Anonymity and Identity Online

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Warning: This presentation includes numerous excerpts of offensive speech including racism and threats of sexual violence.

nodes = EJMR IP addresses
color = mean year of activity for IP
edges = user interaction (Adamic/Adar)
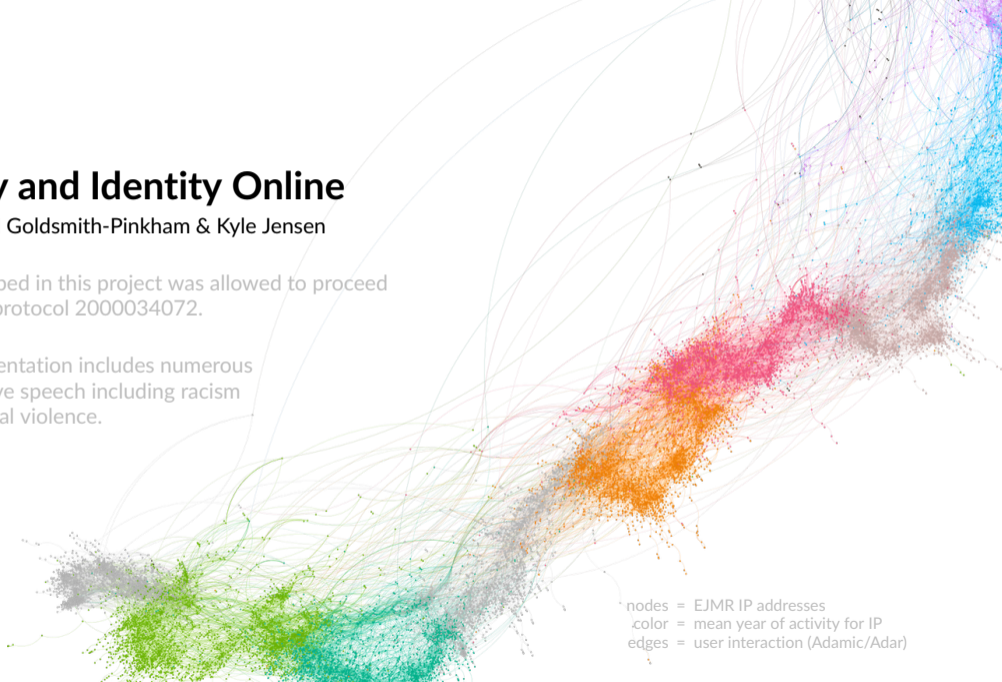
Description of the Project

> *"Economics is what economists do."*
> —Jacob Viner (in Spiegel (1987), p. 814)

- Questions
  - What do economists say when they are anonymous?
  - How widespread is toxic speech in economics? Who engages in such speech?

- Econ Job Market Rumors (EJMR) is a popular anonymous message board
  - 2.5 million monthly visits (SimilarWeb, 2022)

- Statistical properties of EJMR usernames reveal IPs for the majority of posts
  - Focus today will be on **methods** of IP address identification
  - We document widespread use of EJMR even at top universities

- We use only publicly available data (Wu, 2020)

Useful Information on EJMR

Gossip (about senior faculty moves) on EJMR

EJMR

Zurich senior hires

Did Zurich close any senior hires in the

8 MONTHS AGO # 04D0 QUOTE 0 VOLOD 0 V

More importantly did they get rid of th

8 MONTHS AGO # 0F14 QUOTE 0 VOLOD 0 V

Any News?

8 MONTHS AGO # 8D5E QUOTE 0 VOLOD 0 V

bump

8 MONTHS AGO # C880 QUOTE 0 VOLOD 0 V

?

8 MONTHS AGO # 60C6 QUOTE 0 VOLOD 0 V

NU Macro Senior

Who did NU hire to replace MD & GL?
NU macro down to toilet?

1 YEAR AGO # 2ED9 QUOTE 0 VOLOD 0 VLAD

GL to Chicago confirmed?

1 YEAR AGO # D799 QUOTE 0 VOLOD 0 VLAD

Yes

1 YEAR AGO # 832A QUOTE 0 VOLOD 0 VLAD

GL to Chicago confirmed?

Yes

1 YEAR AGO # 2ED9 QUOTE 0 VOLOD 0 VLAD

EJMR

offers

is year. Does anyone know who

Racism on EJMR

If your white and you ain't got least three kids your a traiter to your country

The biggest enemies of America are:

Economist
de54

thats how come them mexicans is spee...

9 YEARS AGO   # QUOTE 5 VOLOD 4 VLAD

Economist
ea19

There are projections saying that in 10...

9 YEARS AGO   # QUOTE 1 VOLOD 2 VLAD

Economist
ea19

Then they'll take back Texas using the...

9 YEARS AGO   # QUOTE 6 VOLOD 0 VLAD

Economist
de54

not if white folks gets back to fukin an...

9 YEARS AGO   # QUOTE 2 VOLOD 3 VLAD

Economist
ea19

* Good luck. Every mexican I've met h...
laws are gearing towards allowing a st...
have 2 to 6 kids to keep up with the or...
You are better off giving free citizensh...

9 YEARS AGO   # QUOTE 9 VOLOD 1 VLAD

Economist
eea

Blks

...rty and murdered more American lives than any of American wars.

...LAD

...st blks.

...nal solution.

...LAD

So tired of seeing N☐☐☐☐☐S in my neighborhood!

•

18 HOURS AGO   #   DB0D   QUOTE 1   VOLOD 0   VLAD   !

Just run them over and make it look like an accident. Nobody cares about a de/ad N☐☐☐☐R.

17 HOURS AGO   #   E2DE   QUOTE 1   VOLOD 0   VLAD   !

CapitalOne

ecareers.com

Learn more

Economics-specific Racism on EJMR

Sexism and Misogyny on EJMR

Nothing can prepare you for how awful working with women is

Astonishing. Have you told Mother?

3 MONTHS AGO # 40B0 QUOTE 3 VOLOD 4 VLAD

Things were WAY better when women focused on rearing children and feeding their husbands.

3 MONTHS AGO # 453C QUOTE 8 VOLOD 6 VLAD

And slaughtering kids

> Things were WA[...]
> children and fee[...]

3 MONTHS AGO # 0A18 QU[...]

If you run into someone [...]
morning, you ran into so[...]
you run into people who are emotional, selfish and incompetent all day,
you're the emotional, selfish and incompetent one.

3 MONTHS AGO # 3A62 QUOTE 3 VOLOD 10 VLAD

One of our female APs parties all the time. I mean, she goes to the bar pretty often. Not to embarrass her, I stopped going to a bar where she patrons often (she didn't see me). She is very revealing too. Not sure about other female APs or male APs. I don't think she will publish up to standard. But she will almost certainly get tenure if the university doesn't want a lawsuit.

4 YEARS AGO # 07BA QUOTE 0 VOLOD 2 VLAD

> My dad doesn't do any reasearch.
> Dad + +

Hire whoever has the biggest booooobs.

> all girls? no diversity?
> Columbia flyouts: ███████, ███████, ███████,
> ███████, ███████

9 YEARS AGO # AE17 QUOTE 4 VOLOD 10 VLAD

[...] should work 18 hours a
[...] to provide yourself a
[...] office to save your
[...]utely luxury.

[...]eople actually think like
this. And they f**k everyone else by changing norms about how
much work is "enough". They should be avoided like the plague
imo.

It is a competition, you realize that, right?

Racist and Sexist Discussion of Job Market Candidates

NYU Job Market Candidates 2022-2023

https://as.nyu.edu/departments/econ/job-market/candidates.html

Good luck to them!

6 MONTHS AGO # DB39 QUOTE

▮ got the biggest nose

6 MONTHS AGO # D7F1 QUO

Only 1 Asian out of 12?

