

# PRODUCTIVITY BELIEFS & EFFICIENCY IN SCIENCE

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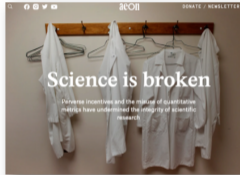
*University of Toronto*

March 2026

*Max Planck Institute for Innovation and Competition*

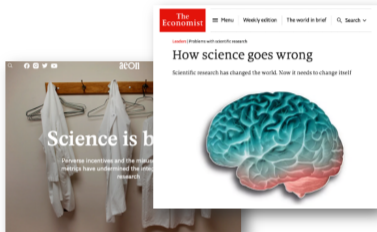
# DEBATES ABOUT PRODUCTIVITY AND EFFICIENCY IN SCIENCE

## BUT ARE MARGINAL PRODUCTS EQUATED?



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**Science is broken**  
Distorted incentives and the metrics have undermined the value of research

**The Economist** | Menu | Weekly edition | The world in brief | Search

Leaders | Problems with scientific research

## How science goes wrong

Scientific research has changed the world. Now it needs to

### Bad Incentives Undermine the Scientific Process

JAN 29, 2016 | Jenna A. Robinson

**T**HE SCIENTIFIC PROCESS IS BROKEN. Mentality, and the insufficient review, researchers spend less time solving a publication. But that wasn't always the case.

**THE JAMES G. MARTIN CENTER FOR ACADEMIC RENEWAL**

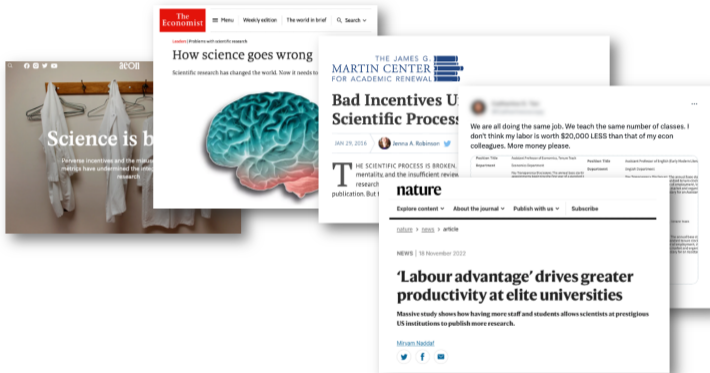
We are all doing the same job. We teach the same number of classes. I don't think my labor is worth \$20,000 LESS than that of my econ colleagues. More money please.

Position Title	Assistant Professor of Economics, Texas Tech	Assistant Title	Assistant Professor of English (Early Modern/Late)
Department	Economics Department	Department	English Department
Salary Range	The "Transparency Initiative" The annual base pay for an Assistant Professor in the school of economics is \$70,000. The starting salary for an Assistant Professor is \$70,000.	Salary Range	The "Transparency Initiative" The annual base pay for an Assistant Professor in the school of English is \$70,000. The starting salary for an Assistant Professor is \$70,000.
Number of Positions	Academic positions	Number of Positions	Academic (part-time)
Employment Type	Faculty	Employment Type	Faculty
Posting Number	2020	Posting Number	2020
Position Title	Assistant Professor of Sociology, Texas Tech	Position Title	Assistant Professor of History, Indiana State
Department	Sociology Department	Department	History Department
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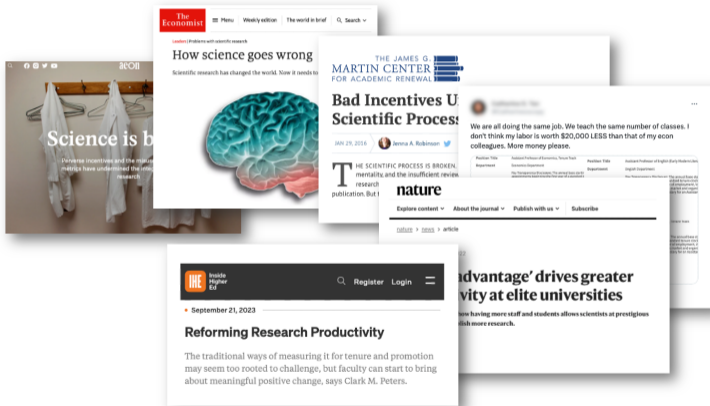
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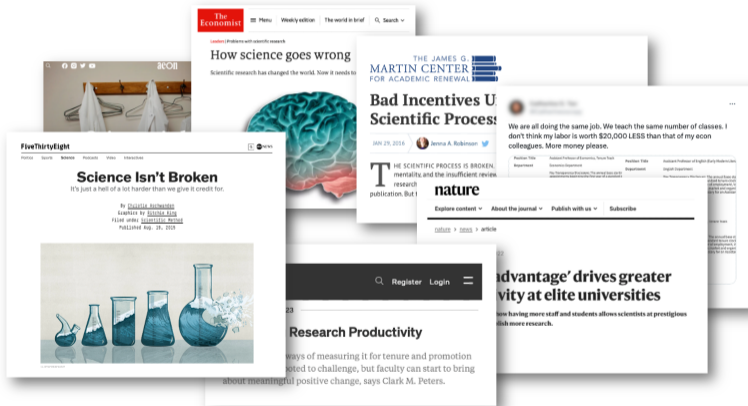
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# EMPIRICAL ECONOMICS OF SCIENTIFIC PRODUCTION FUNCTIONS

