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# FINANCING THE WAR ON CANCER

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## ABSTRACT

We estimate the potential gains of life-extending treatments to life insurance companies and apply it to immunotherapy. These treatments promise to dramatically raise durable survival rates for a growing number of cancer patients but are often prohibitively expensive for patients and governments alike. Our main insight is that life insurance companies have a direct benefit from such treatments as they lower the insurer's liabilities by pushing the death benefit further into the future and raise future premium income. Using detailed survival data from clinical studies, we quantify the insurers' benefit from immunotherapy for melanoma patients. Extrapolating to 17 other cancer sites, we estimate the insurance sector's benefit to equal $6.8 billion a year. We discuss various financing mechanisms that exploit this value creation, which depend on the relative bargaining power of insurers and consumers. Moreover, the potential gains for life insurers, which could only accrue if health insurers cover the cost of the treatments and households finance the out-of-pocket expenditure, may warrant some exploration of new boundaries between life and health insurance. We discuss the broader implications for medical innovation and long-term care insurance markets.



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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 have resulted in significant gains in long-term survival.[1] A major drawback is that the cost of immunotherapy is often extremely high. The combination of Yervoy (ipilimumab) and Opdivio (nivolumab), used in the treatment of melanoma, costs $159,100 for a standard twelve-week course. The cost of the CAR-T cell therapy Kymriah is $475,000.

Existing solutions to finance immunotherapy care 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.[2,3] When health care is tied to employment, as typical in the U.S., 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 ACA often exceeds 30% of pre-tax income.[4] Facing ever tighter budgets and mounting debt, governments cannot afford the cost of the drugs minus the copay. To illustrate, Figure 1 plots the number of new cancer drugs against the country's GDP per capita in 2016. Included are 42 new cancer drugs that were developed between 2011 and 2015. Of the 42 drugs, 37 were available in the United States by 2016. By contrast, in South Korea and Spain, countries with a GDP per capita

[1]Immunotherapy refers to a set of treatments that stimulate the body's immune system to attack cancer cells. The American Cander 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. Unlike traditional cytotoxic chemotherapies and radiation, immunotherapies are fairly well tolerated, leave the healthy cells unscathed, can be repeated indefinitely, resulting in a more durable response.

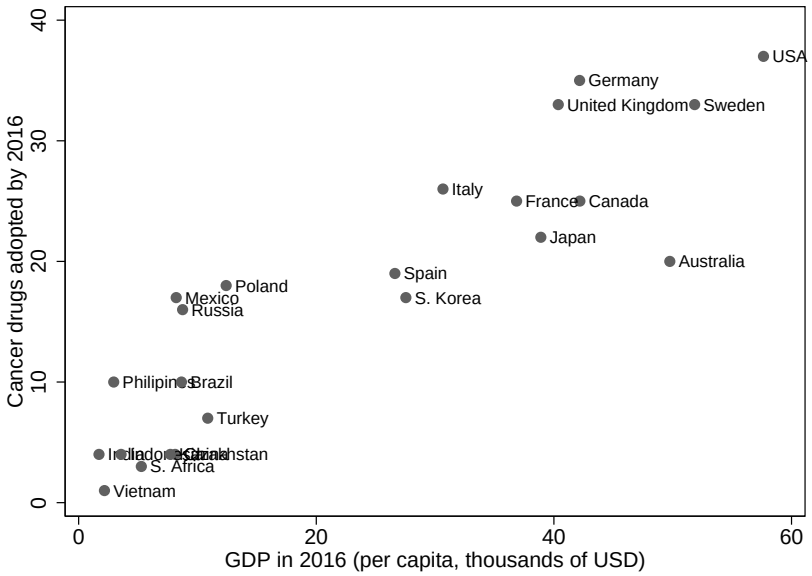
[2]Gupta, Morrison, Fedorenko, and Ramsey (2015) find that cancer diagnoses increase default and foreclosure rates, in part due to incomplete insurance coverage. Davidoff, Erten, Shaffer, Shoemaker, Zuckerman, Pandya, Tai, Ke, and Stuart (2013) find that the average out-of-pocket expenditure for Medicare beneficiaries with cancer equals $4,727 using data from 1997 to 2007.

[3]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 the programs' involvement in case 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).

[4]For example, the Silver plan under the Affordable Care Act (ACA, commonly known as ObamaCare), provides health care that costs $5,500 per 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 for this plan. The combined $20,200 amounts to 31% of pre-tax 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 pre-tax income.

of about 60% of the GDP per capita of the United States, fewer than 20 drugs were available.

Figure 1: **Adoption of New Cancer Treatments Across Countries.**
The figure plots the number of cancer drugs launched between 2011 and 2015 that are available across countries (vertical axis) relative to the 2016 GDP per capita in USD. Source: QuintilesIMS Institute (2017).




Second, various credit-based solutions have been discussed in earlier 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.

In 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, (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.

Our main insight is that life insurers experience large benefits from life-extending treatments and we quantify the gains for the case of immunotherapy. An example illustrates our basic insight. Consider an individual who purchases a life policy at age 30 and is diagnosed with stage-4 melanoma at age 40.

Per dollar of death benefit (or, face value), the policy now has a value of -$0.95 to the insurer. 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 $362,000 would generates a benefit that is the same as the entire $159,000 cost of the state-of-the-art Yervoy plus Opdivio treatment for a 12 weak treatment course. A patient would typically face "only" the copay and maximum out-of-pocket costs, about $20,000 for the typical family on Obamacare. 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.

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, the cost of the treatment, and patient demographics (in particular age and sex). Section 1 provides a model with these ingredients. Section 2 compiles evidence on these parameters and quantifies the insurers' benefit from immunotherapy for the case of metastatic melanoma.

We compile evidence that suggests similar benefits for 17 other cancer sites and staging with FDA-approved immunotherapies and we compute the aggregate benefit. Importantly, many households own life insurance policies. Among all financial instruments (stocks, bonds, annuities, etc.), life insurance enjoys the highest participation rate with 68% of men between age 35 and 54 owning 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 about $6.8 billion per year, given the incidence of cancer for which immunotherapies are currently available. The total cost of immunotherapies for consumers with life insurance is $10.1 billion and we estimate their aggregate copay to be $4.1 billion. This underscores the potential funding that can be unlocked.

