have not been integrated historically, posing large organizational challenges." Such operational frictions may delay innovation.

2. Regulatory Frictions. Insurance companies are highly regulated financial intermediaries and the regulatory frameworks for health and life insurance policies differ substantially. Managing the economic and regulatory risks in each industry requires different expertise. In addition, there are regulatory internal capital market frictions that limit the flow of funds between subsidiaries (see Koijen and Yogo 2015, in the context of life insurers). Sixty-one percent of survey respondents mention that "There are regulatory frictions to obtaining approval for such combination insurance products" (see survey question 2).

One salient regulatory difference between health and life insurance emphasized in Section II is the treatment of preexisting conditions. If the integrated insurance product would be classified as health insurance by regulators, then the insurer would lose the ability to condition on an individual's health status when pricing life insurance. This would increase adverse selection concerns. Among regulatory barriers, 52% of respondents (making it the top answer for survey question 3) selected as the main regulatory concern that "If life insurance combines aspects of health insurance, it may limit the ability to account for preexisting condition during the underwriting process."

The second important regulatory barrier revealed by the survey is consumer financial protection issues, in particular the legal and reputational risk related to the confines of what therapies the insurance would and would not cover. Indeed, the survey indicates that executives worry about this risk as 30% of the respondents mention it as a reason combination products have not been introduced (see survey question 2). In addition, 43% of the respondents mention that "regulation regarding consumer protection as it is challenging to explain new consumer products to consumers" is

one of the main regulatory challenges to introducing combination products (see survey question 3).

Last, there are also fixed regulatory costs to innovation. The regulation of health and life insurance is left to the states. Any new health-and-life insurance combination product would need to obtain approval from 50 state insurance regulators. Survey respondents do not seem to think that this process would be overly arduous.

3. Uncertainty about the Response of Health Insurers. The U.S. life insurance market is a large and concentrated market. A change in strategy by a large life insurer may have a significant impact on health insurers. The best response by health insurers is unknown, and this uncertainty may lead to inaction. Life insurers may face at least two forms of uncertainty if they offered combination products: legal risks and coverage decisions by health insurers.

Copays protect health insurers against moral hazard related to overuse of medical services. If a life insurer offers a product that offsets the out-of-pocket costs for life-extending treatment of a health insurance policy holder, this may undermine the protection from moral hazard that copays grant the health insurers. Life insurers may expose themselves to the risk of being sued by the health insurers.

Even if there is no direct legal risk, there is the additional risk that health insurance companies may respond by increasing out-of-pocket costs for the treatments subsidized by life insurers. This would make it more expensive for life insurers to provide the combination product. The uncertainty over health insurers' future coverage decisions may be enough to dissuade life insurers to enter in this market in the first place.

Discussions with industry experts suggest that this is not a major concern. In addition to the accelerated death benefit and critical illness riders that are sold on life insurance policies, which can already be used to help patients afford their copays, there exist health insurance contracts that explicitly cover the out-of-pocket health costs of all types.[31] Second, moral hazard seems a less severe concern for critical illnesses like stage 4 cancer than it is for other health care expenditures that improve the quality of

31. Some of this insurance is marketed to executives. This contract keeps moral hazard at bay by setting a maximum annual benefit and a maximum per event benefit.

life. Third, it would take a long time before these products gained enough market share for health insurers to notice a difference in use and engage in the response envisioned above. Finally, we note that this concern disappears when life and health insurers formally integrate.

V.C. Initial Evidence of Innovation

Despite the regulatory, institutional, and legal frictions that may stifle innovation and impede the development of a life insurance product that provides coverage for life-extending medical treatments, there has been recent product innovation that at least partially fills the need we identify in this article. This activity suggests that the potential benefit of combination products has increased recently.

1. Accelerated Death Benefits. Life insurance contracts issued in recent years frequently come with an accelerated death benefit (ADB) rider that can be purchased as an add-on.[32] ADBs are usually structured as a lump-sum payment, reduce the death benefit at the time of payment, and reduce future premium payments pro rata.

An open question is whether ADBs are even a possible financing option for life-extending treatments once life expectancy exceeds 24 months conditional on receiving the treatment. Indeed, ADBs are designed for people with a terminal illness rather than to help people survive. The 12 to 24-month expected survival restriction imposed by HIPAA on ADBs will become more binding in the future, as more therapies extend life for more people and for longer.

Even if the patient is allowed to trigger the ADB for life-extending treatments, ADBs are an inferior solution. First, they reduce the death benefit which was meant to offer financial stability to the policy holder's dependents. Second, NAIC Model Regulation 620 prohibits imposing restrictions on policy holders' use of ADB proceeds. The inability of the life insurer to restrict the use of proceeds to life-extending treatments renders ADBs an imperfect instrument. If it were able to restrict the use to life-extending medical treatments, our article implies that life insurers could

32. The Health Insurance Portability and Accountability Act (HIPAA) of 1996 provides for the tax-advantaged payment of ADBs under a life insurance contract to people with a survival prognosis of 12 to 24 months provided by a board-certified physician.

provide a rider at a zero or even negative price. Such a rider would increase demand beyond the traditional ADB rider.

