No time to die: The patent-induced bias towards acute conditions pharmaceutical R&D

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Introduction

Motivation

- Private and social R&D incentives are generally not aligned
- Require empirical evidence to pin down distortions

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    - Bias towards improving survival, rather than overall health
    - Adjusting for the wedge, this bias goes away

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$\rightarrow$ Provides evidence for a distortion in the direction of R&D

Outline

1) Private and social value of medical treatments
    - Wedge arising from surplus appropriability problem (Jones and Williams 2000)
2) R&D production function
3) Empirical analysis: estimating the elasticity of R&D

The private and social value of treatments

Willingness to pay

Murphy and Topel (2006) define the remaining lifetime expected utility at age a as

$$\int_a^\infty H(t)u\left(c(t), l(t)\right)\tilde{S}(t,a)e^{-\rho(t-a)}dt$$

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Willingness to pay for ΔS and ΔH

$$WTP(a) = \int_a^\infty \left[\underbrace{v(t)\Delta S(a,t)}_{WTP_S} + \underbrace{\frac{\Delta H(t)}{H(t)}\frac{u(c(t),l(t))}{u_c(c(t),l(t))}}_{WTP_H}\right]dt$$

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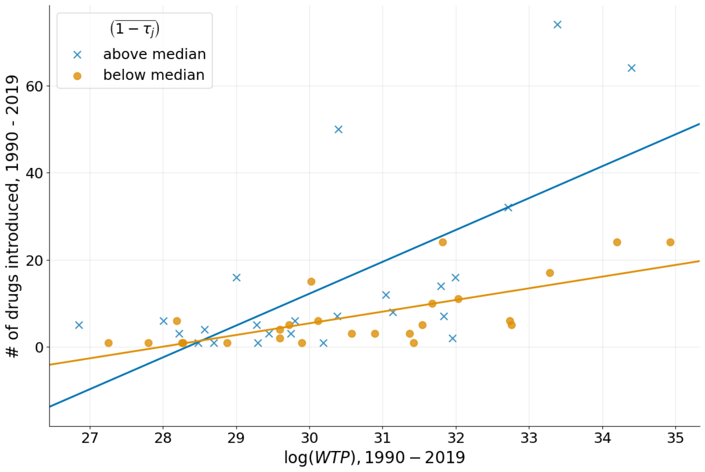
Private-social wedge

- Data source: Global Burden of Disease Study (1990-2019)
- Estimate $\text{WTP}_{j,20}$ and $\text{WTP}_{j,\infty}$ for each j
- Approximate the private-social wedge $(1-\tau) \sim \frac{\text{WTP}_{20}}{\text{WTP}_{\infty}}$

Does the private-social wedge matter for drug development?



DALY

R&D production function

Firm profit

$$\pi_j = f(z_j)D_j - \delta z_j^{\alpha}$$

where D_j is the willingness to pay for a treatment for condition j, z_j is the number of treatments developed, $f(z) = 1 - \frac{1}{z}$ denotes the share of total demand that can be appropriated with z treatments, and $\delta > 0$, $\alpha > 1$ describes the R&D cost. Hence

$$\frac{\partial \pi_j}{\partial z_j} = 0 \iff z_j = \left(\frac{1}{\alpha\delta} D_j\right)^{\frac{1}{\alpha+1}}$$

Empirical analysis

How does pharmaceutical R&D balance demand for survival and health?

Objective

$$\log(z_j) = \underbrace{\beta_S D_j^S + \beta_H D_j^H}_{D_j = D_j^S + D_j^H} + w_j' \gamma + \varepsilon_j$$

where

- z_j - R&D intensity of condition j
- D_j - demand for treatments for condition j measured in WTP
  - D_j^S and D_j^H measure demand for survival and health, respectively
- w_j - vector of controls

Identification - shift-share IV

Objective

$$\log(z_j) = \underbrace{\beta_S D_j^S + \beta_H D_j^H}_{D_j = D_j^S + D_j^H} + w_j'\gamma + \varepsilon_j$$

Shift-share IV - Intuition Instrument

- Demographic shift induced by the aging of the "baby boom" generation Population shares
- Age groups are differentially exposed to diseases Age profiles