Section 3 discusses how this benefit could be shared between life insurers and their policyholders,

[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 head aged 51 to 64.

depending on their relative bargaining power, which opens the possibility of new financing mechanisms. Moreover, the potential gains for life insurers, which could only accrue if health insurers cover the cost of the treatments and households finance the out-of-pocket expenditure, may warrant some exploration of new boundaries between life and health insurance. An integrated insurer would offer higher coverage rates for life-extending treatments by internalizing the benefit to the life insurance arm.

If consumers have all bargaining power, then the insurer covers the copay and yet still earns $2.7 billion from the immunotherapy breakthroughs. First, the patient gains access to treatment and the benefits of a longer life, while maintaining financial stability. The patient would not have to spend most of their savings on treatment nor have to lapse or sell her life insurance policy. She can resume life after cancer in good financial as well as physical health. If and when she dies, the life insurance policy would serve its intended purpose of providing financial stability for her dependents.

Alternatively, if the insurer has all the bargaining power, he can allow consumers to borrow against their death benefit at fair value to finance immunotherapies or reduce the death benefit by the cost of the treatment. The former solution uses the increased death benefit tied up in the insurance company as collateral, thereby bringing credit solutions within reach for a large group of patients. The latter solution corresponds to a perfectly efficient life settlement market, a secondary market place for life insurance policies. 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 bargaining power, there would be enormous gains in reputation for life insurance companies from saving lives. Furthermore, life insurance would become a more valuable product to consumers because it would now pay for life-enhancing medical treatment in case of a cancer diagnosis. Widespread adoption of this funding model would increase life expectancy in the

[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.

population, which would lower the cost of life insurance. The life insurance market would grow for all these reasons. A virtuous cycle 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 immunotherapies, accelerating the virtuous cycle.

Section 4 discusses the broader implications for the adoption of life-extending technologies, long-term care insurance, and the incentives for medical innovation. Section 5 concludes.

# 1 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. As a result of market incompleteness and moral hazard, we assume that the health insurer's optimal coverage rate $c^\star < 1$. Consequently, the health insurer does not fully reimburse the cost of immunotherapy.

We assume that a life insurance policy has been purchased before the new life-extending treatment is discovered. We discuss the long-run implications for life insurance markets in Section 3 and medical innovation in Section 4. 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 $\pi$ while alive is given by:

$$L\left(x,\pi,\mu\right)=\pi(x_0)\int_0^\tau \exp(-rs)_sp_x ds - F\int_0^\tau \exp(-rs)_sp_x\mu(x+s)ds, \tag{1}$$

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, and $\tau$ the residual maturity of the life insurance policy. Whole life insurance policies correspond to $\tau=\infty$ (large $\tau$). The first term is the discounted value of the premium payments, the second term the discounted value of the death benefit.

If the individual is diagnosed with the disease (say, cancer), 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 $L\left(x, \pi, \mu^D\right)$. This decrease stems from a reduction in expected premium payments and the closer proximity of the death benefit payout.

However, a life-extending treatment 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 therapy (to patient and health insurer). This treatment is successful with probability $\theta$.[7] The assumption that the treatment is successful with some probability is particularly well-fitting for immunotherapy. Only a fraction of patients responds to the treatment with durable gains in survival and it is typically not possible to determine beforehand who will show positive response. Conditional on treatment, the value of the life insurance policy increases from $L\left(x, \pi, \mu^D\right)$ to $\theta L\left(x, \pi, \mu\right) + (1-\theta) L\left(x, \pi, \mu^D\right)$.

The life insurer's benefit of treating a patient equals

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

implying that the 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, $\theta\left(L\left(x, \pi, \mu\right) - L\left(x, \pi, \mu^D\right)\right)$, contains a premium and a face value component:

$$\underbrace{\theta\pi(x_0) \int_0^\tau \exp(-rs)({}_sp_x - {}_s\, p_x^D) ds}_{\text{Premium component}} \underbrace{- \theta F \int_0^\tau \exp(-rs)({}_sp_x \mu(x+s) - {}_s\, p_x^D \mu^D(x+s)) ds}_{\text{Face value component}}, \tag{3}$$

where ${}_sp_x^D$ is the survival probabilities for an individual of age $x$ who is diagnosed with the disease

[7] While immunotherapies significantly extend life on average, these treatments only work for about 30-50% of patients. 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.

but does not receive the new treatment. The insurer's benefit in (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 pre-paid 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 to the situation without treatment.

# 2 Quantifying Life Insurers' Benefits of Immunotherapy

## 2.1 Data

The mortality rates conditional on a 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 nine cancer registries across the country and has expanded the coverage to eighteen registries representing approximately 28 percent of the U.S. population.[8] The database is the standard source for academic studies in medicine and health economics.

We use SEER*Stat software to collect the survival rates for patients diagnosed with melanoma between 2004 and 2014.[9] We collect the observed survival rate over a one-year horizon, conditioning on the stage of the cancer[10] as well as the patient's race (black or white), sex, and age group (30-34, 35-39, ..., 60-64, 65+) from the latest SEER 18 database submitted on November 2016.

In addition, we collect the expected survival rate without information on a cancer diagnosis, con-

[8] 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.

[9] The software can be downloaded from https://seer.cancer.gov/seerstat/software/. We used the latest version 8.3.4.

[10] We use the Derived AJCC Stage Group, 6th ed (2004+) variable from the SEER 18 database. Since we filter the patients diagnosed with cancers between 2004 and 2014, the staging information is widely available. Additional information on cancer staging in SEER is available from: https://seer.cancer.gov/seerstat/variables/seer/ajcc-stage/.

ditional on the same demographics. SEER*Stat calculates the expected survival rate using the *NCHS Annual US Life Tables* published by the National Center for Health Statistics. We use the underlying tables[11] and use the 2012 life tables, the latest year used in SEER, for each demographic group.