## AND THE (MOSTLY) LACK THEREOF

- estimating misallocation requires producer-level production functions
  - researcher-level structural models with researcher-level productivity are rare (Qiu 2023)
- prevailing methods require “impossible” data
  - input-output covariance: require output quantities

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*“what constitutes a scientific paper makes for an elastic yardstick of scientific achievement”*

*— Adams and Griliches (1998)*

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- prevailing methods require “impossible” data
  - input-output covariance: require output quantities
  - first order conditions: traditional factor share methods require input prices

# PRODUCTIVITY BELIEFS AND EFFICIENCY IN SCIENCE

## PAPER OVERVIEW

**RQ1:** how dispersed are productivity beliefs?

**RQ2:** what is the \$ cost of misallocation?

- model: researchers' production & consumption
- key: WTP for inputs reveals productivity beliefs
- data: national survey of US academics



## MODEL OF (OUR) UTILITY FUNCTIONS

## RESEARCHER'S PRODUCTION AND CONSUMPTION

STATIC, SUBJECTIVE EXPECTATIONS OVER NEXT 5 YEARS (HENCE "BELIEFS")

$$U_i =$$

# RESEARCHER'S PRODUCTION AND CONSUMPTION

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$$U_j = \max_{\substack{\text{research}_j \\ \text{fundraising}_j}} u_j(\text{income}_j) + v_j (\alpha_j \cdot \text{funding}_j^{\gamma_j} \cdot \text{research}_j^{1-\gamma_j}) - c_j(\text{work time}_j)$$

$$\text{s.t. } \text{funding}_j = \text{guaranteed}_j + \varphi_j \cdot \text{fundraising}_j$$

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**fixed, state variables**

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**researcher's choice variables**

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**$u(\text{income}) = \text{concave function of income}$**

**$c(\text{work time}) = \text{convex function of work, extra disutility from admin.}$**

**slopes depends on observables**

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**v(output) = concave function of output; slope depends on observables**

**variable inputs; observed**

**production parameters; directly estimated**

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# ESTIMATING PRODUCTIVITY BELIEFS VIA WTP FOR INPUTS

## VERY SIMPLE STYLIZED EXAMPLE

- production and consumption:

$$\max_{X_i} M_j + \alpha_j X_i - X_i^{c_i}$$

income  $M$

variable input  $X$

productivity  $\alpha$

input cost  $c$

- key assumptions (beyond this example)

1. convex costs
2. “revenue” is monotonic in  $Q$  & observable or predictable

$$c_i > 1$$

$$v_j \cdot \alpha_j \cdot X_i \text{ with } v_j = 1$$

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- offer to  $i$ :
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- $WTP_i$  for  $\Delta$  equates:

$$\underbrace{\max_{X_i} M_i + \alpha_j \cdot X_i - X_i^{C_i}}_{\text{utility if no purchase}} = \underbrace{\max_{X_{i'}} (M_i - WTP_{i'}) + \alpha_j \cdot (X_{i'} + \Delta) - X_{i'}^{C_i}}_{\text{utility if purchase } \Delta}$$

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- with data  $(WTP_i, \Delta)$  productivity belief is identified:

$$\alpha_j = WTP_i / \Delta$$

SURVEY: DESIGN & DATA

# NATIONAL SURVEY OF ACADEMIC RESEARCHERS

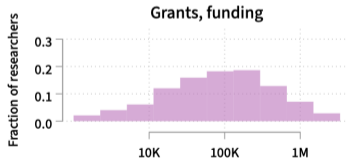
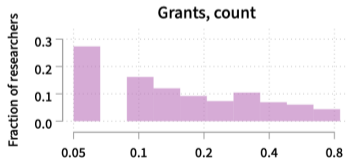
RESEARCH-ACTIVE US PROFESSORS, 2022-2023

- population
  - professors at ~150 largest US institutions of higher ed.
  - collected from web: name, affiliation, rank, e-mail
  - all fields of “research” 
- response rate and restrictions
  - e-mail sample: 131,672 e-mails
    - ↳ completed survey: 4,388 (3.33%)
    - ↳ reported non-zero salary & research time: 4,003 (91.2%)
- broader summary stats: PLOS ONE (2026), 21(2), e0340642

- chemistry
- engineering
- agriculture
- geography
- biology
- medicine & health
- physics
- medical school
- humanities
- computer science
- communication
- other social science
- psychology
- sociology
- law
- mathematics
- education
- business
- political science
- economics

# RESPONDENTS ARE (OBSERVABLY) REPRESENTATIVE

PER TRADITIONAL SCIENTOMETRICS; ANNUAL FLOWS



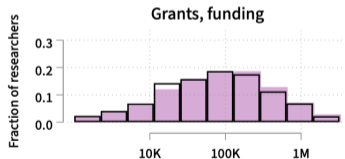
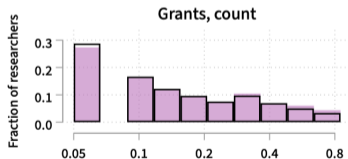
Sample e-mailed