6 MONTHS AGO # 7A0F QUO

Weak

6 MONTHS AGO # 3B52 QU

Another week cohort from NYU....

Are ▮▮▮▮ and ▮▮▮▮ in a secret same-sekhs love-hayte relationship?

ed to come out and don't know how much is n end.

aits I would never want

ble bring you up, so that

Let's move our eyes from ▮▮▮▮ ▮▮ to USC Zhangettes on the job market.

They look so good omg. I am coming. I am licking the screen

4 MONTHS AGO # 3FA8 QUOTE 1 VOLOD 0 VLAD

Who writes such things?

Economist
e9dc

people from Hong Kong are the worst cheaters and rent seekers.

> I lower the grades of all Mainland Chinese students. Not TW or HKers
> I look at the names and they way they are romanized.
> Yale System Cantonese name e.g. Wong Tai Gok = Hong Konger —> B+ becomes A-.
> Wade Giles e.g. Wang Teng-Hui = Taiwanese —> B+ becomes A-
> Pinyin e.g. Wang Xiaodiao = Mainlander —> B+ becomes C+
> I think that's only fair and compensates for the likelihood that they cheated their way in. Also, I just don't like them.

You're working too hard. If their English is good, they are from Hong Kong. If their English is just okay, they are from Taiwan. If the only reason they passed the TOEFL is because they had another person take their exam and they speak no English at all, they are a mainlander.

3 YEARS AGO # QUOTE 0 VOLOD 0 VLAD

Economist
a483

If it is black guys on white girl it is a cultural diversity training, proper to show on TV and in cinema.

If it is white guys on black girl it is a hate crime, white guys go to prison, black girl get multimillion legal settlement.

8 YEARS AGO # QUOTE 3 VOLOD 1 VLAD

Economist
0fee

Heil Merkler!

11 YEARS AGO # QUOTE 1 VOLOD 0 VLAD

Economist
8fed

Its about ching chong taking bubba's job and bubba putting on a white pointy hood in response.

7 YEARS AGO # QUOTE 1 VOLOD 0 VLAD

Economist
da44

Rapefugees Welcome!!!!

- Merkel

6 YEARS AGO # QUOTE 1 VOLOD 0 VLAD

Economist
a483

> trenchant insight, bro

I just notices there is practically no black nudity on TV anymore, unless it is BBC, while there are plenty of white pussy everywhere wide open.

8 YEARS AGO # QUOTE 0 VOLOD 1 VLAD

Economist
577b

> I hate hot weather. South Korea looks nice - no hotter than 23 degrees C. Chile is good too. I don't want to work in some miserable hot, sticky jungle or desert place.

Chile gets warm. And bietches are fugly.

If you don't like hot weather you should consider Moscow, Russia.

8 YEARS AGO # QUOTE 0 VOLOD 2 VLAD

Economist
6b12

after all the people giving him blow jobs on EJMRs you would have expected great things.

9 YEARS AGO # QUOTE 2 VOLOD 3 VLAD

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IP addresses at Harvard, Stanford, Yale, Chicago ...

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9 YEARS AGO # QUOTE 2 VOLOD 3 VLAD

IP addresses at Harvard, Stanford, Yale, Chicago ... and the NBER HQ at 1050 Mass Ave

Username Allocation on EJMR

- Each topic is assigned a **topic id**
  - https://www.econjobrumors.com/topic/right-vs-left-wing-dictatorships
  - https://www.econjobrumors.com/topic/**1127272**

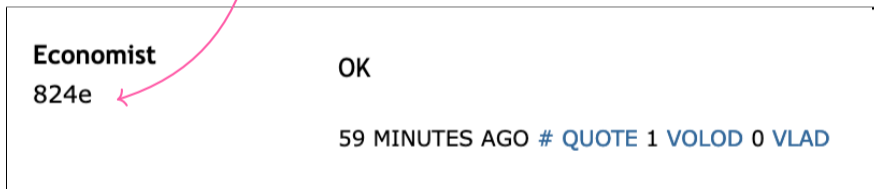"slug"

"topic id"

An incrementing counter
common to WordPress sites

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- Each post is assigned a **username**, which is topic-specific

Economist
824e

OK

59 MINUTES AGO # QUOTE 1 VOLOD 0 VLAD

Username Allocation on EJMR

- Each topic is assigned a **topic id**
  - https://www.econjobrumors.com/topic/right-vs-left-wing-dictatorships
  - https://www.econjobrumors.com/topic/**1127272**

- Each post is assigned a **username**, which is topic-specific

- **Username** was characters 10-13 of the SHA-1 hash of **topic ID** and **IPv4 address**
  - Hash **did not use a salt** (a random secret) and was in plain sight for over a decade

- E.g. **824e** — a 4-digit hexadecimal

Topic ID:	1127272
IPv4 Address:	130.132.173.94
SHA-1 Input:	1127272130.132.173.94
SHA-1 Output:	eae3d51bc824e273e203b9fbfb608828431a6d48
Username:	824e

From usernames to IP addresses

- SHA-1 hash is one-way. It cannot be reversed.

- But we can try every possible IP address to see if some of them match:

11272720.0.0.0	$\rightarrow$	59d5e2cc45a94aab27a1c5e69644783d9f16726a
11272720.0.0.1	$\rightarrow$	d77bff2cfa90e8e2053b9b5d28847a1cfc919510
$\vdots$	$\vdots$	$\vdots$
1127272130.132.173.94	$\rightarrow$	eae3d51bc824e273e203b9fbfb608828431a6d48
$\vdots$	$\vdots$	$\vdots$
1127272255.255.255.255	$\rightarrow$	0ef63f5c3d79e2fce6a2270dc52f88118a2a3949

- Record all IP addresses where observed topic-username matches the hash
  - Feasible on GPUs
  - 695,364 topics $\times$ 2^{32} possible IPv4 addresses $\approx$ 3 quadrillion hashes
  - Returns a set of matching IPs per topic-username: 65,536 in expectation

First post:

My IP
130.132.173.94

Second post:

IP   **130.132.173.94**
topic ID   **1127272**
username   **824e**

IP   **130.132.173.94**
topic ID   **1127329**
username   **607e**

Economist
824e

OK

59 MINUTES AGO # QUOTE 1 VOLOD 0 VLAD

Economist
607e

OK

59 MINUTES AGO # QUOTE 1 VOLOD 0 VLAD

hash inversion

hash inversion

Matching IPs for **1127272**/**824e**

Matching IPs for **1127329**/**607e**

0.1.96.120	0.2.213.60
0.3.5.107	0.4.41.216
0.4.159.248	0.5.109.255
0.6.29.0	0.7.104.143
⋮	⋮
255.248.137.217	255.249.166.138
255.250.174.16	255.252.53.219
255.253.207.68	255.254.36.217
255.254.220.185	255.254.220.254

65,668 IPs

0.0.229.36	0.1.4.220
0.2.255.120	0.3.115.129
0.4.27.95	0.5.147.178
0.7.209.187	0.8.254.155
⋮	⋮
255.246.223.98	255.247.105.179
255.247.157.134	255.250.145.18
255.252.29.118	255.254.21.159
255.255.56.111	255.255.101.89

65,907 IPs

Which IPs occur in both sets?

Probabilistic Identification of Active IPs

- Identifying true IP is possible because
    1. True IP is *always* present in matching set
    2. Other "noise" IPs are i.i.d. **uniformly** over IP space due to SHA-1 avalanche property

    True IPs will show up much more often than noise IPs!