The list of approved immunotherapies is from the Food and Drug Administration (FDA). For each approval, we collect the date of FDA approval, drug brand name, drug scientific name, company that produces it, the cancer site (indication), and the cancer stage for which the drug is approved.

We use SEER to collect 2014 incidence rates for all cancer sites, for which there is an FDA-approved immunotherapy. We use staging information in the SEER data if the FDA approval is for a particular stage of the cancer. We scale up the SEER incidence rate to obtain the total number of annual new cases for the entire U.S. population. This is the incidence.

Costs for each drug are calculated by combining the Medicare payment limit per dose from the October 2017 ASP Drug Pricing Files with the prescribed dosage for a standard treatment course for an average adult weighing 70kg, obtained from the FDA drug labels.[12] The dosing regimen is for a 12-week course. Our cost estimates closely match those in Bach (2009). Sales data on each drug are obtained from annual company 10-K filings for 2016 and 2017.

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.

[11] Available at https://seer.cancer.gov/expsurvival/US.1970thru2012.individual.years.txt, accessed on Feb 22, 2018.

[12] Cost data available from: 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 and prescribed dosage available from: https://www.accessdata.fda.gov/scripts/cder/daf/.

Table 1: Immunotherapies.

| FDA Approval | Drug | Site | Incidence | Cost |
|---|---|---|---|---|
| 1998 Q3 | Herceptin | Breast (HER2+) | 2,853 | $ 20,911 |
| 2006 Q4 | Herceptin | Breast (HER2+) | 33,606 | $ 20,911 |
| 2009 Q4 | Arzerra | Leukemia (CLL) | 15,597 | $ 129,789 |
| 2010 Q2 | Prolia/Xgeva | Osteoporotic fracture | | $ 1,102 |
| 2010 Q2 | Provenge | Prostate | 17,446 | $ 42,867 |
| 2010 Q4 | Herceptin | Gastric or Gastroesophageal Junction (GEJ) | 1,982 | $ 20,911 |
| 2011 Q1 | Yervoy | Melanoma | 3,208 | $ 123,295 |
| 2011 Q3 | Adcetris | Lymphoma (HL, ALCL) | 1,810 | $ 74,466 |
| 2011 Q3 | Prolia/Xgeva | Prostate or Breast Cancer induced Bone loss | | $ 1,102 |
| 2011 Q3 | Zelboraf | Melanoma | 1,283 | $ 36,010 |
| 2011 Q4 | Sylatron | Melanoma | | $ 45,433 |
| 2012 Q2 | Perjeta | Breast (HER2+) | 2,853 | $ 8,457 |
| 2012 Q3 | Prolia/Xgeva | Osteoporotic fracture | | $ 1,102 |
| 2013 Q1 | Kadcyla | Breast (HER2+) | 2,853 | $ 32,279 |
| 2013 Q3 | Perjeta | Breast (HER2+) | 33,606 | $ 8,457 |
| 2013 Q4 | Gazyva | Leukemia (CLL) | 15,597 | $ 31,240 |
| 2014 Q2 | Cyramza | Gastric or Gastroesophageal Junction (GEJ) | 13,210 | $ 40,270 |
| 2014 Q3 | Keytruda | Melanoma | 3,208 | $ 28,472 |
| 2014 Q4 | Blincyto | Leukemia (ALL) | small | $ 71,372 |
| 2014 Q4 | Cyramza | Lung (NSCLC) | 81,174 | $ 40,270 |
| 2014 Q4 | Cyramza | Gastric or Gastroesophageal Junction (GEJ) | 13,210 | $ 40,270 |
| 2014 Q4 | Opdivo | Melanoma | 3,208 | $ 35,799 |
| 2015 Q1 | Opdivo | Lung (NSCLC Squamous) | 15,039 | $ 35,799 |
| 2015 Q2 | Cyramza | Colorectal | 26,843 | $ 40,270 |
| 2015 Q4 | Darzalex | Multiple myeloma | 22,206 | $ 58,349 |
| 2015 Q4 | Empliciti | Multiple myeloma | 22,206 | $ 46,464 |
| 2015 Q4 | Imlygic | Melanoma | 8,440 | $ 10,209 |
| 2015 Q4 | Keytruda | Melanoma | 3,208 | $ 28,472 |
| 2015 Q4 | Keytruda | Lung (NSCLC) | 81,174 | $ 28,472 |
| 2015 Q4 | Opdivo | Kidney (RCC) | 8,558 | $ 35,799 |
| 2015 Q4 | Opdivo | Lung (NSCLC Nonsquamous) | 66,134 | $ 35,799 |
| 2015 Q4 | Opdivo + Yervoy | Melanoma | 321 | $ 159,094 |
| 2015 Q4 | Yervoy | Melanoma | 8,440 | $ 123,295 |
| 2016 Q1 | Arzerra | Leukemia (CLL) | 15,597 | $ 129,789 |
| 2016 Q1 | Gazyva | Lymphoma (NHL) | 8,454 | $ 31,240 |
| 2016 Q1 | Opdivo + Yervoy | Melanoma | 1,604 | $ 159,094 |
| 2016 Q2 | Opdivo | Lymphoma (cHL) | 1,810 | $ 35,799 |
| 2016 Q2 | Tecentriq | Bladder | 7,042 | $ 38,466 |
| 2016 Q3 | Arzerra | Leukemia (CLL) | 15,597 | $ 129,789 |
| 2016 Q3 | Keytruda | Head and Neck | 21,349 | $ 28,472 |
| 2016 Q4 | Darzalex | Multiple myeloma | 22,206 | $ 58,349 |
| 2016 Q4 | Keytruda | Lung (NSCLC) | 81,174 | $ 28,472 |
| 2016 Q4 | Lartruvo | Soft Tissue Sarcoma | 1,777 | $ 44,475 |
| 2016 Q4 | Opdivo | Head and Neck | 21,349 | $ 35,799 |
| 2016 Q4 | Tecentriq | Lung (NSCLC) | 81,174 | $ 38,466 |
| 2017 Q1 | Bavencio | Skin (MCC) | 1,500 | $ 35,336 |
| 2017 Q1 | Keytruda | Lymphoma (cHL) | 1,810 | $ 28,472 |
| 2017 Q1 | Opdivo | Bladder | 7,042 | $ 35,799 |
| 2017 Q2 | Bavencio | Bladder | 7,042 | $ 35,336 |
| 2017 Q2 | Darzalex | Multiple myeloma | 22,206 | $ 58,349 |
| 2017 Q2 | Imfinzi | Bladder | 7,042 | $ 41,550 |
| 2017 Q2 | Keytruda | Lung (NSCLC Nonsquamous) | 66,134 | $ 28,472 |
| 2017 Q2 | Keytruda | Bladder | 7,042 | $ 28,472 |
| 2017 Q2 | Keytruda | MSI-H or DMMR (mostly colorectal) | 26,843 | $ 28,472 |
| 2017 Q2 | Rituxan Hycela | Lymphoma and Leukemia | 50,949 | $ 21,445 |
| 2017 Q3 | Blincyto | Leukemia (ALL) | 5,465 | $ 71,372 |
| 2017 Q3 | Keytruda | Gastric or Gastroesophageal Junction (GEJ) | 18,117 | $ 28,472 |
| 2017 Q3 | Kymriah | Leukemia (ALL) | 3,100 | $ 475,000 |
| 2017 Q3 | Mylotarg | Leukemia | small | $ 45,250 |
| 2017 Q3 | Opdivo | Colorectal (MSI-H) | 26,843 | $ 35,799 |
| 2017 Q3 | Opdivo | Liver (HCC) | 3,777 | $ 35,799 |
| 2017 Q3 | Yervoy | Melanoma | 3,208 | $ 123,295 |
| 2017 Q4 | Adcetris | Lymphoma (pcALCL, CD-30 MF) | small | $ 74,466 |
| 2017 Q4 | Gazyva | Lymphoma (NHL) | 8,454 | $ 31,240 |
| 2017 Q4 | Ogiviri | Breast or stomach (HER2+) | 4,834 | $ 20,911 |
| 2017 Q4 | Opdivo | Melanoma | 8,440 | $ 35,799 |
| 2017 Q4 | Perjeta | Breast (HER2+) | 33,606 | $ 8,457 |
| 2017 Q4 | Yescarta | Lymphoma (NHL; DLBCL) | 7,330 | $ 373,000 |
| 2017 Q4 | Zelboraf | ECD | small | $ 36,010 |
| 2018 Q1 | Imfinzi | Lung (NSCLC) | 122,282 | $ 41,550 |

