How Much Are Medical Innovations Worth?

An Analysis Based on Millions of Patients and Thousands of Cost-Effectiveness Studies

Preliminary Draft

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Disclosure

The views expressed in this article are those of the authors. They do not necessarily represent those of the Bureau of Economic Analysis.

Introduction

Motivation

- Share of spending on health care has risen from 5 percent of GDP in 1960 to 17.7 percent in 2019
- Life expectancy has increased by 9 years over this period
- Potential connection:
  - New technology contributes to improved health outcomes (Murphy and Topel 2006)
  - New technology also drives spending growth (Chernew and Newhouse 2011)
- Many economists believe that technology improvement is "worth it," but it is difficult to measure the costs, benefits and real output of the sector

Introduction

Motivation

- In 2018, R&D spent on health care exceeds R&D for many other high tech areas of the economy
  - About $194 billion spent on health care
  - $108 billion spent on semiconductors, computers and components, and computer system design

Introduction

Measurement

- Technological improvements are reflected in national output for high-tech goods:
  - Computers - processing power, memory (Aizcorbe 2006 and Byrne et al. 2018)
    - 12 percent annual price decline (BLS CPI for computers and peripherals)
  - Smart phones - screen size, megapixels, memory, processing power
    - 17 percent annual price decline driven by quality improvements (Aizcorbe et al. 2020)
- Technology improvements are not reflected in the output for the medical care sector

Introduction

Measurement

- Measuring the value of medical innovation is difficult:
  - Moral hazard, principal agent problems, and imperfect information affect revealed preference approaches
  - Challenging to disentangling medical care from other factors (e.g., smoking and obesity) using health outcomes measures (e.g., observed mortality)
  - Measurement issues are distinct for each condition (e.g., viral suppression for HIV vs. lowering blood sugar for diabetes)
  - Information on treatments is fragmented across research studies

Our contribution

Simplifying data on health care innovations

- We gather fragmented information from thousands of cost-effectiveness studies (Tufts Cost-Effectiveness Registry Database)
- We systematically extract information on quality and costs from medical studies for specific conditions and treatments
- We connect this information to medical care claims to study real-world implications for economic measurement
- Both detailed and scalable approach to examining innovation in health care
- Able to handle conditions that do not have easy to measure outcomes (e.g., Hepatitis C)

Preliminary findings

- We show changes in costs, quality of treatments, quality-adjusted price indexes for three conditions
- Effects of innovation are different across conditions, with quality adjusted prices declining for two of the conditions
- More work is needed to expand analysis across more conditions

Literature

Detailed examination of individual conditions

- Depression - Berndt et al. 2002, Cataracts - Shapiro et al. 2001, Heart Attacks - Cutler et al. 1998, Diabetes - Eggleston et al. 2019, Heart Attacks, Heart Failure, Pneumonia - Dauda et al. 2020, and Romley et al. 2020 eight medical conditions

Comprehensive approaches

- Cost-effectiveness studies and implications for quality adjustment - Dunn et al. 2021
- Accounting of population health and spending by condition - Cutler et al. 2020

Theory

Define compensating variation implicitly using an indifference condition following Cutler et al. 1998:

$$U(H_1(m_1), Y - p_1 \cdot m_1 + CV) = U(H_0(m_0), Y - p_0 \cdot m_0)$$

First order Taylor-series approximation:

$$CV = \frac{U_h}{U_x} \cdot \Delta H_m - (p_1 \cdot m_1 - p_0 \cdot m_0)$$

- $\frac{U_h}{U_x}$: Value of health in units of the numeraire (\$ value of a statistical life year)
- ΔH_m: Change in health due to medical care treatment

Utility-based quality-adjusted price index:

$$P = \underbrace{\frac{s_1}{s_0}}_{\text{Unadjusted price index}} - \underbrace{\frac{\frac{U_h}{U_x} \cdot \Delta H_m}{s_0}}_{\text{Quality adjustment}}$$

- $s_i = p_i \cdot m_i$ — price of treatment in period i (e.g., cost of diabetes treatment)
- ΔH_m — change in health due to medical care
- $\frac{U_h}{U_x}$ — dollar value for an improvement in health (\$ value of a statistical life year)

Data

Tufts Medical Center Cost-Effectiveness Analysis Registry (CEAR) database

- 8,244 studies, 22,150 comparisons, covering 1976-2019
- Two Tufts researchers extract over 40 variables from each article including:
  - Costs of treatments (total out-of-pocket expenditures and insurer payments)
  - Quality-adjusted life years (QALYs) of treatments
- 4 Key variables:
  - (1.) QALY of intervention; (2.) Cost of intervention;
  - (3.) QALY of comparison treatment; (4.) Cost of comparison treatment;
- Other variables: Medical condition, type of intervention (e.g., drugs or procedure), study population (e.g., age and sex)
- Detailed wording for the treatment drugs/procedures