2. Critical Illness Insurance. In the United States, critical illness insurance (CII) is usually sold as a stand-alone product. The typical contract makes a one-time tax-free payment of a prespecified policy amount if a condition on a list of major illnesses materializes. These policies are marketed essentially as supplementary health insurance to help people cope with the high costs associated with major disease. When sold as separate products, there is no possibility of internalizing the benefits of CII for the value of the life insurance contract. As with ADBs, the insurer does not restrict the use of CII payouts. Only recently did some U.S. insurers begin to offer a life insurance policy with critical illness rider; other LI-CII combination products exist in Asia.[33]

In sum, ADB and CII riders on life insurance policies share two design flaws: (i) they do not restrict the list of critical illnesses that trigger a payout to life-threatening diseases for which there exists a life-extending treatment, and (ii) they do not restrict the use of the proceeds to expenses incurred for the available treatment. As such these existing products fail to fully exploit the natural complementarity between life and health insurance we emphasize. Therefore, the products are more expensive and the demand lower than it would be if the two design flaws were remedied. This minor design change may have major consequences.

3. Customer Interaction after a Life Policy Has Been Underwritten. Health, life, and long-term care insurers are all trying to engage more with their policy holders (often through new technology) in an effort to incentivize better health behaviors and better

33. Two examples are John Hancock and Nassau Re. The Life Insurance with Critical Illness Rider offered by John Hancock is available to people age 65 or younger. The rider provides a one-time critical illness benefit that does not reduce the death benefit. The list of critical illnesses contains both diseases for which there does and does not exist a life-extending treatment. The Phoenix Safe Harbor Term Life contract offered by Nassau Re comes with four living benefit riders: critical illness, chronic illness, terminal illness, and unemployment. For a critical illness, up to 95% of the death benefit can be accelerated. This amount is subtracted from the death benefits. The actual benefit amount received depends on the illness and its effect on life expectancy. The actual benefit received is larger for terminal illness. The HealthVital II Major Illness Plan, offered by AXA in Hong Kong, provides major illness protection up to age 100. Upon the diagnosis of any one of the 62 covered major illnesses, it pays out 100% of the policy value. This payout terminates the policy. If the policy holder dies before claiming a major illness benefit, the policy value is paid out as a death benefit instead.

predict future health outcomes. An example is the Vitality product offered by John Hancock. The industry is developing better tools to measure health status, such as a LifeScore (LifeScore Labs subsidiary of MassMutual), or using epigenetic data (LifeEpigenetics). These developments will affect health and life insurance markets in the direction that our article envisions, which is to treat the life insurer as an equity holder in the policy holder's life.

VI. Broader Implications

VI.A. Financing Life-Extending Treatments

Our insights extend beyond cancer and immunotherapy to any life-extending medical treatment that is expensive. We mention several examples below.

The drug Sovaldi cures hepatitis C with 90% probability and few side effects but costs $84,000 for a standard 12-week course. Left untreated, hepatitis C attacks the liver and can lead to cancer or liver failure. A life insurance company would have an incentive to provide care-free access, using the mechanisms described in Section IV.G.

A second example is organ transplants. In 2017, nearly 17,000 kidney transplants were performed in the United States at an average cost of $415,000 per transplant. In the United States about 8,000 people die each year because organs are not available in time. Life insurance companies may also have an incentive to stimulate the development of artificial organs.

A third example is severe heart failure, a condition that afflicts about two million Americans. A new device, MitraClip, sharply reduces death rates. A randomized control trial shows a 48% drop in all-cause mortality in the 24 months after the device is implanted (Stone et al. 2018). The device costs $30,000, not counting the cost of hospitals and doctors.

A fourth example is HIV/AIDS, which affects 37 million people worldwide. About 22 million have access to antiretroviral therapy. While AIDS-related deaths have fallen by 51% since the peak in 2004, nearly 1 million still died in 2017 (UNAids). A year of optimal treatment costs $18,300 in the United States.

A fifth example are gene therapies, such as Novartis's Zolgensma that is priced at $2.1 million per patient. Zolgensma was approved in May 2019 for children younger than two years diagnosed with spinal muscular atrophy (SMA). The treatment also promises durable improvements in survival.

A sixth and maybe more controversial example is opioid addiction. The Centers for Disease Control and Prevention reports that opioid-related deaths in the United States have quadrupled from 2000 to 2017; cumulative deaths over this period number 700,000. Mortality rates among opioid addicts are 6 to 30 times as high as in the general population (Darke, Degenhardt, and Mattick 2007). Opioid substitution treatment (OST) with methadone or buprenorphine is effective at reducing mortality. In a large study conducted in Taiwan that followed 1,283 patients for 5 years, life expectancy for OST subjects was 7.2 years longer than for non-OST subjects (Chang et al. 2015). A twenty-year longitudinal study in Australia found a 29% reduction in mortality for OST recipients (Degenhardt et al. 2009). Moral hazard is arguably much higher for OST than for most other life-extending treatments and may require stricter payment limits.