## 2.2 New Immunotherapies and Improvements in Survival

**Immunotherapies: Approvals, Incidence, and Cost** Table 1 illustrates the rapid expansion of FDA-approved immunotherapies. Each row corresponds to a FDA approval event; the approval dates in column 1 are listed in chronological order. The second column reports the drug's brand name. The third column reports the cancer site. The fourth columns 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) in the seventh row of the table pertains to metastatic (stage 4) melanoma. The incidence number also pertains to stage-4 melanoma. Column 5 reports the cost of the drug for a 12-week treatment. This is a lower bound on the cost.[13]

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. In addition to checkpoint inhibitors, adoptive cell therapies such as CAR-T cell therapy and oncolytic virus therapy have been approved 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 (in combination with chemotherapy). As the incidence numbers in column 4 indicate, current therapies are applicable to hundreds of thousands of cases in the U.S. alone. Third, the cost of these drugs is high, often on the order of annual median U.S. household income and sometimes a multiple thereof.

**Survival Improvements** Figure 2 illustrates the improvements in survival for recently-approved immunotherapies for stage 3-4 melanoma (Panel A), leukemia (Panel B), lung cancer (Panel C), and

[13]Some treatments are one-time, in which case we report the one-time cost. Several treatments are longer than 12 weeks, but we still only report the 12-week cost. For example, Herceptin (first row of Table 1) can be up to 52 weeks. Moreover, 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.

breast cancer (Panel D). The graphs are taken from the clinical studies.[14] 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 30% 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. In part, this is due to the recent nature of 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.[15] Hundreds of ongoing and future clinical trial studies will remedy this problem. Nevertheless, the early evidence on survival gains is encouraging. Also, as mentioned before, an important advantage relative to traditional cancer therapies is that immunotherapies are fairly well tolerated, leave the healthy cells unscathed, and can be repeated, all of which 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 ten-year survival rate is lifted from 75% without to 84% with immunotherapy.