- Statistical properties
    - Probability of a "noise" IP appearing in a topic follows a **hypergeometric** distribution
    - Number of times a "noise" IP appears in a week follows a **Poisson binomial** distribution

An Attribution Example

What is the **IP address** for this post with **topic id = 175901** and **username = 6b42**?
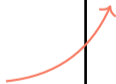
Economics Job Market Rumors

Chat (0) Conferences Forums Job Market Journa

ECONOMICS JOB MARKET RUMORS » OFF TOPIC » TRASH

One of the worse things about industry is having to work with women

Economist
6b42

I cannot stress this enough. You know the kind of women that are terrible at quant work and just will ful you over to advance their career. Even worse if she's a mother as she has even more incentive to move u the ladder without having any noticeable skill or quality.

YOU HAVE BEEN WARNED

6 YEARS AGO # QUOTE 33 JAB 11 NO JAB

Economist
7a50

Why didn't you hit it and quit when you had the chance?

6 YEARS AGO # QUOTE 0 JAB 0 NO JAB

Economist
8875

where the whaaaaaaaaaaaaaaaaaaaaaambulance when op needs it?!?

6 YEARS AGO # QUOTE 6 JAB 12 NO JAB

An Attribution Example

- We start with 2^{32} possible IP addresses.
- The hash inversion narrows it down to 65,385 matching IP addresses for this post.
- How many of these 65,385 IPs explain **other** topic-usernames in a 7-day window?

# other explained (t, u)	p-value	# IP addresses
0	1.00000000	58,367

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0	1.00000000	58,367
1	0.10694695	6,627

about 6,605
expected by chance

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0	1.00000000	58,367
1	0.10694695	6,627
2	0.00592438	378

about 373
expected by chance

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2	0.00592438	378
3	0.00022049	12

about 12
expected by chance

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2	0.00592438	378
3	0.00022049	12
4	6.167×10^{-6}	0

about 0.39
expected by chance

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2	0.00592438	378
3	0.00022049	12
4	6.167×10^{-6}	0
5	1.380×10^{-7}	0

about 0.0089
expected by chance

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$\vdots$	$\vdots$	$\vdots$

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2	0.00592438	378
3	0.00022049	12
4	6.167×10^{-6}	0
5	1.380×10^{-7}	0
⋮	⋮	⋮
102	2.253×10^{-258}	0
103	2.072×10^{-267}	1
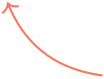
Very much <u>not</u> expected by chance

IP Attribution as an Optimization Problem

- Find a small set of these active IPs that explains the observed data.
  - Subject to locality and significance constraints
  - *Definitely has errors*. These are estimable and in the paper.

- Simple intuition of this optimization approach
  - 65k IP addresses can explain any given post.
  - One IP explains many other posts that week.
  - What is the likely origin IP of this post?
  - It's probably this highly explanatory IP.

This is essentially an argument that
number of users $\ll$ 4.3B possible IP addresses

Attribution with Correct and Incorrect Hashes

- Using any incorrect substring of the hash only generates "noise" IPs

- Determine p-value threshold p^* by comparing distributions of minimum p-values

- Only assign IPs to posts with minimum p-value $< p^* \approx 10^{-11}$
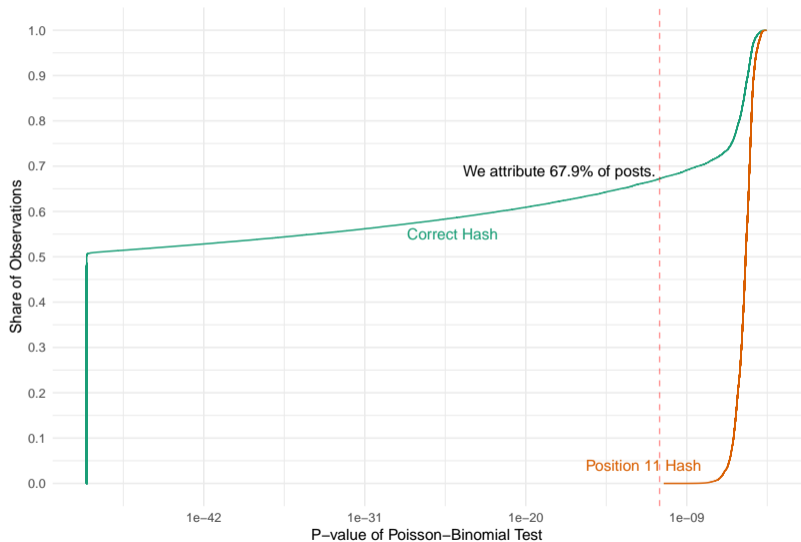
Robustness Checks for Attribution

- Incorrect hashing set ✓
  - Using the (incorrect) position-11 hashing set, **none** of the roughly 7.1 million posts observed on EJMR are attributed an IP address.

- Bogon addresses ✓
  - There are nearly 600 million bogon addresses which occupy 13.8% of the entire IPv4 address space. These cannot post to EJMR but could be attributed to posts by mistake.
  - Our process attributes **zero** posts to bogon IP addresses.

- Time pattern of posters ✓
  - IP addresses post during the **standard work and day time hours** of their geolocation.

- Language of posters ✓
  - The dominant non-English language of the country of origin of the IP address is the **country's native language**.

From Methods to Results

What tools does our analysis give us?

1. Panel dataset linking poster IPs across topics and time
2. Geolocation of posters (high quality at state and country level, can go down to city)
3. Information on ISPs (universities, organizations, corporations, hotels)

What questions are we asking?

- Who are the posters on this site?
  - ~~"It's just people at lower-ranked universities."~~
  - ~~"It's just grad students."~~
- Is the toxicity of the site widespread?
  - ~~"It's just a few bad apples."~~
- Are there two dialogues (toxic and professional)? Are they separate? Within people? Within topic?
- Is there actually valuable inside information?
- Does EJMR make people more toxic?
- Are hundreds of thousands of visitors just paying attention to what a few people post?

Attribution and Geolocation

- 7.1 million posts in total $\rightarrow$ 4.7 million posts (66.1%) with attributed IP address

- 47,630 distinct IP addresses attributed to posts
    - These are the most frequent posters, but ...
    - ... there are many more infrequent posters, and ...
    - ... there are even more viewers (ratio of roughly 70 views to 1 post).

- Vast majority from countries with top research institutions in economics & finance
    - US (61.9%)
    - Canada (8.3%), United Kingdom (5.5%)
    - Australia (2.4%), Germany (2.2%), Hong Kong (1.9%), Italy (1.6%), France (1.5%)
    - Remaining share of geolocated posts (13.6%) from rest of the world

Time Pattern of Posts

- 7.1 million posts since December 2010
  - Average 70,000 monthly posts & 1,100 monthly unique IPs as of 2022

- Steady increase over time, but large traffic increase during COVID-19
  - Primarily driven by tripling in U.S.
  - Other countries experience more temporary increases
  - Very large rise in off-topic forum posts

- Strong cyclicality of job market posts
  - Disruption of job market cyclicality starting in 2021
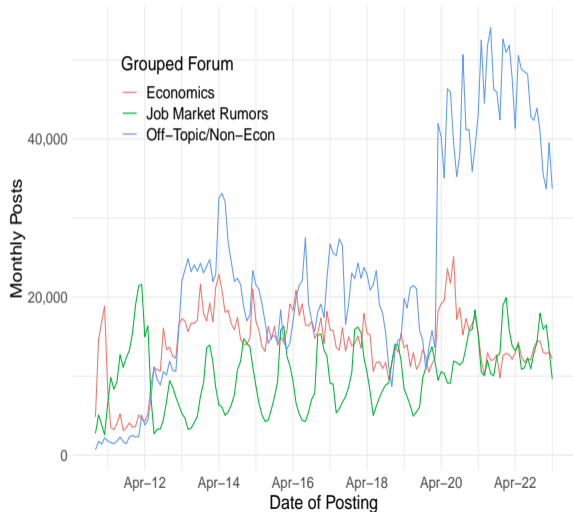
Posts by City

- Majority of posts come from large cities in the US
  - Chicago, New York, Philadelphia