Completed survey

(also use randomized incentives to test for sample selection; cannot reject the null)

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PER TRADITIONAL SCIENTOMETRICS; ANNUAL FLOWS



Sample e-mailed

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# SUMMARY STATISTICS: MODEL VARIABLES

STATE AND CHOICE VARIABLES FROM RESEARCHERS' PERSPECTIVE

	state var.	choice var.	mean	s.d.
salary, \$/year	✓		163,558	89,792
<u>funding, \$/year</u>				
guaranteed	✓		66,374	121,936
fundraised		✓	93,909	144,013
<u>time, hrs./week</u>				
total work		✓	50.5	12.2
research		✓	19.2	10.1
fundraising		✓	4.5	5.5
duties	✓		26.7	11.1

# SUMMARY STATISTICS: PEOPLE

SOME OF THE COVARIATES THAT DETERMINE CONSUMPTION AND COST FUNCTIONS

	mean or share
full professor	41%
tenured	58%
non-tenure track	19%
age	41
female	45%
non-white	12%
international-born	29%
1 <sup>st</sup> -3 <sup>rd</sup> gen. in us	30%
risk-tolerance [0,10]	5.3
married or partnered	82%
household income	\$260,000
household dependents	1.0

# SUMMARY STATISTICS: RESEARCHERS' OBJECTIVES

KNOWLEDGE PROXIES ARE NOT ALL POSITIVELY CORRELATED

“how often is \_\_\_\_\_ your intended research output / audience?”

---

articles    books    materials    products    academics    policy    business

books

materials

products

academics

policymakers

businesses

public

---

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“how often is \_\_\_\_\_ your intended research output / audience?”

	articles	books	materials	products	academics	policy	business
books	-0.13						
materials	0.08						
products	-0.13						
academics	0.48						
policymakers	0.01						
businesses	-0.03						
public	-0.12						

# SUMMARY STATISTICS: RESEARCHERS' OBJECTIVES

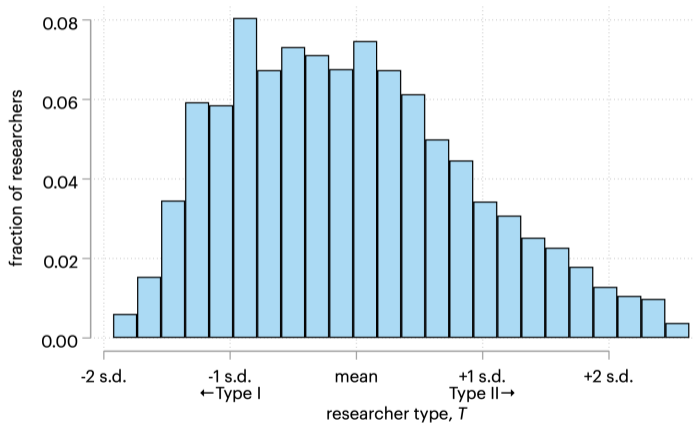
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“how often is \_\_\_\_\_ your intended research output / audience?”

	articles	books	materials	products	academics	policy	business
books	-0.13						
materials	0.08	-0.20					
products	-0.13	-0.12	0.23				
academics	0.48	-0.01	0.02	-0.24			
policymakers	0.01	-0.00	0.10	0.25	-0.07		
businesses	-0.03	-0.07	0.20	0.38	-0.12	0.24	
public	-0.12	0.19	0.04	0.21	-0.20	0.28	0.13

# PCA-BASED INDEX OF HETEROGENEITY

COMPRESS NON-MODEL COVARIATES INTO SINGLE SCALAR



(this index determines slopes of (dis-)utility functions)

**SURVEY: EXPERIMENTS & PARAMETER ESTIMATES**

## WTP EXAMPLE: LOWER SALARY, MORE FUNDING

ALSO ASKED ABOUT TRADING OFF SALARY AND ADMIN. DUTIES

Consider a scenario where your primary institution is offering you **\$1,000,000 in unrestricted research funding**, but only if you are willing to take a **smaller salary for the next 5 years**, after which, your salary would return to its current level. *Nothing else about your job would change.*

Your current situation (per your responses) and the new offer are described below:

	<i>Guaranteed research funding</i>	<i>Annual salary</i>
<b>Currently:</b>	\$400,000 total	\$160,000
<b>New offer:</b> <i>more funding smaller salary</i>	\$1,400,000 total	\$_____?