## 2.3 Estimating Survival Gains

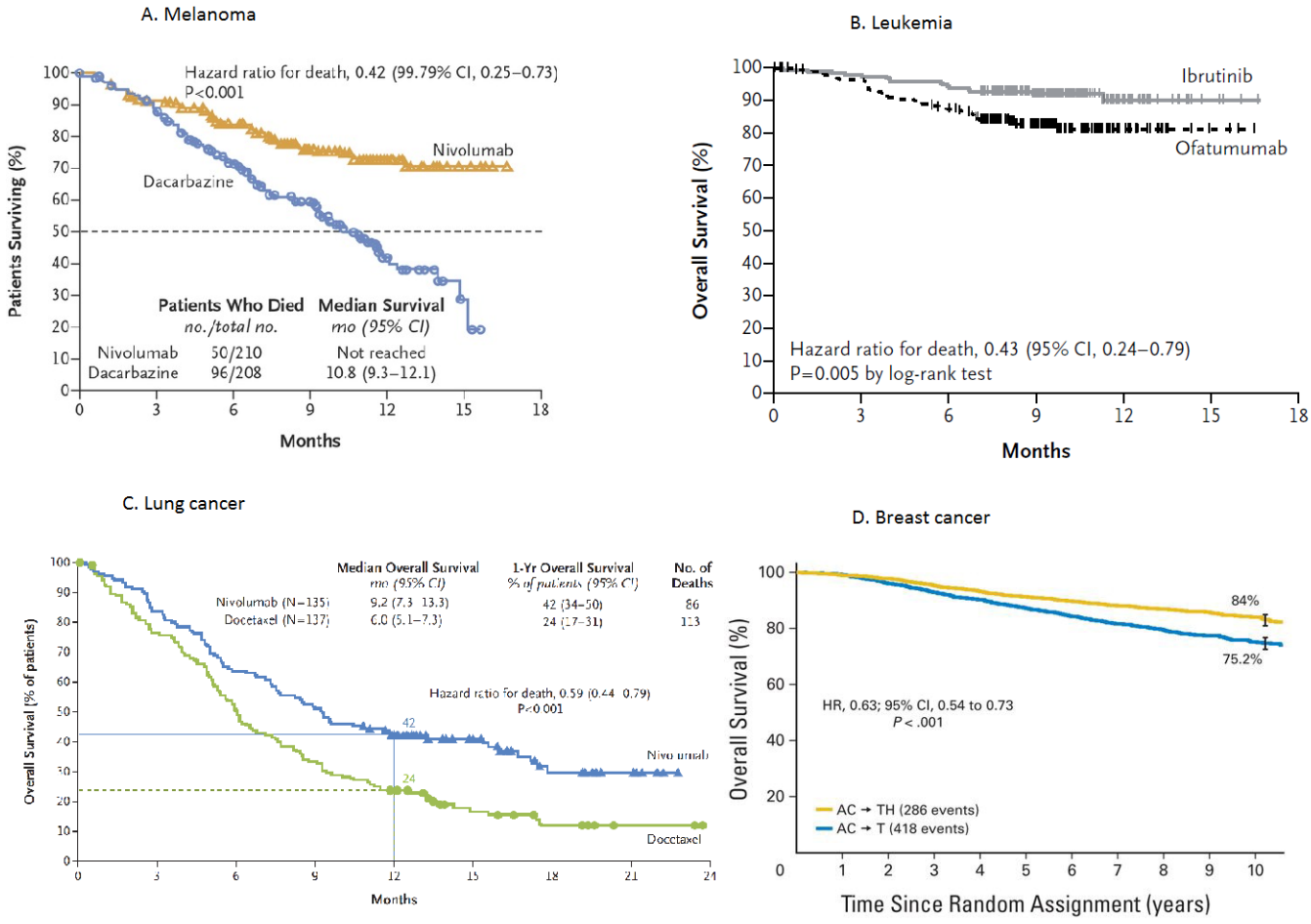
To assess the impact of a cancer diagnosis on a life insurer's liabilities, we estimate survival models for individuals with and without a cancer diagnosis. We use the Gompertz-Makeham mortality model in which the instantaneous mortality rate of an individual, without a cancer diagnosis, of age $x$ with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

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

[14] The figures are reproduced with permission from Robert et al. (2015), Byrd et al. (2014), Brahmer et al. (2015), and Perez et al. (2014), respectively.

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

Figure 2: **Improvements in Survival.**
The three figures illustrate the improvements in survival rates for melanoma (Panel A), leukemia (Panel B), lung cancer (Panel C), and breast cancer (Panel D).




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 clinical trial (Robert et al. 2015). The survival curves for the control group in the clinical trial 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. We focus on white men and women, since melanoma is rare for black individuals. We then combine men and women in the same proportion as in the clinical study by Robert et al. (2015).

We use the information in Panel A of Figure 2 to estimate $\theta$, the likelihood of success of the immunotherapy. Specifically, we estimate $\theta$ to match the one-year survival rate conditional on treatment in Robert et al. (2015), ${}_1p_x^T(z)$, as:

$${}_1p_x^T(z) = {}_1\, p_x(z)\theta + {}_1\, p_x^D(z)(1-\theta).$$

We use the mixed survival curves by gender for age 65, the median age of patients in the clinical study.[16] In case of melanoma, we find that $\widehat{\theta} = 0.5$ closely fits the survival curves conditional on immunotherapy treatment. This indicates that the treatment is effective for half of the patients.

## 2.4 A Life Insurer's Benefit of Immunotherapy for Melanoma

Panel A of Table 2 reports the life insurer's benefit of 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 clinical study by

[16] We assume that $\theta$ does not vary by age and gender. As more detailed data become available from ongoing clinical studies, this assumption can be relaxed.

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, Poterba, Warshawsky, and Brown, 1999) to determine the insurance premium $\pi$. Panels B and C break down the benefit into the premium and face-value components as in equation (3).

The main insight of the table is that the life insurer experiences large benefits from immunotherapy treatment of stage-4 melanoma. For an individual who purchased life insurance at age 30 and is diagnosed at age 40, the benefit is $0.44 per dollar of death benefit (face value). A policy with a death benefit of $362,000 would be sufficient to cover the entire $159,000 cost of the Yervoy plus Opdivio treatment for a 12 weak treatment course. The patient would typically face "only" the copay and maximum out-of-pocket costs, about $20,000 for the typical family on Obamacare. A life insurance policy with a face value as small as $46,000 would generate a large enough benefit to cover the copay.