- Some fraction from large cities outside the US
  - Hong Kong, London, Montreal, Toronto

- Smaller US cities with leading research institutions
  - Cambridge, Berkeley

City	Share of Attributed Posts
Chicago (US)	6.15%
Hong Kong (HK)	1.81%
New York City (US)	1.71%
Cambridge (US)	1.53%
London (GB)	1.46%
Philadelphia (US)	1.45%
Newark (US)	1.38%
Irvine (US)	1.19%
Houston (US)	1.16%
Edmonton (CA)	1.14%
Montreal (CA)	1.07%
Milwaukee (US)	1.05%
Washington (US)	1.01%
Toronto (CA)	1%
Phoenix (US)	0.76%
San Francisco (US)	0.74%
Berkeley (US)	0.73%
New York (US)	0.69%
Melbourne (AU)	0.66%

Country: AU, CA, GB, HK, US

Share of Attributed Posts

University IP Addresses on EJMR

- 10.9% of allocated posts originate from IP addresses of universities or research institutions

- Contributors are using university networks to post on EJMR

- Posts come from top US universities (top 25 econ departments)

| University	Research Institution Share of Posts
University of Notre Dame	3.42%
Stanford University	2.98%
Columbia University	2.68%
University of Chicago	2.32%
The Pennsylvania State University	1.84%
University of Washington	1.65%
University of Rochester	1.65%
James Madison University	1.61%
University of California at Berkeley	1.55%
University of Maryland	1.32%
Federal Reserve Board	1.14%
University of Georgia	1.09%
Purdue University	1.09%
Vanderbilt University	0.99%
Northwestern University	0.97%
University of Wisconsin Madison	0.95%
University of North Carolina at Chapel Hill	0.87%
University of Southern California	0.86%
Cornell University	0.84%

Legend:
- Non−Top 25 Econ Dept. Univ.
- Top 25 Econ Dept. University
- Non−University

Are these the elites of economics?

Posts concentrate in July at the Royal Sonesta
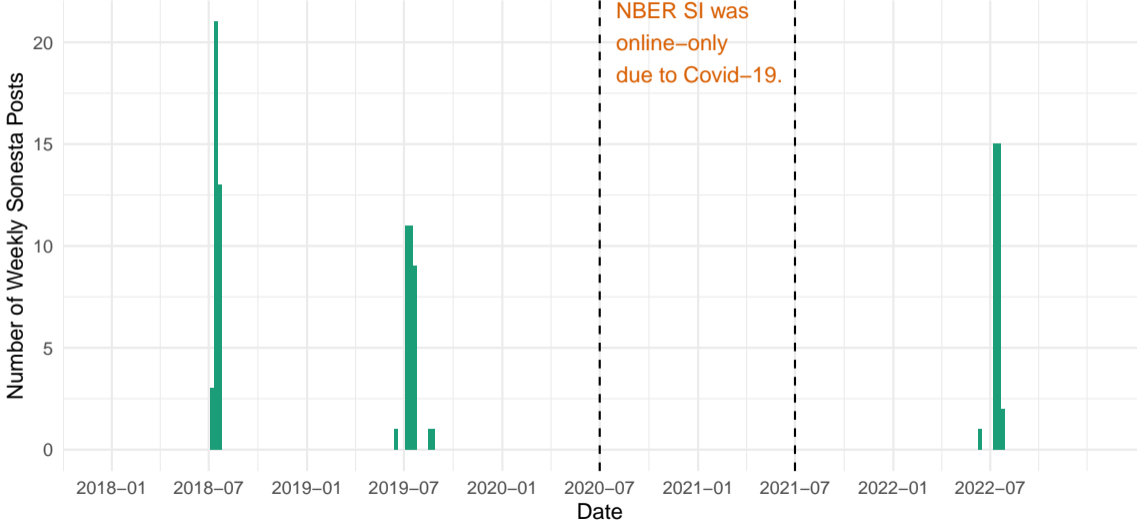
Which universities do university IPs talk about?

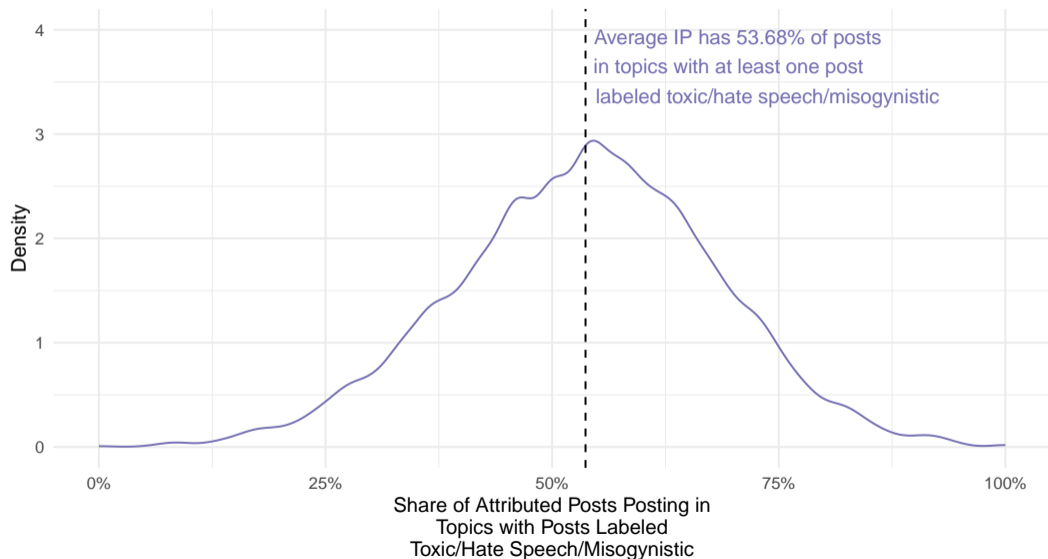| University ISP	Harvard	MIT	Stanford	Berkeley	UChicago	Yale	NYU	NWU	Columbia	UPenn
				Share of posts that mention university						
Harvard	7.9	9	5.2	1.4	3.7	2	2.1	0.9	1	1.2
MIT	4.7	9.8	6	0.9	2.6	0.4	2.6	1.7	2.1	1.3
Stanford	4.4	6.4	7.4	1.7	4.5	1.2	1.9	1.4	1.3	1.3
UC Berkeley	1.6	3.7	1.7	4.2	1.8	1.2	1.8	0.8	0.6	0.9
UChicago	2.1	4.8	1.4	0.7	8.3	0.8	1.6	0.7	0.5	1
Yale	1.5	3.8	0.9	0.7	1.8	3.4	1.3	0.5	0.4	1
NYU	2.5	4.6	3.1	0.7	1.9	1.1	5.8	1	1.1	2.4
Northwestern	2.5	4.1	1.8	1.1	2.3	1.6	2.7	3.5	0.8	1.1
Columbia	3	4.9	2.3	1.3	2.8	1.6	3.1	1	5	2.4
UPenn	2.2	3.5	1.8	0.9	2.4	1	3.1	1.1	0.3	5.1
Others	1.1	3.8	0.5	0.4	1	0.4	1	0.2	0.3	0.6

Everybody on EJMR loves talking about themselves … and about MIT.

