Innovation networks and business-stealing

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Creativity and networked innovation

Research involves putting ideas together
building on knowledge ("shoulders of giants")

Externalities: sharing knowledge helps others advance / invent

Researchers / firms / organizations scared of competition
Less likely to share advances as they make them

Ideas slower moving, inventive process slowed

Collaboration versus competition

Inventors collaborate to gain from synergies of cooperation

But wary of diffusion of knowledge, threat of business-stealing

Under-invest in partnerships?

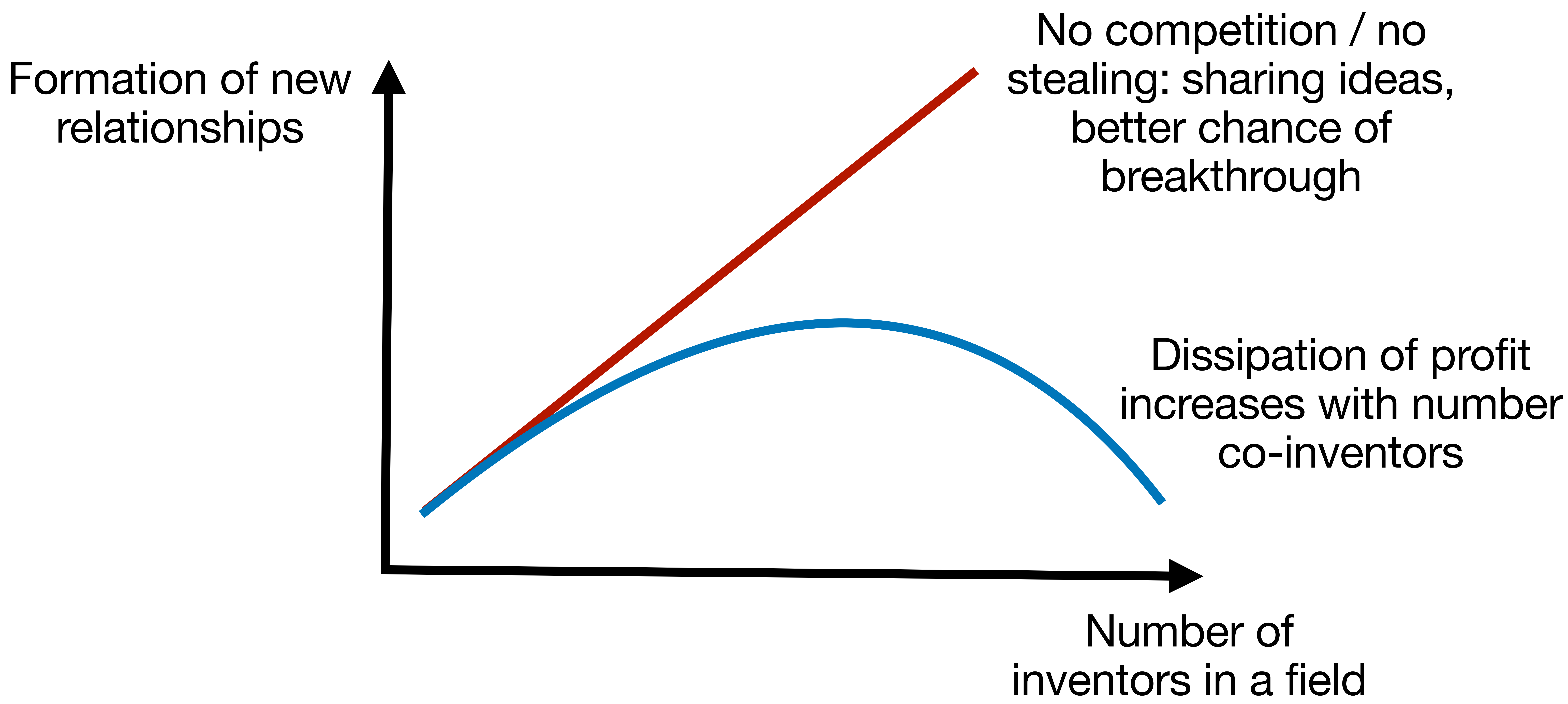
Depends on competition, and whether have idea already