Data

Tufts CEAR cleaning

- Create link across studies that can also be merged to medical claims data
- Use detailed string variable for treatments (intervention and comparator) to standardize across studies
- Cleaned by hand:
  - Standardize treatment names to merge with NDC codes, HCPCS codes, or CPT codes
  - Drop:
    - Vague treatments: "anti-hypertension medication", "surgery"
    - Treatments not in insurance claims (e.g., diet, exercise, education, advice, timing of treatment)
    - Diagnostics and screening guidelines (not treatments)

Data

Tufts CEAR Coverage: ≈ 210 3 digit ICD-10 categories with studies

Top 20 Reported:

Rank	Tufts 3-digit ICD-10 categories	Number of Articles
1	I30-I52: Other forms of heart disease	449
2	E10-E14: Diabetes mellitus	383
3	C50: Breast cancer	314
4	B15-B19: Viral hepatitis	313
5	I20-I25: Ischemic heart diseases	296
6	B20-B24: Human immunodeficiency virus [HIV] disease	279
7	C15-C26: Malignant neoplasms of digestive organs	257
8	J09-J18: Influenza and pneumonia	203
9	I60-I69: Cerebrovascular diseases	197
10	C51-C58: Malignant neoplasms, breast	193
11	F30-F39: Mood [affective] disorders	144
12	B95-B97: Bacterial and viral infectious agents	134
13	N17-N19: Acute kidney failure and chronic kidney disease	132
14	M80-M85: Disorders of bone density and structure	126
15	C30-C39: Malignant neoplasms of respiratory organs	121
16	J40-J47: Chronic lower respiratory diseases	121
17	R83-R89: Abnormal findings on examination	120
18	C81-C96: Malignant neoplasms of lymphoid tissue	119
19	M15-M19: Osteoarthritis	113
20	M05-M14: Inflammatory polyarthropathies	110

Issues

- Goal: Use CEAR data to get one QALY/cost estimate for each treatment.
  - Issue: Many different studies to average over
  - Issue: Which drug is being compared varies
  - Issue: Level of QALYs/Costs vary by target population and other study specific factors
- To address these issues, think of this as a type of meta analyses

Data

MarketScan® Claims Data

- Commercial Claims data - IBM® MarketScan® Research Databases
  - Years of data: 2007-2018
  - Individuals under 65, enrolled at least 360 days
  - Averages around 29 million enrollees per year
  - Individual patient identifiers link to detailed medical claims data (i.e., line items in "explanation of benefits" form)
    - Diagnosis codes (ICD-9 and ICD-10)
    - Price information (insurer and consumer combined)
    - Treatment specific codes (i.e., NDC, HCPCS, or CPT)
- Supplement with data from SSR Health to adjust drug spending for rebates (Kakani et al. 2020)

Hepatitis C

Background

Use Hepatitis C as an illustration of our data/methods.

- Blood-borne virus.
- Leads to liver cirrhosis and potentially death
- Prognosis is 10-15 years - with treatment not fatal
- In 2016, 2.4-5 million people were estimated to have hepatitis C, about 15,000 die each year
- Considerable new innovation during our sample period