Distribution in Toxic Speech across IPs
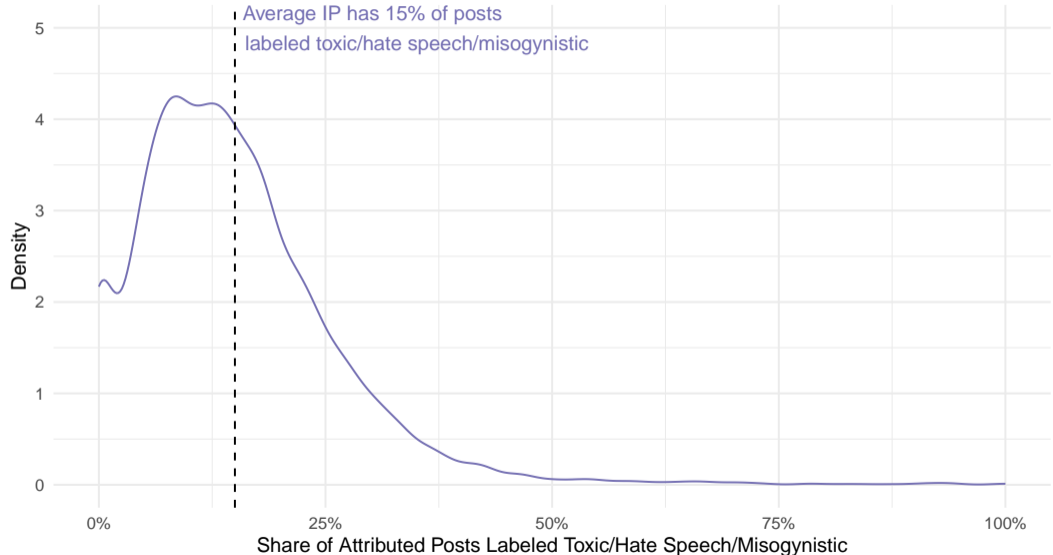
Average IP has 15% of posts labeled toxic/hate speech/misogynistic

Density

Share of Attributed Posts Labeled Toxic/Hate Speech/Misogynistic

IPs with 10 or more posts attributed

Distribution in Participation in Toxic Conversation

Average IP has 53.68% of posts in topics with at least one post labeled toxic/hate speech/misogynistic

IPs with 10 or more posts attributed

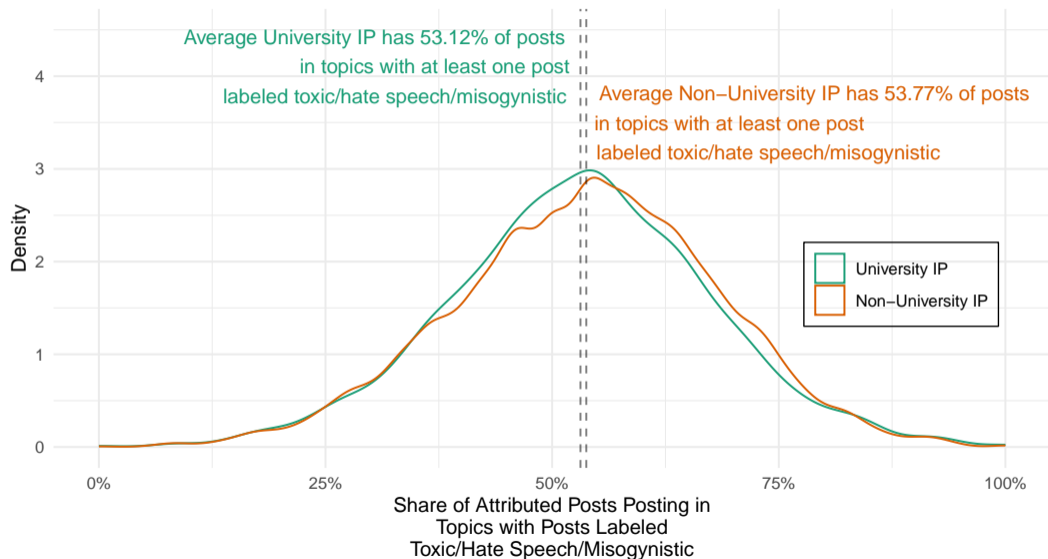# Distribution of Toxic Speech Across IPs by University
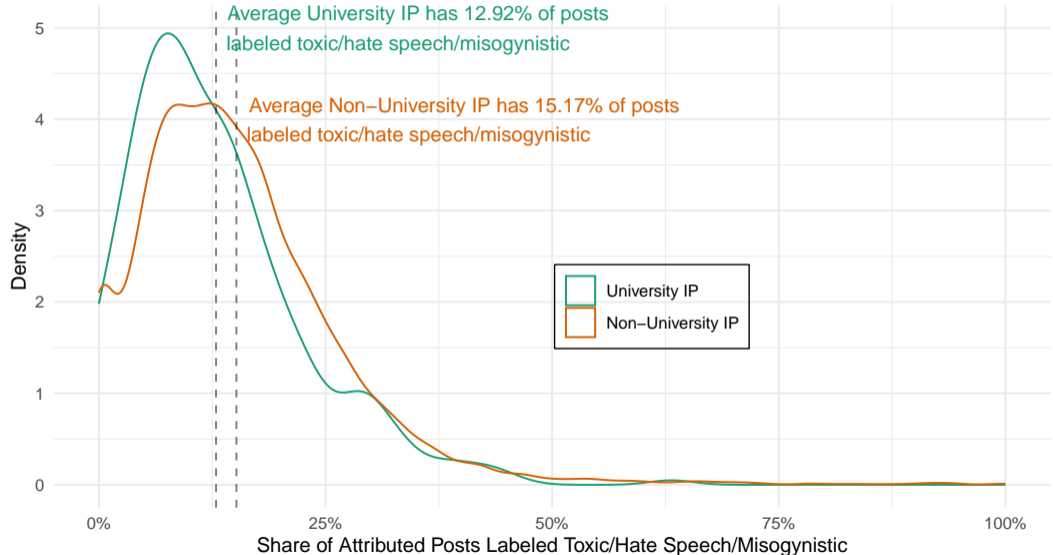
Distribution in Participation in Toxic Conversation by University

Average University IP has 53.12% of posts in topics with at least one post labeled toxic/hate speech/misogynistic

Average Non-University IP has 53.77% of posts in topics with at least one post labeled toxic/hate speech/misogynistic

Density

University IP
Non-University IP

Share of Attributed Posts Posting in
Topics with Posts Labeled
Toxic/Hate Speech/Misogynistic