Elasticity of innovation with respect to demand

Predictor: **WTP**

	(1)	(2)	(3)	(4)	(5)	(6)
β	0.142	0.155				
	(0.015)	(0.016)				
β_S			0.078	0.079	0.074	0.075
			(0.011)	(0.011)	(0.010)	(0.010)
β_H			0.001	0.004	0.013	0.018
			(0.009)	(0.010)	(0.009)	(0.009)
p-value for $H_0 : \beta_S/\bar{D}_S = \beta_H/\bar{D}_H$			0.00	0.00	0.00	0.00
Controls						
period and category FE	✓	✓	✓	✓	✓	✓
trial length		✓		✓		✓
income		✓			✓	✓
Instrument relevance						
Cragg-Donald	142.9	144.4	124.8	112.5	135.1	126.6
N	950	950	950	950	950	950

Correcting for the gap between private and social R&D incentives

Caveat: firms only appropriate a fraction of the generated surplus, as generic alternatives enter and monopoly rents disappear after patent expiry

Corrected specification

$$z_j = \beta_S \left((1-\tau_j)^S D_j^S \right) + \beta_H \left((1-\tau_j)^H D_j^H \right) + w_j' \gamma + \varepsilon_j$$

with

- $(1-\tau)^S = \frac{\text{WTP}_{20}^S}{\text{WTP}_{\infty}^S}$ and $(1-\tau)^H = \frac{\text{WTP}_{20}^H}{\text{WTP}_{\infty}^H}$

Elasticity of innovation with respect to demand

Predictor: **WTP corrected by** $(1-\tau)$

	(1)	(2)	(3)	(4)	(5)	(6)
β	0.180	0.201				
	(0.022)	(0.025)				
β_S			0.047	0.048	0.045	0.046
			(0.009)	(0.010)	(0.008)	(0.008)
β_H			0.011	0.013	0.026	0.031
			(0.011)	(0.013)	(0.011)	(0.012)
p-value for $\beta_S/\bar{D}_S = \beta_H/\bar{D}_H$			0.00	0.00	0.08	0.19
Controls						
period and category FE	✓	✓	✓	✓	✓	✓
trial length		✓		✓		✓
income		✓			✓	✓
Instrument relevance						
Cragg-Donald	89.8	85.1	105.5	94.8	107.5	101.5
N	950	950	950	950	950	950

Summary

This paper

- Proposes a novel metric for quantifying the gap between social and private returns to health innovations
- Study the elasticity of R&D to demand for survival and health
- Findings
    - Bias towards improving survival rates, rather than overall health
    - Adjusting for the wedge, this bias goes away

Next steps

- Explore innovation policies correcting for the wedge, including variable patent lengths
- Quantify the effect of policies on R&D allocations

Questions or comments?

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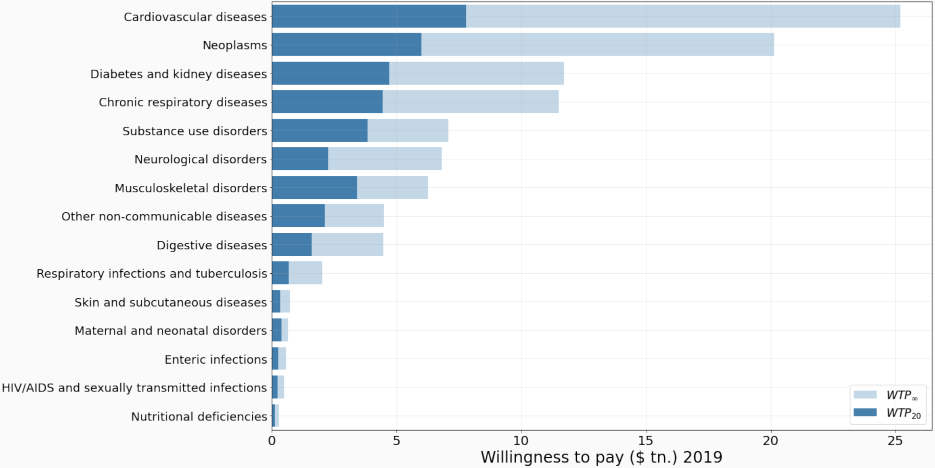
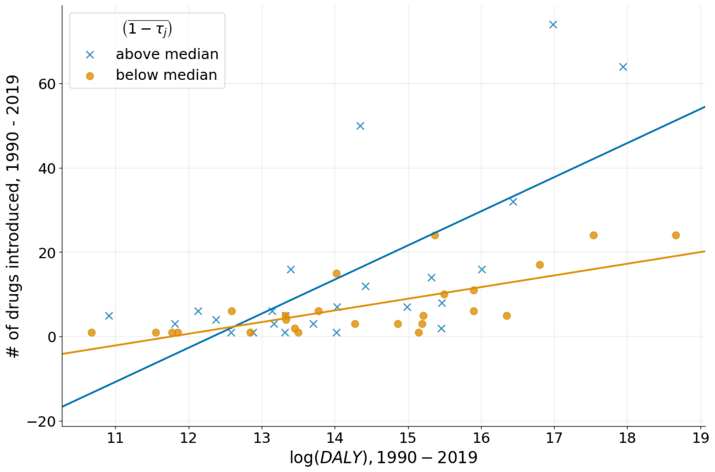
Thank you!