**Q. What is the smallest salary that could make you take the new offer?**

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**Q. What is the smallest salary that could make you take the new offer?**

[warning: entering stated-preferences territory]

# SURVEY DATA AND STATED PREFERENCE CHECKS

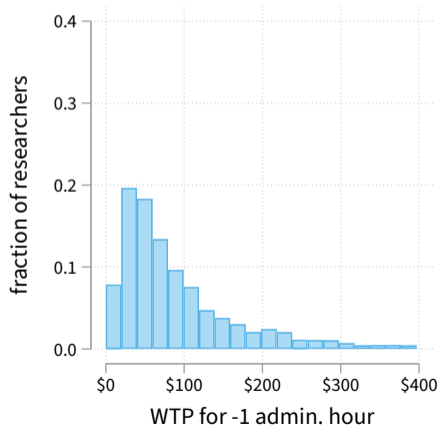
EVERYTHING BUT THE KITCHEN SINK

- self-reported salaries align with publicly-reported salaries
- randomized survey incentives cannot reject null of no sample selection (Heckman 1979)
- WTP for benchmark good doesn't covary with WTP for inputs (Dizon-Ross & Jayachandran 2022)
- WTP for time correlates with implied hourly wage
- use winsorization and Bayesian shrinkage on productivity parameters
- focus within scientific “markets” = field of study × career-stage
- constrain reallocations to be within survey experiment variation

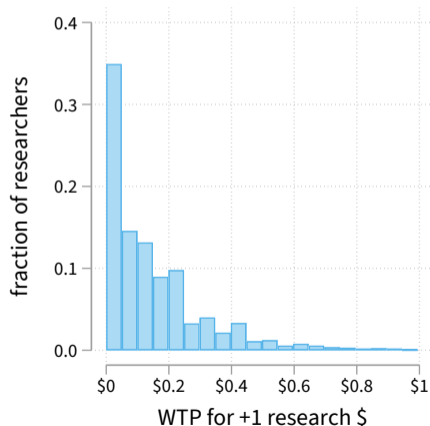
# WTP FOR INPUTS

AVERAGING ACROSS SURVEY EXPERIMENTS

**less administration** med=\$68



**more funding \$** med=\$0.1



# A VIEW OF RESEARCHERS' UTILITY FUNCTIONS

CETERIS PARIBUS CHANGE IN COMPONENTS

for the average researcher, expected utility from...

	$\Delta X$	$\Delta U$
salary	\$75,000 ↗ \$340,000	
research output	5 <sup>th</sup> ↗ 95 <sup>th</sup> percentile	
research time	4 ↗ 38 hrs./week	
administration time	0 ↗ 22 hrs./week	

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salary	\$75,000 ↗ \$340,000	+60%
research output	5 <sup>th</sup> ↗ 95 <sup>th</sup> percentile	+3%
research time	4 ↗ 38 hrs./week	
administration time	0 ↗ 22 hrs./week	

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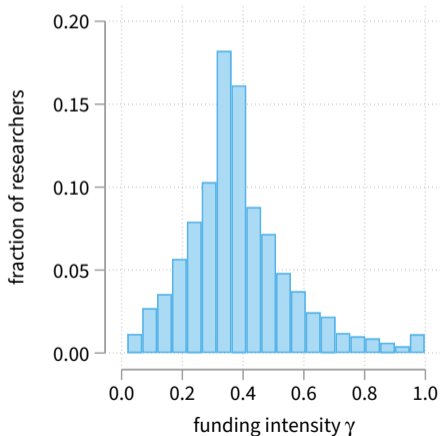
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administration time	0 ↗ 22 hrs./week	-24%

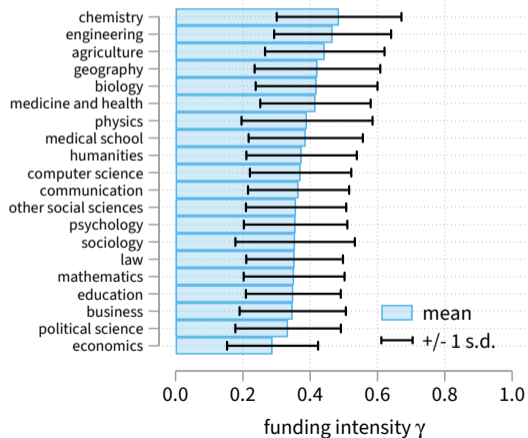
# FUNDING INTENSITY

$$\alpha_i \cdot \text{FUNDING}_i^{\gamma_i} \cdot \text{RESEARCH TIME}_i^{1-\gamma_i}$$