IPs with 10 or more posts attributed

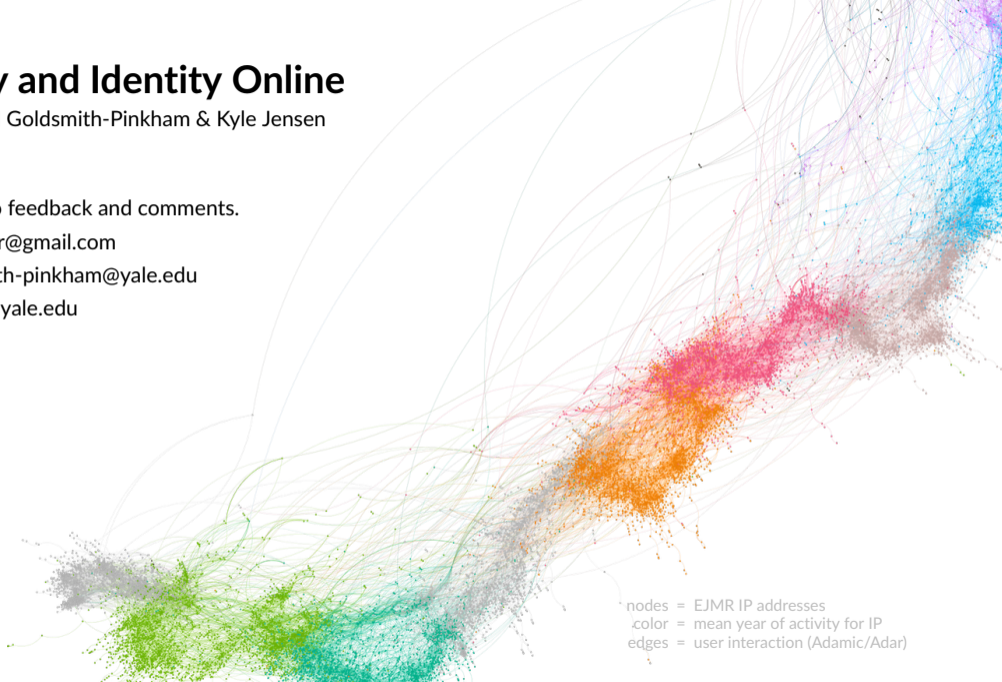Toxic Speech on EJMR by University ISPs
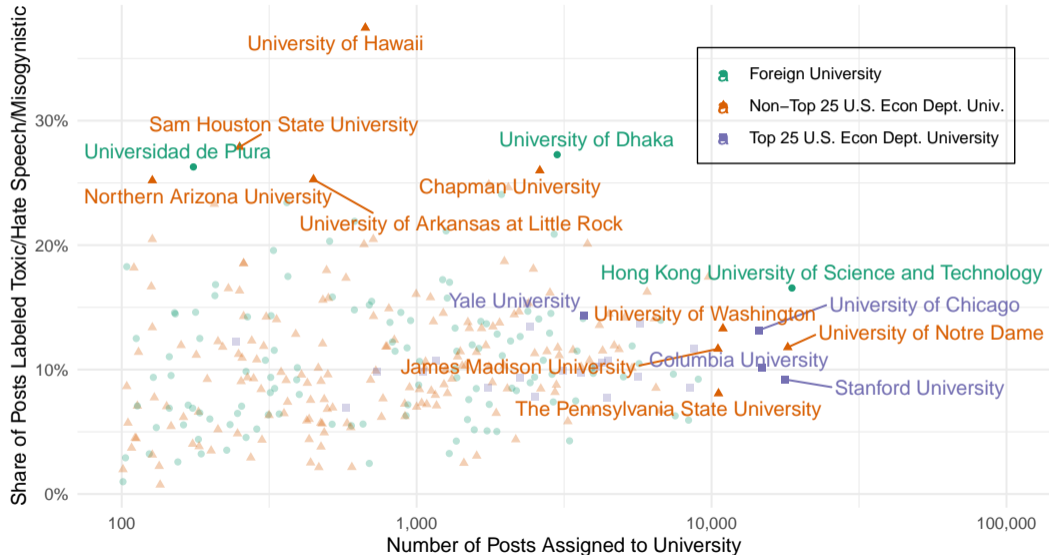
Note: Only universities with more than 100 posts are shown.

Anonymity and Identity Online

Florian Ederer, Paul Goldsmith-Pinkham & Kyle Jensen

We look forward to feedback and comments.

- florian.ederer@gmail.com
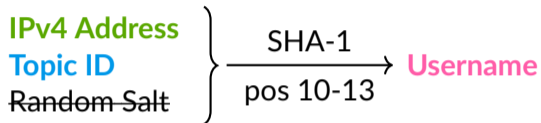- paul.goldsmith-pinkham@yale.edu
- kyle.jensen@yale.edu

nodes = EJMR IP addresses
color = mean year of activity for IP
edges = user interaction (Adamic/Adar)

Appendix

From usernames to IP addresses (in practice)

- Hash inversion is conceptually simple but intolerably slow in practice.
    - 695,364 topics $\times$ 2^{32} possible IPv4 addresses $\approx$ 3 quadrillion hashes
    - Check which hashes correspond to observed topic-username combinations
    - Easy to write code in Python, but would take over 60 years on a modern CPU

- Computation is tractable with graphical processing units (GPUs).
    - Basically the same as Bitcoin mining
    - Hash inversion is highly parallelizable
    - 230 hours of total computing time on Nvidia A100 devices each with 6,912 cores

- Hash inversion is only feasible because there is **no salt**.
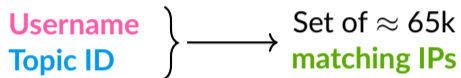
From usernames and topics to IP addresses

"Hash"

IPv4 Address
Topic ID
~~Random Salt~~
}
$\xrightarrow[\text{pos 10-13}]{\text{SHA-1}}$
Username

"Inverse Hash"

Username
Topic ID
}
$\longrightarrow$
Set of $\approx$ 65k
matching IPs

$$g(\underbrace{\text{Topic ID}}_{\text{observed}}, \overbrace{\text{IPv4 Address}}^{\text{unobserved}}) = \underbrace{\text{Username}}_{\text{observed}}$$

Known many-to-one function

Set of matching IPs
$$= g^{-1}(\underbrace{\text{Topic ID}}_{\text{observed}}, \underbrace{\text{Username}}_{\text{observed}})$$

Inverse function returns a set

IPv4 Address $\in$ Set of matching IPs

Finding Active IP Addresses

- Statistical properties
    - The noise IPs that match a topic-username (t, u) are **uniformly** distributed across the IPv4 space.
    - The probability that a noise IP a is observed in any particular set $A_{(t,u)}$ containing IPs that match (t, u) is a **hypergeometric** distribution which depends on the number of u in t.
    - The number of times n_a that a noise IP a is observed across all matching IP sets $A_{(t,u)}$ follows a **Poisson binomial** distribution.

- Our approach
    - Null hypothesis that observed counts of an IP a are generated purely by noise
    - Calculate probability under the null hypothesis that an IP a would be observed n_a times *by chance* (i.e., calculate p-values for each a)
    - Rejection of null hypothesis $\rightarrow$ IP a is active

Attributing Active IP Addresses to Posts

- IP address Attribution as an optimization problem
    - Find a small covering set of active IPs for the observed posts.
    - Compute p-values for each a in the set $A_{(t,u)}$ for all (t, u).
    - For each (t, u), identify the IP with the lowest p-value.
    - If its p-value $< p^*$, attribute to that IP. Otherwise, leave (t, u) unattributed.

- Simple intuition of this optimization approach
    - 65k IP addresses can explain any given post, but imagine one of these IPs *also* explains many posts in other topics around the same time.
    - What is the likely origin IP of this post? It's probably this highly explanatory IP.

Algorithmic IP address attribution approach

- Key assumptions
  - Sparsity of IP posters + uniformity of hash over full IPv4 space

- Potential issues with current approach
  1. Multiple-hypothesis testing problem / inference on winners
  2. A given IP will show up $N\pi_0$ times randomly, even under the null hypothesis.

- Solutions
  1. Choose conservative p-value thresholds $p^* \approx 10^{-11}$ based on known null distribution
  2. Window the data in relatively short time intervals (7 days, 31 days, 91 days)

- Work in progress
  - Generative model to construct probability statements for each post and IP combination

Choosing the p-value threshold p^*

- Use a wrong substring of SHA-1 hash to construct a pure noise baseline
  - Repeat the entire hash inversion with incorrect hash positions.
  - Compute p-values and attribute post to IP with lowest p-value.
  - Calculate p^* such that we would obtain **zero** attributions of posts to an IP

- Window-specific p-value thresholds p^*

$$p^*_{7d} = 1.37 \times 10^{-10}$$
$$p^*_{31d} = 2.51 \times 10^{-11}$$
$$p^*_{91d} = 1.39 \times 10^{-11}$$

- With these p^*, the number of IP addresses that never posted to EJMR but that we mistakenly attribute to any of the roughly 7 million posts is, in expectation, **less than one**.