Appendix

Willingness to pay in the United States



Drugs introduced vs. Disability-adjusted life years (DALY)



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Measuring pharmaceutical R&D

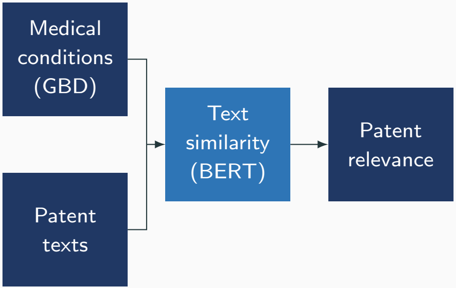
Challenge: no harmonized classification system for R&D per medical condition

- FDA
- Clinical trials

Measuring R&D

- Source: pharmaceutical patents (USPTO)
- Method: textual similarity

Innovation pipeline



Text to data

Patent relevance

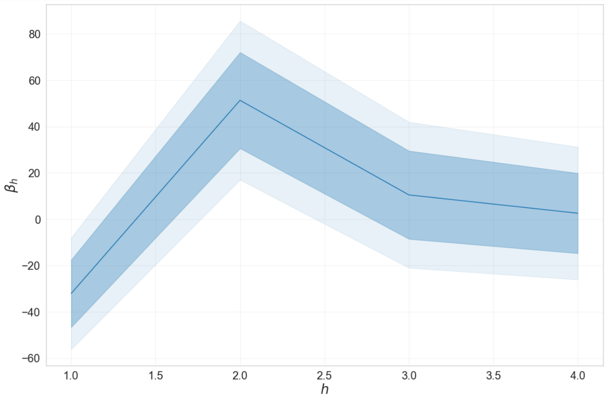
$$z_{j,t} = \sum_{i \in N_t} d(p_i, t_j)$$

where

- $d(.,.)$ - measure of textual similarity
- p_i - patent title
- t_j - medical condition
- N_t - set of all patents granted in year t

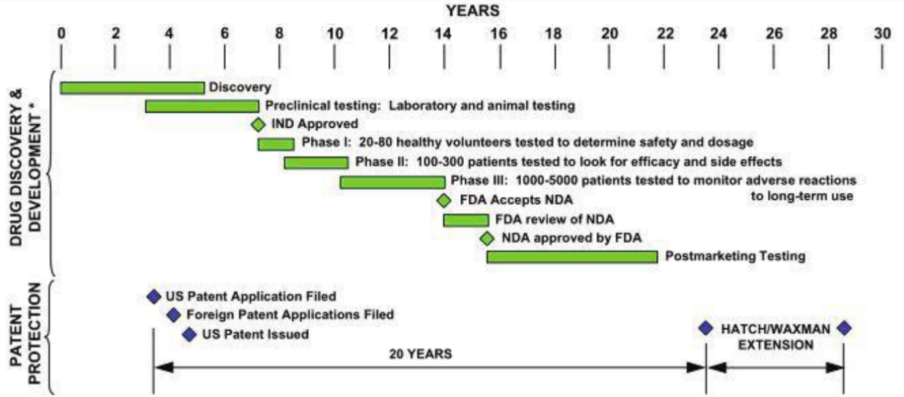
Validating the measure

Local projections: $c_{j,t+h} = \alpha_{j,h} + \gamma_{t,h} + \boldsymbol{\beta_h} z_{j,t} + \sum_{l=0}^{L} a_{h,l} c_{j,t-l} + \sum_{l=1}^{L} b_{h,l} x_{j,t-l} + \xi_{j,h}$



- $c_{j,t}$ - number of Phase I clinical trials targeting condition j in year t
- $z_{j,t}$ - average relevance of patents for condition j in year t

Innovation pipeline



Source: Lakdawalla (2018)