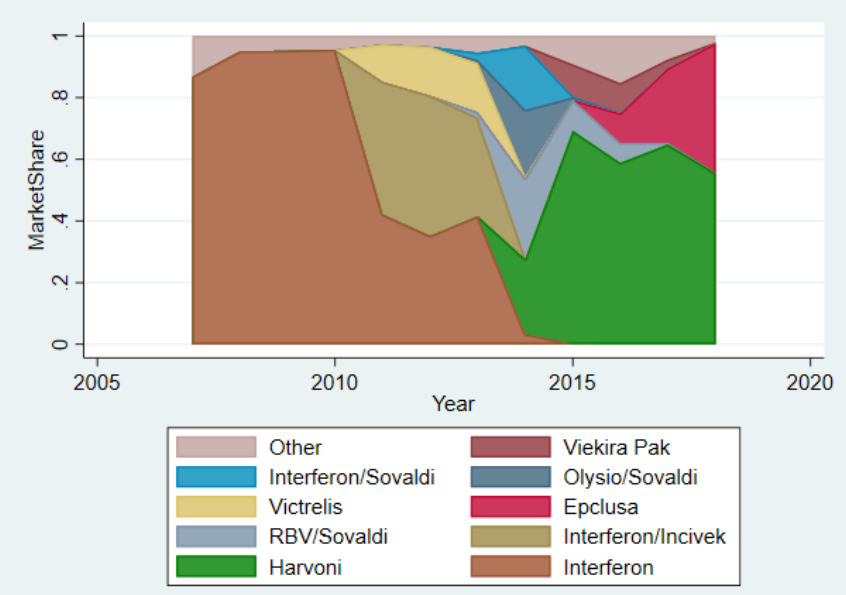
Hepatitis C

Background

- Prior to 2011, interferon based regimen was main treatment
  - Interferon has a low cure rates
  - Physician administered, i.e. requires regular office visits.
  - Strong flu-like side effects.
- Sovaldi enters in late 2013
  - Taken orally in combination with other drugs, fewer side effects
  - Cure rates up to 97%
  - But regimen costs $84,000
- Harvoni entered in late 2014
  - Higher cure rates, different genotypes
  - Lower cost than Sovaldi

Hepatitis C

Background



Methods

- Y_{ut} is outcome variable for either QALY or cost measure.
  - u — Study comparison that includes two observations
  - t — Treatment of a particular drug or procedure
- Goal is to recover average QALY/cost for each treatment, not a study-specific effect

Methods

Averaging over studies to measure treatments

Regression Model: $log(Y_{ut}) = \bar{Y}_t + T_u + \epsilon_{ut}$

- $\bar{Y}_t$ — Treatment specific factors (e.g, Sovaldi adds 3 QALYs relative to interferon)
- T_u — Comparison specific factors (e.g., study was done on an older population so both comparator and intervention are sicker)
- ϵ_{ut} — Unobserved treatment/comparison specific factors (e.g., different responses to intervention and comparator for this comparison)

Goal is to recover average QALY/Cost per treatment: $\bar{Y}_t$

Methods

Price of treatment

Two approaches to measure expenditures per treatment:

- Estimate costs based on CEAR data
- Estimate costs based on commercial claims data

Current method applied uses claims data:

- Assign spending based on diagnosis code on claims
- For drugs, leverage information from the Medical Expenditure Panel Survey (MEPS), where diagnosis is observed
- Compute lifetime costs based on life expectancy table

Estimates of spending by condition are preliminary

Preliminary results

Hepatitis C

$$log(Y_{ut}) = \bar{Y}_t + T_u + \epsilon_{ut}$$

	(1) Group	(2) Is Index Treatment	(3) Δ QALYs from Index
Epclusa	1	0	2.511
Harvoni	1	0	2.583
Interferon	1	1	
Interferon/Incivek	1	0	1.262
Interferon/Sovaldi	1	0	2.104
Olysio/Sovaldi	1	0	2.614
RBV/Sovaldi	1	0	1.092
Victrelis	1	0	0.748

Price index

$$P = \underbrace{\frac{s_1}{s_0}}_{\text{Unadjusted price index}} - \underbrace{\frac{\frac{U_h}{U_x} \cdot \Delta H_m}{s_0}}_{\text{Quality adjustment}}$$

- s_1 and s_0 — claims data
- ΔH_m — cost-effectiveness data for QALYs and claims data for treatments used in practice
- $\frac{U_h}{U_x}$ — \$ value of a statistical life year - \$50k, \$100k, and \$250k