# Summary of Hash Inversion and IP Attribution Steps

1. Create **topic**-specific **usernames** from hashes of all possible **topic**-**IP** pairs

2. For each **topic**-**username** find the set of **matching IPs**

3. Evaluate which **matching IPs** occur "much too often" than expected by random chance ("active IPs") in a short time window (7 days)

4. Attribute **active matching IP** with lowest p-value $< p^*$ to post or leave post unattributed

Detecting Hash Changes

- Hash changed on July 8, 2013

- Average minimum p-values are much lower for the correct hash

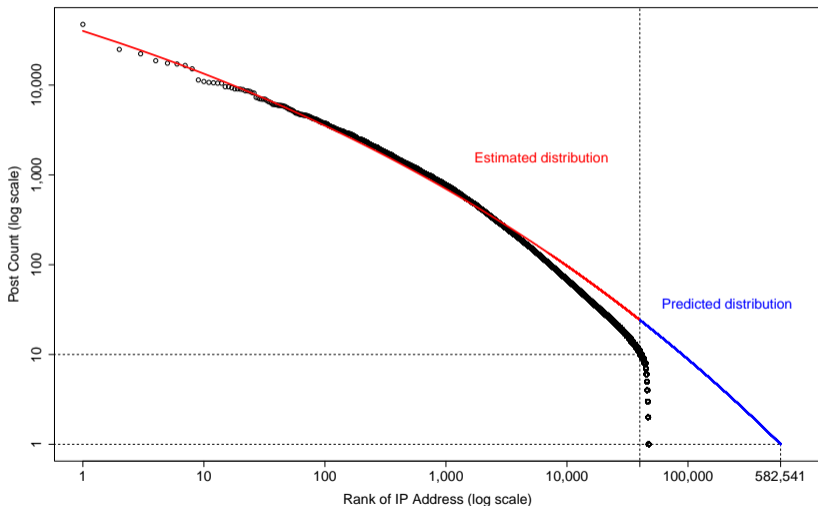- Average minimum p-values of incorrect hashes closely track each other
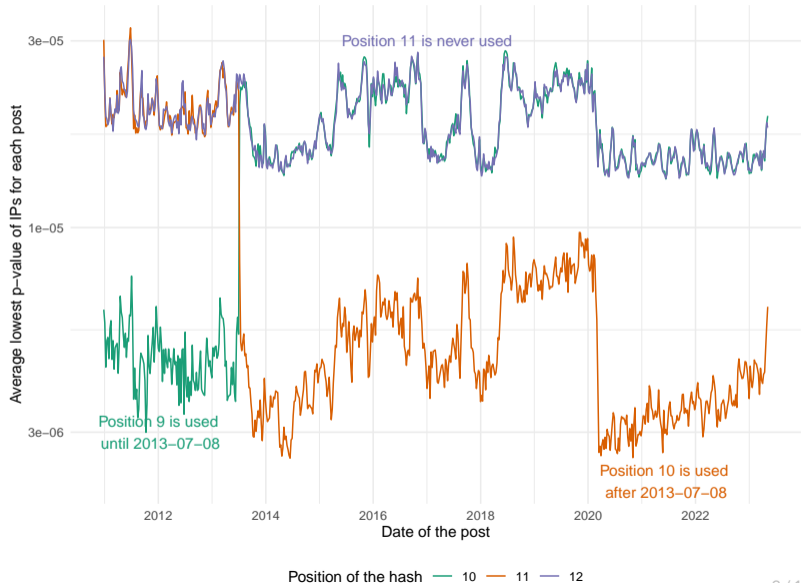
United States and Other Major Countries
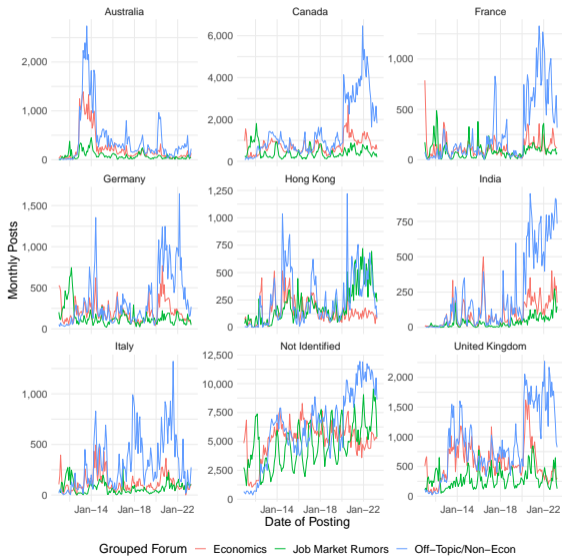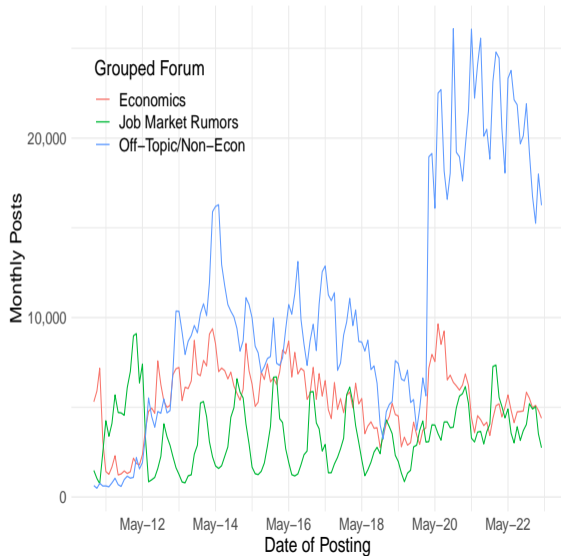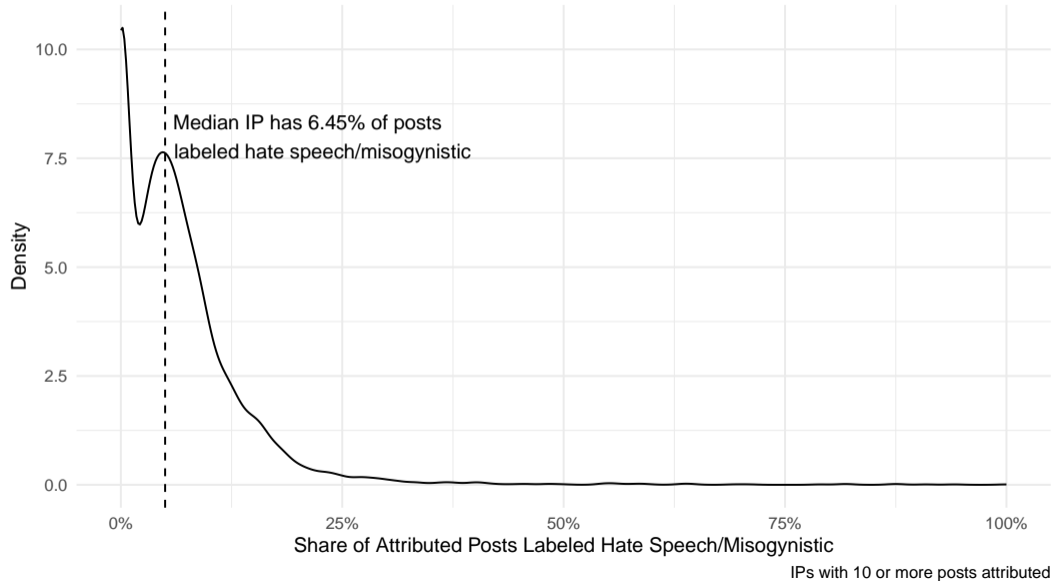
Distribution of IP addresses and posts