Table 2: **The Insurer's Benefit of Immunotherapy for Melanoma per Dollar of Face Value.** The table reports the insurer's benefit (Panel A) and the breakdown in the premium and face-value effect (see equation (3)) in Panel B and C, respectively. 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.

| | Panel A: Insurer's benefit | | | | | Panel B: Premium effect | | | | | Panel C: Face value effect | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age of | Age of diagnosis | | | | | Age of diagnosis | | | | | Age of diagnosis | | | | |
| purchase | 30 | 40 | 50 | 60 | 70 | 30 | 40 | 50 | 60 | 70 | 30 | 40 | 50 | 60 | 70 |
| 30 | 0.48 | 0.44 | 0.37 | 0.30 | 0.22 | 0.13 | 0.11 | 0.10 | 0.08 | 0.06 | 0.36 | 0.32 | 0.28 | 0.22 | 0.16 |
| 40 | | 0.49 | 0.42 | 0.33 | 0.24 | | 0.17 | 0.14 | 0.11 | 0.08 | | 0.32 | 0.28 | 0.22 | 0.16 |
| 50 | | | 0.49 | 0.39 | 0.28 | | | 0.21 | 0.17 | 0.12 | | | 0.28 | 0.22 | 0.16 |
| 60 | | | | 0.49 | 0.36 | | | | 0.27 | 0.19 | | | | 0.22 | 0.16 |
| 70 | | | | | 0.49 | | | | | 0.32 | | | | | 0.16 |

If we decompose the benefit into the premium and the face value components, we find that the former accounts for $0.11 and the latter for $0.32 in the example. The face value component is invariant to the age of purchase, and declines strongly 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 individual is diagnosed with cancer, the benefits of restoring that person to health are largest. 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 willingness-to-pay is 22 cents per dollar of face value. A policy with a $100,000 death benefit would suffice to cover a typical $20,000 copay.

In Table 5 in the appendix, we explore the sensitivity of our estimates to the interest rate, the markup, and the effectiveness of immunotherapy. We assume that the interest rate is the same when the policy is purchased compared to 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 zero, 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. The effectiveness of immunotherapy has a first-order effect on the insurer's benefit; the benefit is linear in $\theta$. 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 $\theta = 0.50$ to $0.65 when $\theta = 0.75$. Conversely, a lower value of $\theta = 0.25$, would reduce the benefit to $0.22. Using a lower value of $\theta$ (than the point estimate) could be a way of taking into account model uncertainty surrounding the long-term survival gains resulting from immunotherapy (Hansen and Sargent, 2001).

## 2.5 Life Insurance Coverage

Our insights applies broadly as life insurance ownership is prevalent. Table 3 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 2, and the same gender ratio as in the clinical trial, a life insurance company would be experience a benefit of $106k for a representative

40-year old who purchased their policy at age 30.

Table 3: **Ownership Rates and Coverage by Age, Gender, and Income.**
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.

| | Ownership rate | | Mean death benefit | |
|---|---|---|---|---|
| Age | Men | Women | Men | Women |
| 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 |

| | Ownership rate | | Mean death benefit | |
|---|---|---|---|---|
| Income | Men | Women | Men | Women |
| 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 |

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 as high as $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, illustrating the relevance of our financing solutions we discuss in Section 3 also for households with income levels below the median.

## 2.6 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, of that cancer $i$ in

group $j$ in a year, $LIpart_j$ the life-insurance participation rate of group $j$, $LIamt_j$ the average death benefit of the group's life insurance policy, $C_i$ the cost of immunotherapy treatment for cancer $i$, and $b_{ij}$ the life insurance company's benefit per dollar of death benefit, which depends on both patient demographics and cancer site. We provide further details on the precise calculations in Appendix B.

The aggregate benefit in a given year across all 17 cancer sites and demographic groups is:

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

Table 4 shows the incidence rate of cancer (column 2) for the sites for which the FDA has approved at least one immunotherapy (column 1). 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 330,000 new cases per year. Column 3 reports the per-capita cost. Column 4 lists the copay, which we set to a \$20,000 maximum out-of-pocket cost plus insurance premium that the patient shoulders, or the cost of treatment if the cost is lower than the copay.

The next three columns compute the aggregate benefit and the aggregate cost and copay for consumers with life insurance. The aggregate benefit amounts to \$6.77 billion per year. Using a 3% interest rate to discount the annual life insurance benefit flow results in a \$226 billion value. To put this 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.[17]

The total cost of immunotherapy, for consumers owning life insurance, amounts to \$10.14 billion, implying that the insurer's benefit corresponds to 67% of the total cost. Accounting for the fact that consumers only pay the copay, the \$6.77 billion benefit to the life insurance sector well exceeds the out-of-pocket costs to consumers of \$4.11 billion.

[17]Source: Annual report of the Federal Insurance Office at the U.S. Department of Treasury.

Table 4: **Aggregate Benefit, Costs, and Copays.**
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 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 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.

| Cancer Site<br>Per capita or aggregate | Incidence | Costs<br>PC | Copay<br>PC | Benefit<br>A | Costs<br>A | Copay<br>A | Benefit/Costs<br>A/A | Benefit/Copay<br>A/A |
|---|---|---|---|---|---|---|---|---|
| Lung-NSCLC | 122,282 | 34,663 | 20,000 | 2,595 | 2,745 | 1,584 | 95% | 164% |
| Breast | 32,456 | 16,579 | 16,579 | 285 | 343 | 343 | 83% | 83% |
| Colorectal | 26,843 | 34,847 | 20,000 | 732 | 603 | 346 | 121% | 211% |
| Myeloma | 22,206 | 55,377 | 20,000 | 428 | 794 | 287 | 54% | 149% |
| Head and Neck | 21,349 | 32,136 | 20,000 | 598 | 437 | 272 | 137% | 220% |
| Gastric and GEJ | 18,117 | 32,481 | 20,000 | 496 | 375 | 231 | 132% | 215% |
| Prostate | 17,446 | 42,867 | 20,000 | 308 | 467 | 218 | 66% | 141% |
| Leukemia-CLL | 15,597 | 105,142 | 20,000 | 154 | 1,059 | 201 | 15% | 77% |
| Kidney | 8,558 | 35,799 | 20,000 | 221 | 196 | 110 | 112% | 201% |
| Lymphoma-NHL/FL | 8,454 | 31,240 | 20,000 | 177 | 167 | 107 | 106% | 165% |
| Melanoma | 8,440 | 75,689 | 20,000 | 175 | 402 | 106 | 43% | 164% |
| Lymphoma-NHL/DBCL | 7,330 | 373,000 | 20,000 | 157 | 1,733 | 93 | 9% | 169% |
| Bladder | 7,042 | 35,925 | 20,000 | 145 | 161 | 90 | 90% | 161% |
| Leukemia-ALL | 5,465 | 205,915 | 20,000 | 89 | 316 | 31 | 28% | 289% |
| Liver | 3,777 | 35,799 | 20,000 | 112 | 86 | 48 | 131% | 234% |
| Lymphoma-HL | 1,810 | 205,915 | 20,000 | 52 | 207 | 20 | 25% | 261% |
| STS | 1,778 | 44,475 | 20,000 | 47 | 45 | 20 | 107% | 237% |
| Total | 328,951 | 50,199 | 19,662 | 6,771 | 10,137 | 4,107 | 67% | 165% |

# 3 Sharing the Benefit to Finance the War on Cancer

The previous section discussed the large windfall that has befallen life insurers in the wake of the adoption of immunotherapy. This section describe various ways in which this benefit can be shared between insurers and their customers in the short run. We then discuss potential longer-run implications for the future evolution of life and health insurance markets.