Fewer collaborators: two inefficiencies

- Current team is less efficient
- Information does not diffuse as well

Increasing competition can lead to worse incentives for innovation

Rough intuition



Findings

Model predicts initial increase in collaborators as function of "competition", then decrease

Data shows this pattern (strongly), with a variety of measurements

Event study shows that after a major breakthrough (top 2% patent):

- Significant drop in new coauthors per patent (over 20%)
- Bigger drop with high competition

Outline

Data and approach

A model and some predictions: an inverted-U shape

The inverted-U in the data

An event study: A drop in new coauthors after a breakthrough

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Data and approach

Universe of USPTO data from 1976 to present

Two inventors collaborate / connect if they co-author patent

Measuring competition:

— Number of inventors in same 3-digit CPC class / technology

— Entry rate of inventors

— Price Markups

— Density of co-citations among patents in same community

Data and approach

Inventors in our sample have

— published at least 3 patents over their career

— career lasts at least 3 years

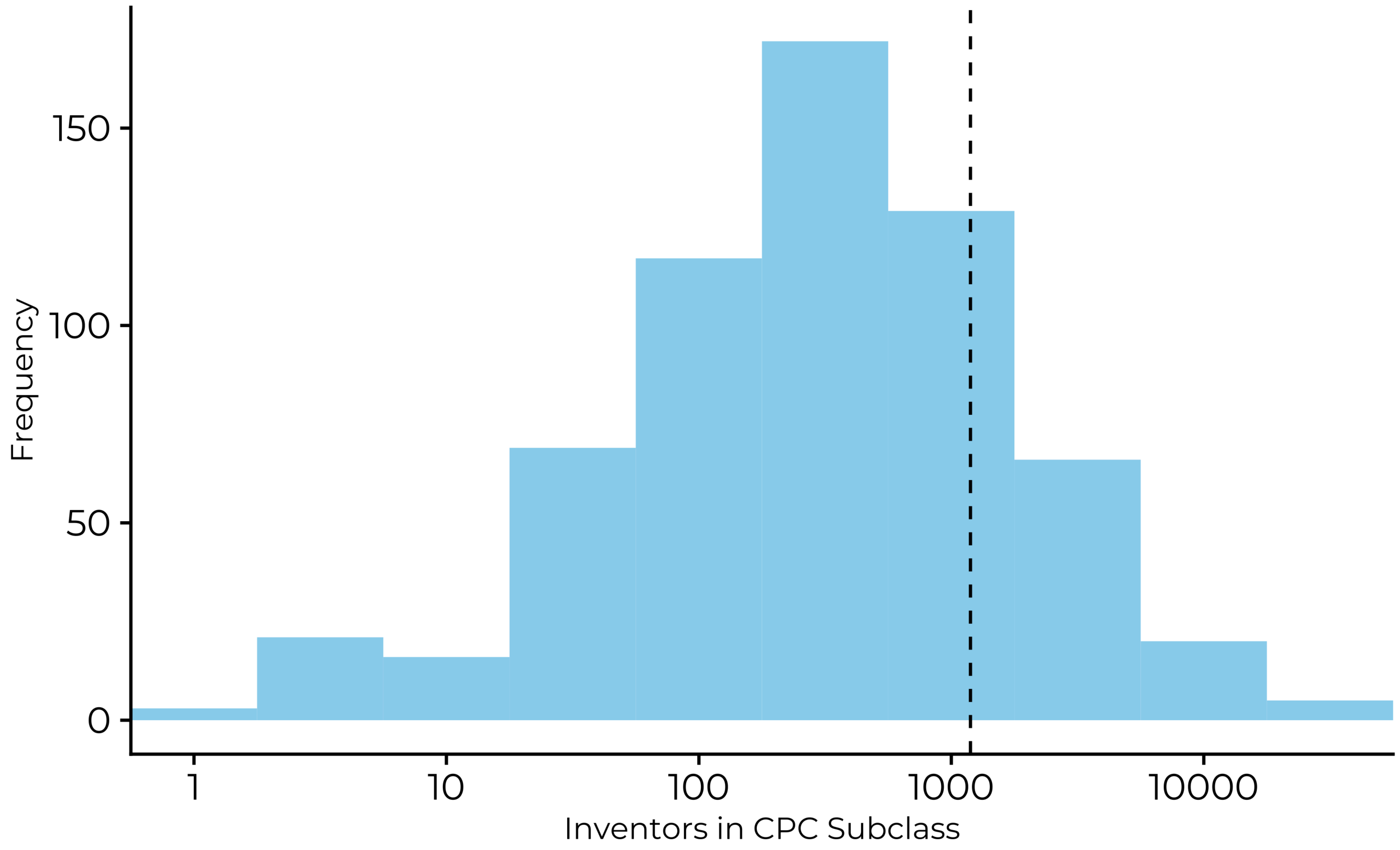
— coauthored with at least 3 people

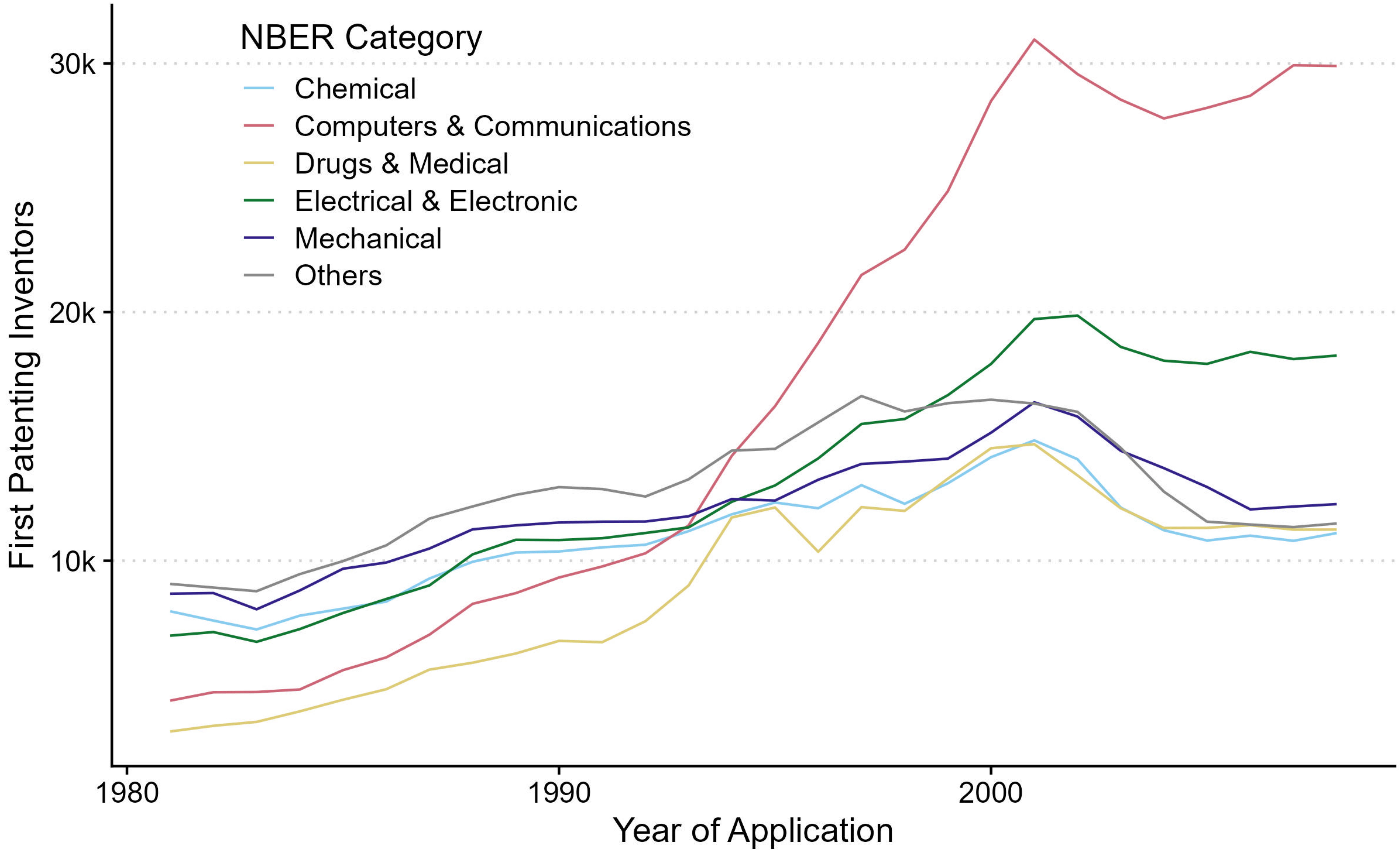
— published at least one patent alone (identify PIs)