## sample distribution

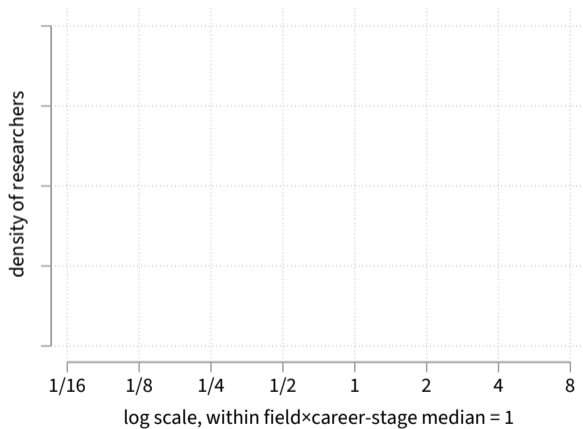


## field-level mean, s.d.



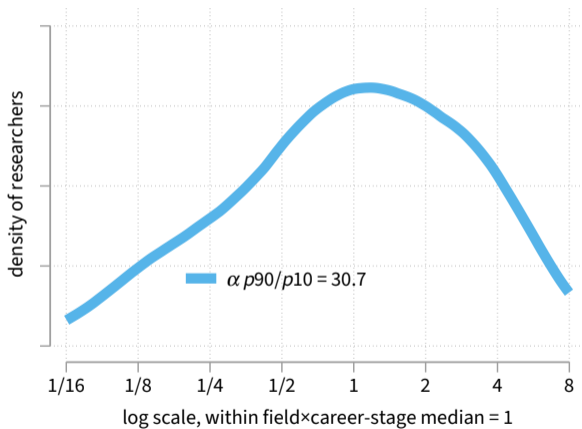
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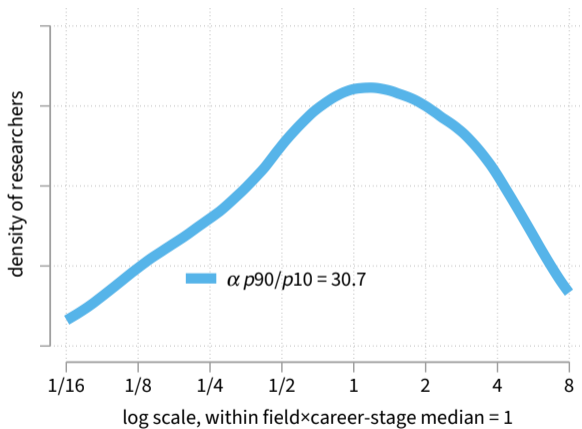
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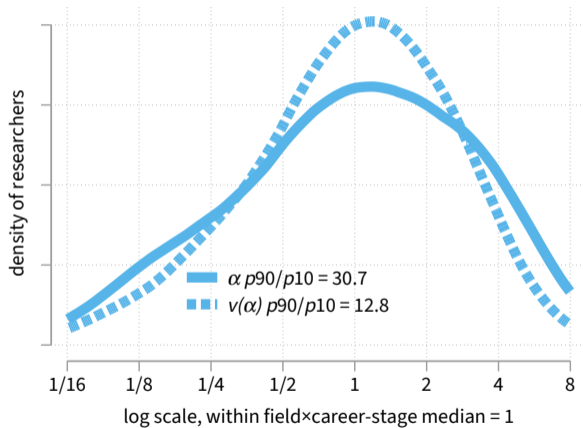
$$\alpha_j \cdot \text{FUNDING}_i^{\gamma_i} \cdot \text{RESEARCH TIME}_i^{1-\gamma_i}$$



output variance decomposition  $\approx 50\%$  due to  $\alpha_i$  +  $50\%$  due to inputs &  $\gamma_i$

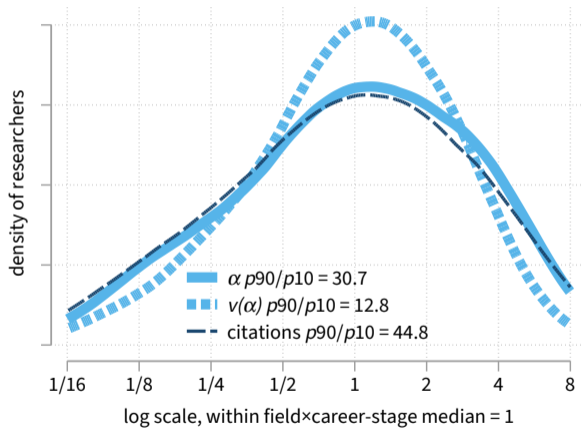
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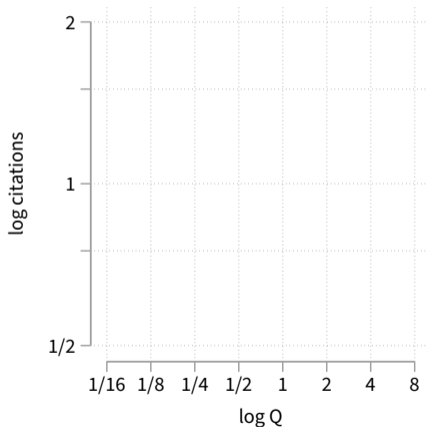
$$\alpha_j \cdot \text{FUNDING}_i^{\gamma_i} \cdot \text{RESEARCH TIME}_i^{1-\gamma_i}$$



## FACE VALIDITY: MODEL-DEFINED OUTPUT & CITATIONS

$$Q_i = \alpha_i \cdot \text{FUNDING}_i^{\gamma_i} \cdot \text{RESEARCH TIME}_i^{1-\gamma_i}$$

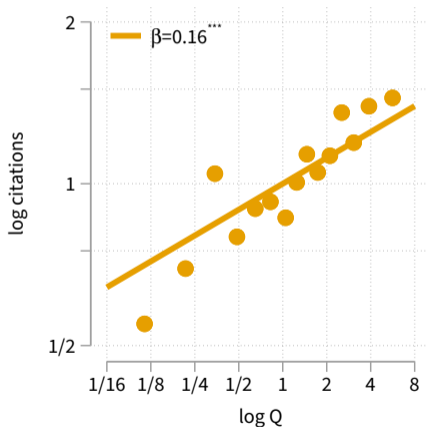
- **if** our approach is “legit” and ...
  - ... citations are positively corr. with true output
  - ... productivity is persistent (eg, Sinatra et al. 2016)**then**  $\text{cov}(Q, \text{recent cites}) > 0$