## 3.1 Short-Run Sharing of the Benefit

If the consumer had all bargaining power, the life insurer could pay for the out-of-pocket costs of treatment, up to their marginal benefit. All life insurance policy holders could receive immunotherapy treatment at no additional cost, while keeping their death benefits in tact. As follows from Table 4, life insurers would be willing to cover 100% of the out-of-pocket costs. Increasing life insurance participation rates and death benefits would raise this share further. Since the aggregate benefit exceeds the out-of-pocket cost ($6.77 vs. $4.11 billion), the insurers would still be left with a large gain of $2.66 billion even if they have no bargaining power whatsoever. This presents a rare opportunity of a free lunch.

If the life insurer had all bargaining power instead, it could shift the cost of treatment onto the policyholder. But, it could allow the consumer to access the increased present value of the death benefit at fair value to pay for immunotherapy and associated medical expenditures. The death benefit would be reduced by the cost of the therapy. Insurance products that offer payment of the death benefit when the policy holder has a major illness and payment of the death benefit upon death when she does not are already offered in Asia. 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 what it was prior to being diagnosed. Conditional on failure of the treatment, the policy holder looses (part of) the death benefit and the financial protection it offers her dependents.

At an intermediate bargaining weight, the life insurer could also offer a loan to pay for treatment. The loan would only need to be repaid if treatment is successful. The loan would be collateralized by the death benefit, to deal with the reduced ability to repay conditional on survival. The terms of the loan would depend on the relative bargaining power. This solution would keep the death benefit in place in all states of the world. And the life insurer would bear (and pool) the (idiosyncratic) treatment risk.

Standard 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.

## 3.2 Potential Long-Run Implications for Life and Health Insurance

By improving access to life-extending treatments, insofar as optimal from a 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 become more valuable to consumers by partially completing health insurance markets with critical illness cover. According to LIMRA data, life insurance coverage has declined during the recent decade from 74% for individuals between 35 and 44 years of age in 2004 to 62% in 2014. By offering life insurance at lower prices with additional benefits to cover life-extending treatments, this trend may slow or reverse. It would result in a larger fraction of the population with life insurance, providing benefits not only when an expensive immunotherapy is needed but also in any other adversity that leads to the death of the breadwinner. The higher demand for immunotherapy drugs and the dynamic effects on innovation discussed in Section 4.3 would result in improved longevity. Higher life expectancy would allow life insurers to further lower insurance premiums, and this would further increase participation

and coverage rates in life insurance. A virtuous cycle emerges.

Life-extending medical innovations like immunotherapy also raise questions about the long-run industrial organization of insurance markets, and in particular whether the current separation between health and life insurance is sustainable going forward. While a thorough analysis of the equilibrium price and provision of insurance in a post-immunotherapy world is left for future research, we summarize the basic economics of integrating health and life insurers.

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 immunotherapy 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):

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

where $c_I^\star$ solves:

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

which implies that $c_I^\star > c^\star$ as $\lambda_c > 0$ and $L\left(x, \pi, \mu\right) > L\left(x, \pi, \mu^D\right)$. 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 since it enables more individuals to pay for life-extending treatments out-of-pocket. There are gains from trade from internalizing the externality between the two insurers that so far operate independently.

The potential benefits of integrating life and health insurance are particularly relevant in the context of critical illness insurance.[18] A key insight from our analysis is that life insurance policies with a critical illness rider for life-extending treatments may in fact be cheaper, rather than more expensive, than policies without such riders. How much of the gain is passed through to the policy holder depends on the relative bargaining power of insurer and consumer.

# 4 Broader Implications

## 4.1 Financing Life-Extending Treatments

Our insights extend beyond cancer and immunotherapy to any life-extending medical treatment that is expensive. The drug Sovaldi cures Hepatitis C with 90% probability and with 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 a strong incentive to provide this drug free of charge to its policy holders.

A second example is organ transplants. In 2017, nearly 17,000 kidney transplants were performed in the U.S. at an average cost of $415,000 per transplant. In the U.S., about 8,000 people die each year because organs are not available in time. If the transplant does not take place for financial reasons, the life insurer could step in. Life insurance companies would also have an incentive to stimulate the development of artificial organs.

[18] In the United States, life insurance with critical illness riders are rare and such policies are more expensive. In other countries, such as Canada, critical illness insurance is more commonly available.

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.

## 4.2 Implications for Life and Long-term Care Insurance Markets

The idea developed in this paper is not limited to life-extending treatments and also applies to long-term care insurance. Long-term care insurers benefit from effective treatments that lower the likelihood that an individual needs expensive care late in life, such as a prolonged stay in a nursing home. For instance, if (partially) effective treatments against Alzheimer's disease were discovered, long-term care insurers would have an incentive to offer such treatments to their policyholders at reduced rates or even free of charge.

## 4.3 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 1. If the drug pipeline is an indication, we are only at the beginning of a major change in cancer care. As of May 2017, pharmaceutical companies were developing 247 immuno-oncology medicines and vaccines, all in clinical trial stage or awaiting review by the FDA. 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 own immune response. Targeted therapies make up 90% of the late phase oncology pipeline in 2016 (QuintilesIMS Institute, 2017).