Preliminary results

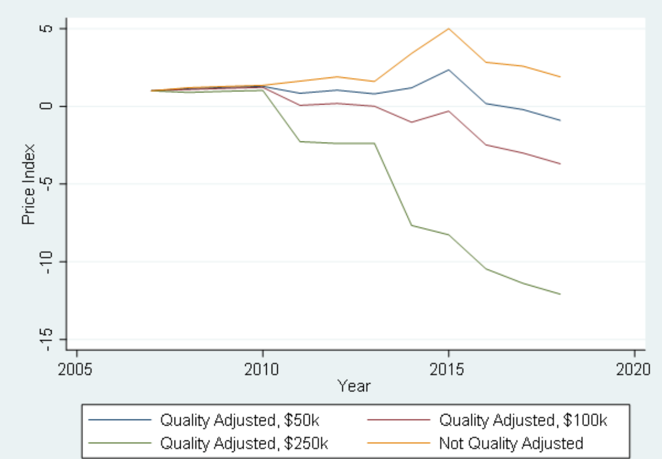
Hepatitis C

	(1) Change in Avg QALYs	(2) Avg Cost	(3) COLI $0 VSLY	(4) COLI $50k VSLY	(5) COLI $100 VSLY	(6) COLI $250k VSLY
2007	0.000	47,446	1.000	1.000	1.000	1.000
2008	0.058	57,025	1.202	1.141	1.080	0.896
2009	0.060	60,869	1.283	1.220	1.157	0.969
2010	0.062	64,076	1.351	1.285	1.220	1.025
2011	0.739	76,880	1.620	0.842	0.063	-2.272
2012	0.813	90,034	1.898	1.041	0.185	-2.384
2013	0.754	75,824	1.598	0.804	0.009	-2.374
2014	2.100	161,625	3.407	1.193	-1.020	-7.659
2015	2.517	237,223	5.000	2.348	-0.305	-8.261
2016	2.522	134,402	2.833	0.175	-2.482	-10.454
2017	2.651	122,636	2.585	-0.209	-3.003	-11.384
2018	2.652	89,892	1.895	-0.901	-3.696	-12.081

Preliminary results

Hepatitis C

Figure: COLI Indexes - Hepatitis C



Preliminary results

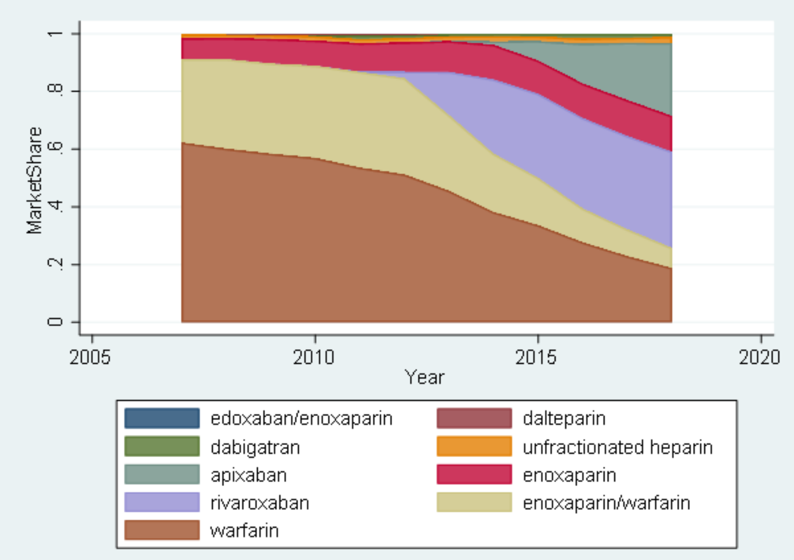
Hepatitis C

Discussion of previous slide:

- Calculation of quality-adjusted index from 2007-2018
  - Cost of treatment in 2007 (Column 2): $47.4k$
  - Cost of treatment in 2018 (Column 2): $89.9k$
  - Gross price index (Column 3): $\frac{89.9}{47.4} = 1.89$.
  - QALY difference between 2007 and 2018 (Column 1): 2.6
  - Assume $\$100k$ as value of statistical life year (Column 5)
  - Quality-adjusted price index: $\frac{89.9-100 \cdot 2.6}{47.4} = -3.59$

Preliminary results

Venous Thromboembolism (Blood Clot)



Preliminary results

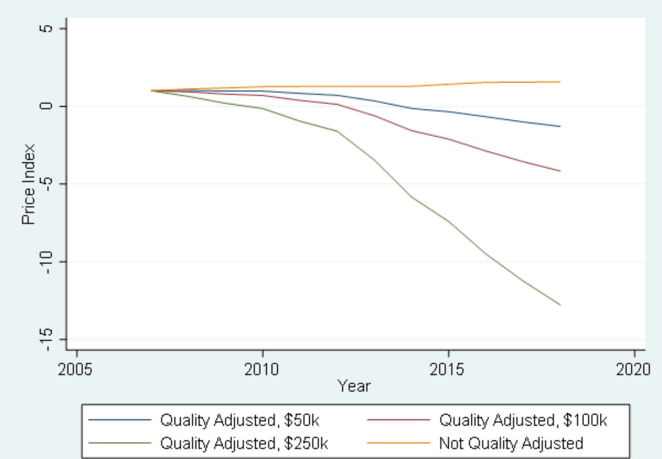
Venous Thromboembolism (Blood Clot)

	(1) Change in Avg QALYs	(2) Avg Cost	(3) COLI $0 VSLY	(4) COLI $50k VSLY	(5) COLI $100 VSLY	(6) COLI $250k VSLY
2007	0.000	1,553	1.000	1.000	1.000	1.000
2008	0.003	1,743	1.122	1.025	0.928	0.636
2009	0.006	1,838	1.183	0.986	0.788	0.195
2010	0.009	1,962	1.263	0.982	0.701	-0.142
2011	0.014	1,990	1.281	0.834	0.386	-0.956
2012	0.018	1,994	1.284	0.707	0.130	-1.600
2013	0.030	2,016	1.298	0.347	-0.604	-3.456
2014	0.044	2,003	1.289	-0.135	-1.559	-5.832
2015	0.055	2,208	1.421	-0.344	-2.110	-7.407
2016	0.069	2,398	1.544	-0.664	-2.872	-9.496
2017	0.079	2,417	1.556	-1.001	-3.558	-11.230
2018	0.089	2,457	1.581	-1.290	-4.161	-12.774