More speculative at this point are gene and stem cell therapies, regenerative medicine, and molecular repair, all of which hold some promise to increase longevity but are expensive. If and when the clinical benefits of such treatments have been shown, life insurance could be an important source of funding.

VI.B. Implications for Long-Term Care Insurance Markets

The idea developed in this article also applies to long-term care insurance. Long-term care insurers benefit from effective treatments that lower the likelihood that a policy holder needs expensive care late in life, such as a prolonged stay in a nursing facility. If (partially) effective treatments against Alzheimer's disease were discovered, long-term care insurers would have an incentive to offer similar financing mechanisms. Like in cancer treatment, immunotherapies hold promise to be the first disease-modifying treatment for Alzheimer's. The same cost of care issues would apply.

VI.C. Implications for Pharma and Innovation in Cancer Drugs

Since the first immunotherapy for HER2-positive breast cancer was approved by the FDA in 1998, the number of new immunotherapies has increased rapidly (recall Table I). If the drug pipeline is an indication, we are only at the beginning of a major change in cancer care. As of May 2018, pharmaceutical companies were developing almost 300 molecules with 60 separate mechanisms, all in clinical trial stages or awaiting FDA review.

Immunotherapies belong to a wider class of targeted therapies that use genetic marker tests to indicate a greater likelihood of tumor response or amplify the patient's immune response. Targeted therapies make up 90% of the late-phase oncology pipeline in 2016 (Quintiles IMS Institute 2017).

Another metric to describe the growth curve in immunotherapy is total drug sales that we summarize in Online Appendix D, Table A.2. We scale the total sales numbers by the per patient costs. Two aspects stand out. First, the total number of U.S. patients receiving the treatment in 2016 based on the sales data (372,000) is close to the number of cancer patients diagnosed in 2016 as reported in Table V based on SEER. This does not mean that all patients diagnosed with cancer receive immunotherapies, as some may receive multiple or combination treatments. But the calculation does illustrate that these treatments are widely used. The second aspect that stands out from the drug sales data is the very steep trend in U.S. and global sales. Global immunotherapy drug sales have nearly tripled in the past four years, from $13 billion to $33 billion, or 26% annually.

The development of life-extending treatments requires major investments. The top-10 pharmaceutical companies spent over $60 billion on R&D in 2015, or almost 20% of revenues. About one-third of the R&D spending is on cancer drugs. Acemoglu and Linn (2004) and Finkelstein (2004) provide evidence that the pharma industry adjusts the amount and direction of medical innovation in response to profit incentives. Using life insurance to finance life-extending treatments would grow the size of the drug market. The impact on pricing is more ambiguous and would depend on the market power of pharmaceutical companies compared with health insurers, the government, life insurers, and patients, but total profits increase in standard models. Those profits could finance further R&D into immunotherapy, eventually leading to wider applicability (more cancer sites) and further improvements for existing sites, generating more gains in life expectancy.

Finally, given the long-term nature of insurance policies, life insurers may have a direct incentive to fund long-term medical innovation, thereby alleviating the underinvestment problems in long-term cancer research (Fernandez, Stein, and Lo 2012; Budish, Roin, and Williams 2015).

In addition to developing new treatments, ongoing research focuses on developing new tools that can better predict whether immunotherapy is likely to be effective for an individual. More, better, and cheaper tests for biomarkers that predict effectiveness

will reduce the cost of clinical trials and further spur drug development. With better and cheaper pretests, the life insurer that finances immunotherapy would waste fewer resources on patients for whom the treatment is unlikely to work. This would act as an increase in the effectiveness parameter θ in equation (2). If a certain therapy is too costly relative to the benefit it provides for the current value of θ, and therefore cannot be financed by the life insurer, then a better pretest could change the cost-benefit calculus. More expensive treatments could now be financed because fewer resources are lost on patients for whom the treatment will not work. If the insurer was already willing to pay at the current θ, then a better pretest would result in fewer dollars spent. In a competitive life insurance market place, this would result in lower insurance premiums.

VII. Conclusion

Life-extending medical innovation creates large benefits to life insurers. We quantify the benefit of FDA-approved immunotherapies, a prime example of such innovation, to be about $9.8 billion a year. This value creation can help finance the cost of cancer care for patients with life insurance. Going forward, life-extending medical innovation may lower the cost of life insurance, stimulate development of new life-extending treatments, and redraw the boundaries between life and health insurance. Our insights are broadly applicable to life-extending medical innovation as well as to medical innovation that lowers the probability of admission to long-term care facilities.

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Supplementary Material

An Online Appendix for this article can be found at *The Quarterly Journal of Economics* online. Data and code replicating tables and figures in this article can be found in Koijen and Van Nieuwerburgh (2019), in the Harvard Dataverse, doi:10.7910/DVN/DWCGBY.

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