Another metric to describe the growth curve in immunotherapy is total drug sales. Drug sales increased from virtually nothing in 2013 to $36 billion in 2016. According to a report by Markets & Markets, global cancer immunotherapy sales are expected to grow at a cumulative annual growth rate

of 14.8% per year from 2017 to 2023. Three blockbuster drugs illustrate this growth trajectory. Sales of Yervoy (ipilumab) increased by 18% from 2016 to 2017 to $1.24 billion, sales of Opdivio (nivolumab) increased by 31% to $4.95 billion, and sales of Keytruda (pembrolizumab) jumped by 172% to $3.81 billion.

The development of immunotherapies requires major investments. The top-10 pharmaceutical companies spent over $60 billion on R&D in 2015, or almost 20% of sales. 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. By using life insurance to finance life-extending treatments, the size of the drug market expands. This would allow pharma companies to spread the cost of R&D over more sales revenue, resulting in lower drug prices holding total profits fixed. Lower drug prices would increase the potency of the life-insurance funding scheme, magnifying the aggregate gains in life expectancy. Drug companies could keep profits high by expanding quantity, rather than being pressured by government and public opinion alike to reduce drug prices or give away drugs to some for free. Those profits could finance further R&D into immunotherapy, eventually leading to wider applicability (more cancer sites) and further improvements for existing sites, generating further gains in life expectancy.

Finally, given the long-term nature of insurance policies, life insurers would have a direct incentive to fund long-term medical innovation, thereby alleviating the under-investment problems in long-term cancer research (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 pre-tests, 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 $\theta$ in equation (2). If a certain therapy is too costly relative to the benefit it provides for the current value of $\theta$, and therefore not financed by the life insurer,

then a better pre-test could change the cost-benefit calculus. More expensive treatments could now be financed since fewer resources are lost on patients for whom the treatment will not work. If the insurer was already willing to pay at the current $\theta$, then a better pre-test would result in fewer dollars spent. In a competitive life insurance market place, this would result in lower insurance premiums.

# 5 Conclusion

Life-extending medical innovation creates large benefits to life insurers. We quantify the benefit of FDA-approved immunotherapies to be about $6.8 billion per year. This value creation can help finance the cost of cancer care for patients with life insurance. Life-extending medical innovation may redraw the boundaries between life and health insurance in the future.

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# A An Insurer's Benefit: Robustness

We compute the robustness of the benefit estimates for late-stage melanoma by varying the interest rate, the markup, and the effectiveness of immunotherapy in Table 5.

Table 5: **The Insurer's Benefit for Melanoma: Robustness.**
The table reports the insurer's benefit if we change the interest rate from 3% to 5% (Panel A), if insurance markets are perfectly competitive (Panel B), and if immunotherapy is more effective and $\theta = 0.75$ (Panel C). 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.

| | Panel A: $r = 5\%$ | | | | | Panel B: Markup = 0% | | | | | Panel C: $\theta = 0.75$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age of | Age of diagnosis | | | | | Age of diagnosis | | | | | Age of diagnosis | | | | |
| purchase | 30 | 40 | 50 | 60 | 70 | 30 | 40 | 50 | 60 | 70 | 30 | 40 | 50 | 60 | 70 |
| 30 | 0.47 | 0.44 | 0.39 | 0.33 | 0.25 | 0.47 | 0.43 | 0.37 | 0.29 | 0.21 | 0.73 | 0.65 | 0.56 | 0.45 | 0.33 |
| 40 | | 0.47 | 0.42 | 0.36 | 0.27 | | 0.47 | 0.41 | 0.32 | 0.24 | | 0.73 | 0.63 | 0.50 | 0.37 |
| 50 | | | 0.47 | 0.40 | 0.30 | | | 0.47 | 0.38 | 0.27 | | | 0.74 | 0.59 | 0.43 |
| 60 | | | | 0.48 | 0.36 | | | | 0.47 | 0.34 | | | | 0.74 | 0.53 |
| 70 | | | | | 0.47 | | | | | 0.46 | | | | | 0.73 |

# B Total Cost and Benefit Calculations

We compute the total benefit as a result of immunotherapy in a given year across all cancer sites (defined to include staging information) $i$ and demographic groups $j$, as in equation (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 3. 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, $C_i$, are given in Table 1. When multiple immunotherapies are available for a site, 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 $\xi$ for every cancer site and demographic group, but the data available are too limited to do so. We therefore assume that a cancer diagnosis triggers a shift in the mortality rate from the healthy rate $\mu(j)$ to the sick rate $\mu^D(i,j)$, where the shifter $\chi_{ij}$ depends on the cancer site and the demographic group:

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

Then the $s$-year survival probability of an individual of age $x$ diagnosed with cancer $i$ is:

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

In other words, $\chi_{ij}$ measures the percentage change in the one-year survival probability for cancer site $i$ and demographic group $j$ when going from healthy to diagnosed (D):

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

Since 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 $\chi_{ij}$. We average $\chi_{ij}$ across age groups, weighted by incidence, separately for males and females (and for each cancer site). The reason for an age-invariant $\chi$ is that otherwise we would have to integrate out future changes in $\chi$ in the calculation of the value of the life insurance contract. Since we find that $\chi_{ij}$ 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 $\chi_{ij}$ to blacks. We verify that this is a good approximation.

Calculating the $b_{ij}$ also requires a parameter $\theta$, measuring the effectiveness of immunotherapy. In theory, we could use clinical studies on each of the immunotherapies for each of the cancer sites to estimate $\theta$, like we did for stage-4 melanoma. Here we do something simpler. For each of the four cancer sites displayed in Figure 2 we calculate an effectiveness parameter:

$$ \theta = \frac{{}_1p_x^T - {}_1\,p_x^D}{{}_1p_x - {}_1\,p_x^D}, $$

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 $\theta$ of 0.51 for Melanoma (as discussed in the main text), 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 one-year survival rates. The average $\theta$ across these four cancer sites is 0.48. We use $\theta = 0.5$ for all cancer sites for simplicity.