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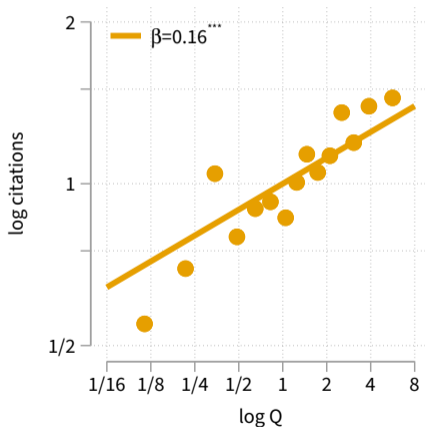
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- **and if** our productivity parameters are “legit”
  - then** cov should hold conditional on inputs

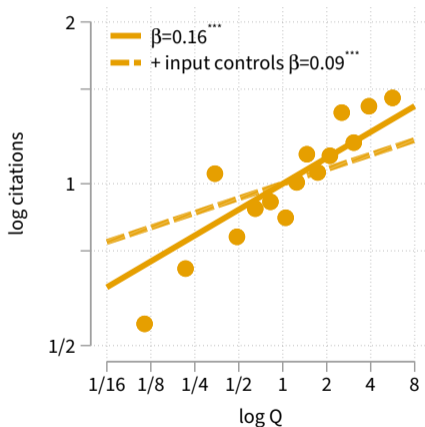


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  - ... productivity is persistent (eg, Sinatra et al. 2016)**then**  $\text{cov}(Q, \text{recent cites}) > 0$  ✓
- **and if** our productivity parameters are “legit”  
**then**  $\text{cov}$  should hold conditional on inputs ✓

*(not saying citations are good!)*



## SOCIAL WELFARE AND MISALLOCATION

# FIRST-BEST ALLOCATION (UNCONSTRAINED)

## RESEARCHER-LEVEL WELFARE

$$\widehat{W}_i = \max_{\{\text{funding}_i, \text{research}_i\}_i} u_i(\text{income}_i) + v_i \underbrace{(\alpha_i \cdot \text{funding}_i^{\gamma_i} \cdot \text{research}_i^{1-\gamma_i})}_{=Q_i} + \kappa \tilde{v}(Q_i) - c_i(\text{work time}_i)$$

$$\text{s.t. } \text{funding}_i = \text{guaranteed}_i + \varphi_i \cdot \text{fundraising}_i$$

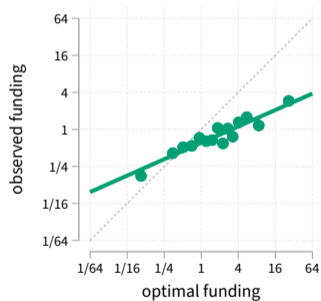
$$\text{work time}_i = \text{admin. duties}_i + \text{other}_i + \underbrace{\text{fundraising}_i}_{=0} + \text{research}_i$$

- for each  $i$ : planner chooses  $\text{funding}_i$  and  $\text{research}_i$
- fixed at observed levels: aggregate funding \$ and research time
- sources of distortions relative to observed: output externalities, input mechanisms and costs

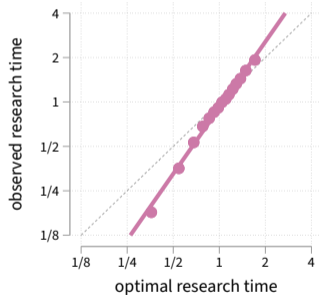
# OBSERVED VS OPTIMAL: INPUTS AND OUTPUTS

POSITIVE COVARIANCE

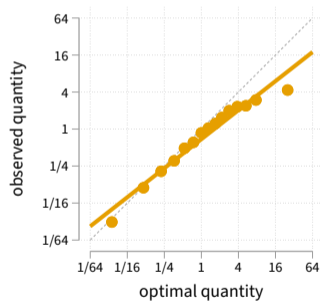
## funding



## research time



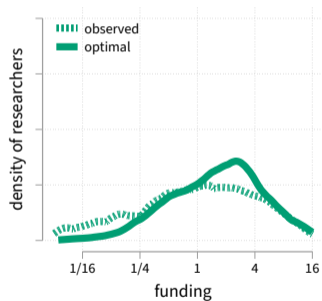
## output quantity



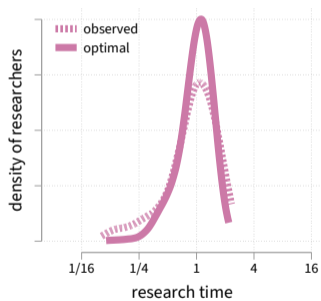
# OBSERVED VS OPTIMAL: INPUTS AND OUTPUTS

## DISTRIBUTION SHIFTS

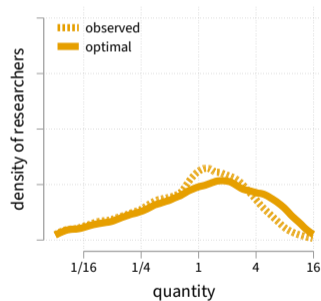
### funding



### research time



### output quantity



# QUANTIFYING INPUT MISALLOCATION

WHO IS OVER- AND UNDER-RESOURCED

$$\frac{\text{observed input level}_i}{\text{first-best input level}_i}$$

- hard to predict: with socio-demographic observables,  $R^2$  often  $< 0.1$
- gender disparity: female researchers have...
  