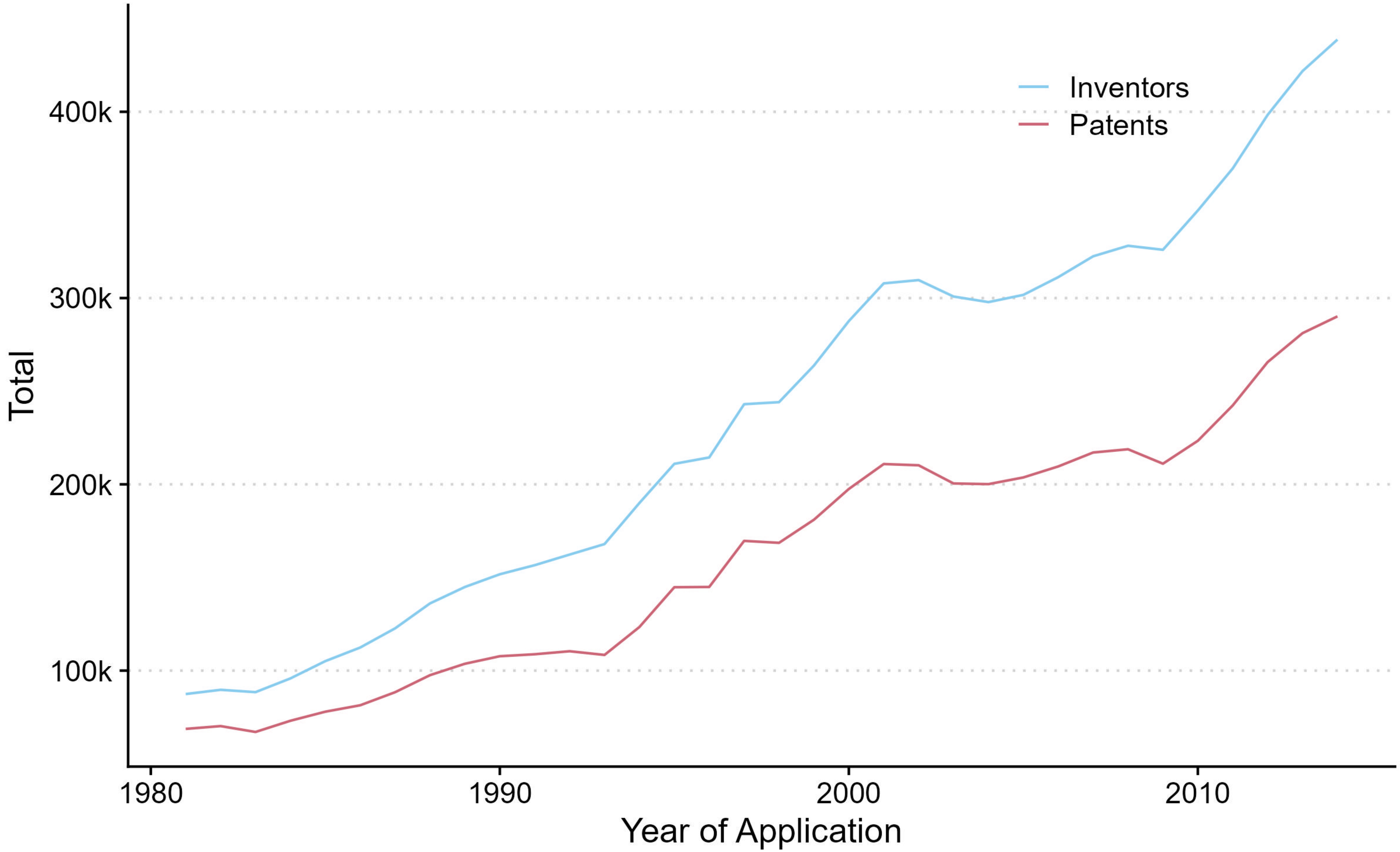
Average career length of 16 years