Preliminary results

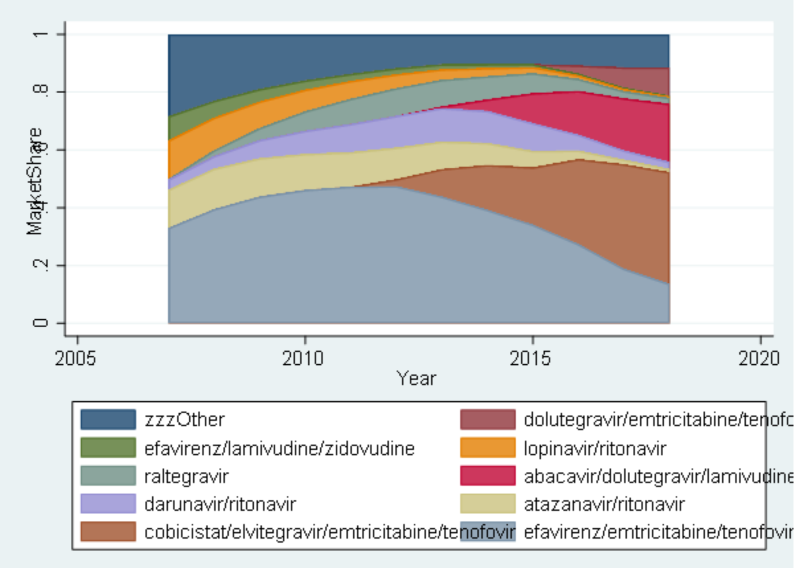
Venous Thromboembolism (Blood Clot)

Figure: COLI Indexes - Venous Thromboembolism



Preliminary results

HIV



Preliminary results

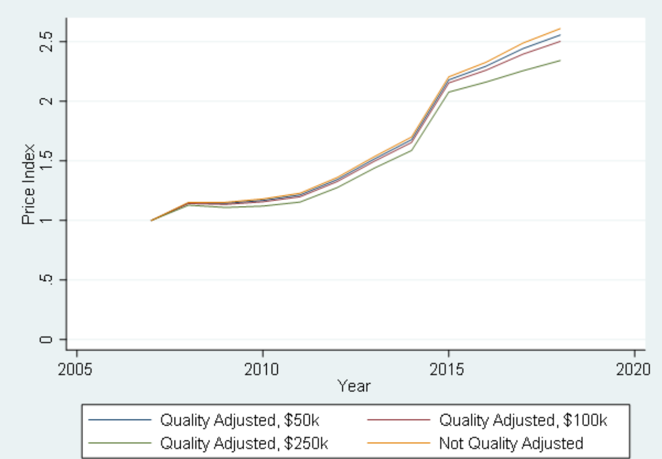
HIV

	(1) Change in Avg QALYs	(2) Avg Cost	(3) COLI $0 VSLY	(4) COLI $50k VSLY	(5) COLI $100 VSLY	(6) COLI $250k VSLY
2007	0.000	210,071	1.000	1.000	1.000	1.000
2008	0.020	241,997	1.152	1.147	1.142	1.128
2009	0.036	242,133	1.153	1.144	1.135	1.109
2010	0.050	247,950	1.180	1.168	1.156	1.121
2011	0.062	258,079	1.229	1.214	1.199	1.154
2012	0.071	285,881	1.361	1.344	1.327	1.276
2013	0.081	322,734	1.536	1.517	1.498	1.440
2014	0.096	357,287	1.701	1.678	1.655	1.587
2015	0.108	463,381	2.206	2.180	2.154	2.077
2016	0.140	489,008	2.328	2.295	2.261	2.162
2017	0.196	523,065	2.490	2.443	2.397	2.257
2018	0.225	548,411	2.611	2.557	2.503	2.343

Preliminary results

HIV

Figure: COLI Indexes - HIV



In progress...

- Gathering similar information for other conditions (currently reviewing over 20 conditions)
- Determining feasibility of analysis for each condition (challenge with missing treatments)
- Heterogeneity of treatments and effects on indexes (i.e., individuals selecting into their best treatment)

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