- 66.1% of posts come from 47,630 IPs.
- These power posters fit stretched exponential.
- Long tail of occasional posters is "unobserved."
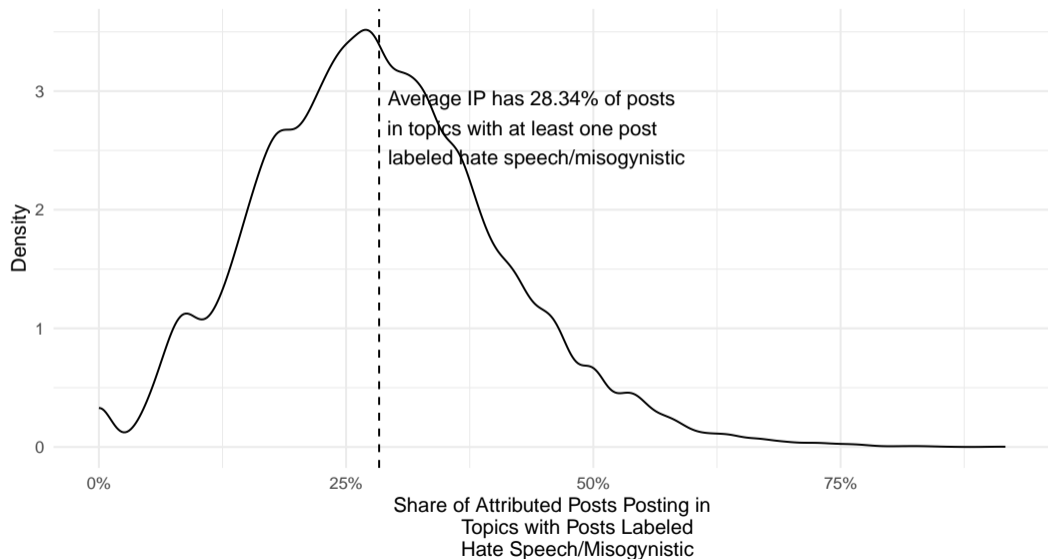- 582,541 IPs are predicted to have posted on EJMR at least once.

Linguistic Analysis

- EJMR posters use l33tspeak and obfuscation to escape automatic EJMR moderation
  - "Hey a$$h01e, I left you a message earlier too. I will be there in Boston to FIEK and RAEP you, so cover your $hitty a$$ and your mouth now." (2014-12-26)
  - "Mold-fa//g//g//ot, I will split your a//s/s in two with my HUMONGOUS super HARD shalong. You will be squealing like the little beia/tch that you are." (2020-01-28)
  - "those d4mn j3ws had no morals either." (2022-08-13)

- Deobfuscation process
  - Collect high-frequency non-English words in English posts to deobfuscate some of the most commonly obfuscated terms
  - Remove common symbol-based obfuscations
  - Transform leetspeak to its canonical form

- Run each post through a number of transformer-based machine learning models for toxicity, sentiment, and misogyny
  - Cross-validate with data by Wu (2020)
  - Note: potential classification error, but unlikely to be correlated across IPs
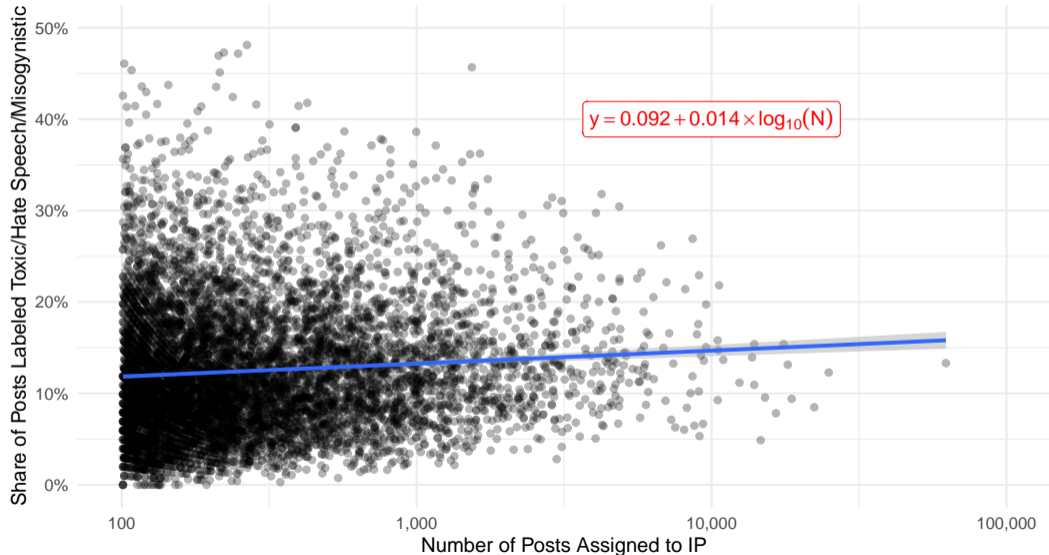
Distribution in Hateful/Misogynistic Speech across IPs

Median IP has 6.45% of posts labeled hate speech/misogynistic

Density

Share of Attributed Posts Labeled Hate Speech/Misogynistic

IPs with 10 or more posts attributed

Distribution in Participation in Hateful/Misogynistic Conversation

Average IP has 28.34% of posts in topics with at least one post labeled hate speech/misogynistic

Density

Share of Attributed Posts Posting in Topics with Posts Labeled Hate Speech/Misogynistic

IPs with 10 or more posts attributed

Do frequent IP posters post more toxic speech? Not really.

$$y = 0.092 + 0.014 \times \log_{10}(N)$$

Note: Only IPs with more than 100 posts are shown.

Toxic Speech on EJMR by University ISPs

$$y = 0.066 + 0.014 \times \log_{10}(N)$$

Share of Posts Labeled Toxic/Hate Speech/Misogynistic (y-axis, 0% to 30%)

Number of Posts Assigned to University ISP (x-axis, 100 to 10,000)

Note: Only IPs with more than 100 posts are shown.

References
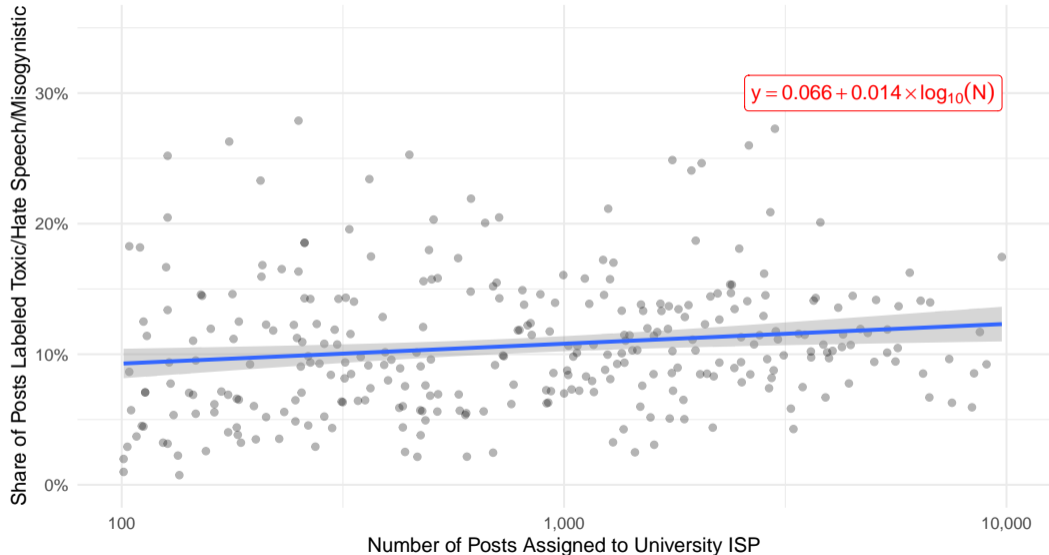
Spiegel, H. W., "Jacob Viner (1892–1970)," in J. Eatwell, M. Milgate, and P. Newman, eds., *The New Palgrave: A Dictionary of Economics*, Vol. IV, London: Macmillan, 1987, p. 812–14.

Wu, Alice H, "Gender Bias Among Professionals: An Identity-based Interpretation," *Review of Economics and Statistics*, 2020, *102* (5), 867–880.