- Matthew effect: researchers with  $+1 \log(\text{citations})$  have...

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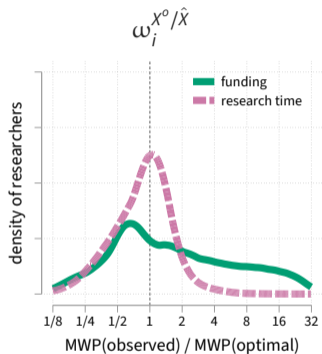
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- Matthew effect: researchers with +1 log(citations) have...
  - 25% more funding \$ (+\$35,000 per year)
  - 5% more research time (+1 week per year)

# RATIO OF MARGINAL WELFARE PRODUCTS

VARIANCE IN WEDGES IS BAD



		$\text{var}(\log \omega_i^{x^o/\hat{x}})$
$X =$	funding	2.40
	research time	0.43

# UNIFORM POLICY (BENCHMARK)

## RESEARCHER-LEVEL WELFARE

$$\bar{W}_i = \max_{\substack{\text{fundraising}_i, \\ \text{research}_i}} u_i(\text{income}_i) + v_i \underbrace{(\alpha_i \cdot \text{funding}_i^{\gamma_i} \cdot \text{research}_i^{1-\gamma_i})}_{=Q_i} + \kappa \tilde{v}(Q_i) - c_i(\text{work time}_i)$$

$$\text{s.t. } \text{funding}_i = \overline{\text{guaranteed}} + \bar{\varphi} \cdot \text{fundraising}_i$$

$$\text{work time}_i = \text{admin. duties}_i + \text{other}_i + \text{fundraising}_i + \text{research}_i$$

- for all  $i$ : planner sets common  $\overline{\text{guaranteed}}$  and  $\bar{\varphi}$
- for each  $i$ :  $i$  chooses  $\text{fundraising}_i$  and  $\text{research}_i$
- fixed at observed levels: aggregate  $\overline{\text{guaranteed}}$  and  $\overline{\text{fundraised}} \$$

# HETEROGENEOUS ACCESS TO FUNDING

IN OBSERVED ALLOCATION RELATIVE TO UNIFORM POLICY

$$i\text{'s observed funding } \$ = \underbrace{\overline{\text{guaranteed}} \cdot (1 - \varepsilon_{Gi})}_{\text{guaranteed } \$} + \underbrace{\overline{\varphi} \cdot (1 - \varepsilon_{\varphi i}) \cdot \text{fundraising}_i}_{\text{fundraised } \$}$$

- larger  $\varepsilon_{Gi} \implies$  researcher gets less guaranteed \$
- larger  $\varepsilon_{\varphi i} \implies$  harder for researcher to fundraise additional \$

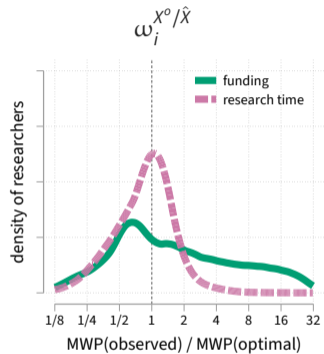
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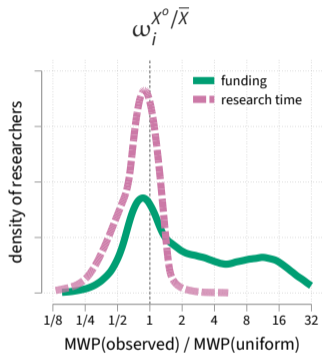
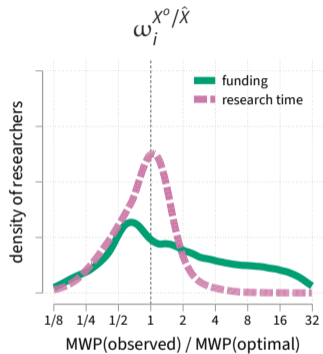
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- larger  $\varepsilon_{Gi} \implies$  researcher gets less guaranteed \$
- larger  $\varepsilon_{\varphi i} \implies$  harder for researcher to fundraise additional \$
- **can't say** whether  $\varepsilon$  are inefficient distortions per se (Bergquist, Lashkari & Verhoogen 2026)
- **can say:**
  - how much of distortions (observed rel. to 1st best) covary with  $\varepsilon$
  - how much of welfare gain from 1st best we can get by setting  $\varepsilon \rightarrow 0$