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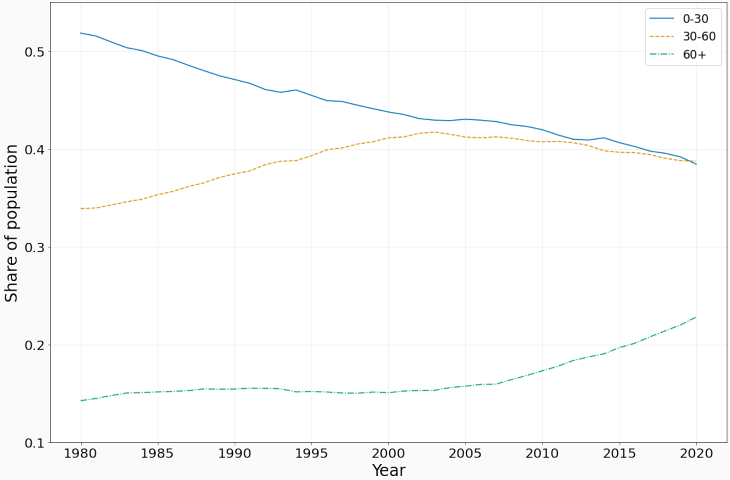
Population shares



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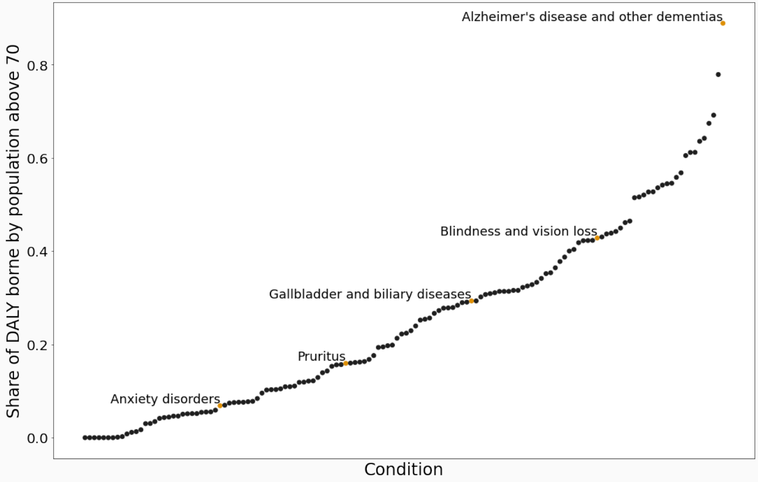
Disease burden per age group



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Shift-share instrumental variable

Shift-share instruments

$$d^l_{j,t} = \sum_n \underbrace{\alpha^l_{j,0} w^l_{j,n,0}}_{s^l_{j,n,0}} g_{n,t}$$

where

- $g_{n,t}$ is the population of age group n at time t
- $w^1_{j,n,0}$ - fraction of the overall YLL of condition j borne by age group n
- $\alpha^1_{j,0}$ - fraction of the overall disease burden (DALY) due to YLL
- $\sum_n \left[s^1_{j,n,0} + s^2_{j,n,0} \right] = 1$

SSIV specification

$$D^S_{j,t} = \lambda_1 d^1_{j,t} + \lambda_2 d^2_{j,t} + w'_{j,t}\phi + \eta_{j,t}$$
$$D^H_{j,t} = \lambda_1 d^1_{j,t} + \lambda_2 d^2_{j,t} + w'_{j,t}\phi + \eta_{j,t}$$
$$z_{j,t} = \alpha_1 d^1_{j,t} + \alpha_2 d^2_{j,t} + w'_{j,t}\gamma + \varepsilon_{j,t}$$

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Instrument validity

The shift-share instrument is consistent if it is

- Correlated with the treatment variable (Relevance)
- Uncorrelated with the unobserved residual (Validity)

Borusyak et al. (2021) show that orthogonality between the instrument and residual is achieved when the shocks g_n are as-good-as-randomly assigned, conditional on observables. Formally, the instrument is consistent if

- $\mathbb{E}\left[g_n|\bar{\varepsilon}, q, s\right] = q_n'\mu$
- $\mathbb{E}\left[\sum_n s_n^2\right] \to 0$
- $\mathrm{Cov}\left(\tilde{g}_n, \tilde{g}_{n'}|\bar{\varepsilon}, q, s\right) = 0$, where $\tilde{g}_n = g_n - q_n'\mu$ is the residualized shock