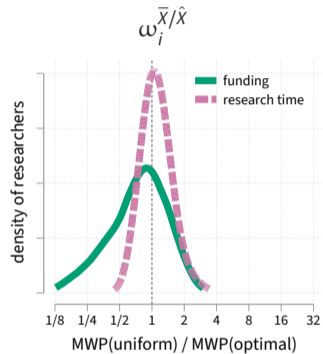
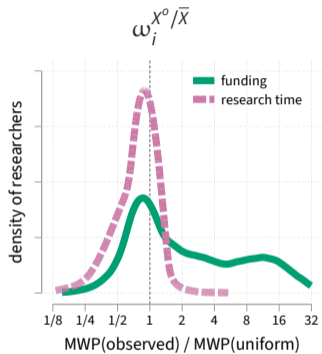
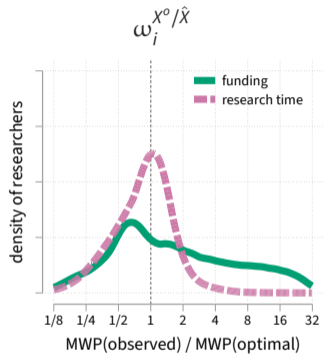
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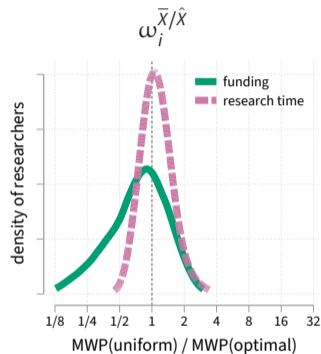
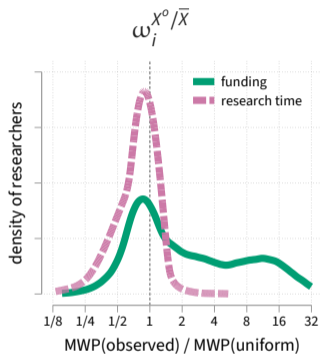
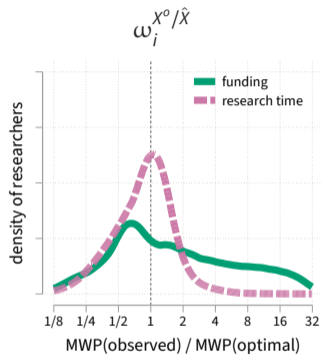
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	$\text{var}(\log \omega_i^{X^o/\hat{X}})$	=	$\text{var}(\log \omega_i^{X^o/\bar{X}})$	+	$\text{var}(\log \omega_i^{\bar{X}/\hat{X}})$	+	$2 \cdot \text{cov}(\dots)$
$X =$ funding	2.40		64%		20%		16%
research time	0.43		51%		24%		25%
	(all)		( $\epsilon$ )		(other)		(interaction)

# COUNTERFACTUAL GAINS

FROM ALTERNATIVE ALLOCATIONS ARE VERY LARGE

	<u>1<sup>st</sup> best</u>		<u>uniform policy</u>	
	mean	s.d.	mean	s.d.
funding				
research time				
fundraising time				
utility, $U_i$				
welfare, $\mathcal{W}_i$				

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	<u>1<sup>st</sup> best</u>		<u>uniform policy</u>	
	mean	s.d.	mean	s.d.
funding	~0%	-22%		
research time	~0%	-31%		
fundraising time	-100%	-100%		
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fundraising time	-100%	-100%		
utility, $U_i$	+0.5%	+0.1%		
welfare, $\mathcal{W}_i$	+2.9%	-0.2%		

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fundraising time	-100%	-100%	+8%	+27%
utility, $U_i$	+0.5%	+0.1%	+0.4%	+0.1%
welfare, $\mathcal{W}_i$	+2.9%	-0.2%	+2.0%	-0.4%

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welfare, $\mathcal{W}_i$	+2.9%	-0.2%	+2.0%	-0.4%

funding \$ equivalent variation

*growth in funding via obs. allocations needed to match welfare gain*

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<u>funding \$ equivalent variation</u>				
<i>growth in funding via obs. allocations needed to match welfare gain</i>				
per researcher	+218%		+132%	
	+\$407 K/year		+\$257 K/year	

# COUNTERFACTUAL GAINS

FROM ALTERNATIVE ALLOCATIONS ARE VERY LARGE

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<hr/>				
<u>funding \$ equivalent variation</u>				
<i>growth in funding via obs. allocations needed to match welfare gain</i>				
per researcher	+218%		+132%	
	+\$407 K/year		+\$257 K/year	
population	<b>+\$49 B/year</b>		<b>+\$31 B/year</b>	

# PRODUCTIVITY BELIEFS & EFFICIENCY IN SCIENCE

BERTOLOTTI, MYERS & THAM

**RQ1:** how dispersed are productivity beliefs? **very!**

$p_{90}/p_{10} \approx 12-30$

**RQ2:** what is the \$ cost of misallocation? **a lot!**

reallocation gains > budget doubling

## broader thoughts & conjectures

- wedges are hard to predict with standard observables
  - maybe more policies promoting truthful revelation of relevant objects
- the age of AI
  - the currency of words is “depreciating”, a new currency is needed
  - the value of uniform input prices will only go up (Adda & Ottaviani 2024)