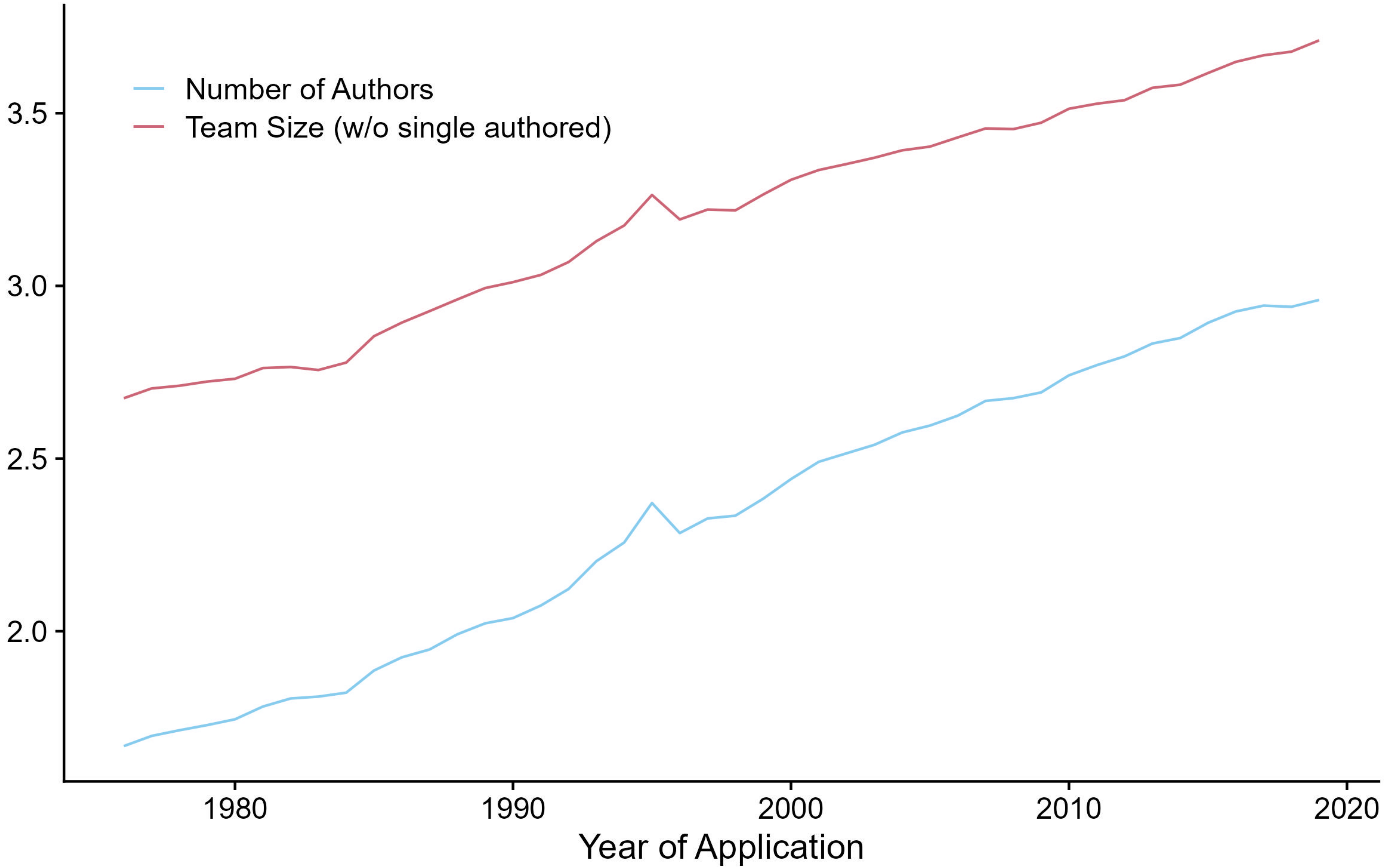
149,490 (150k) unique inventors

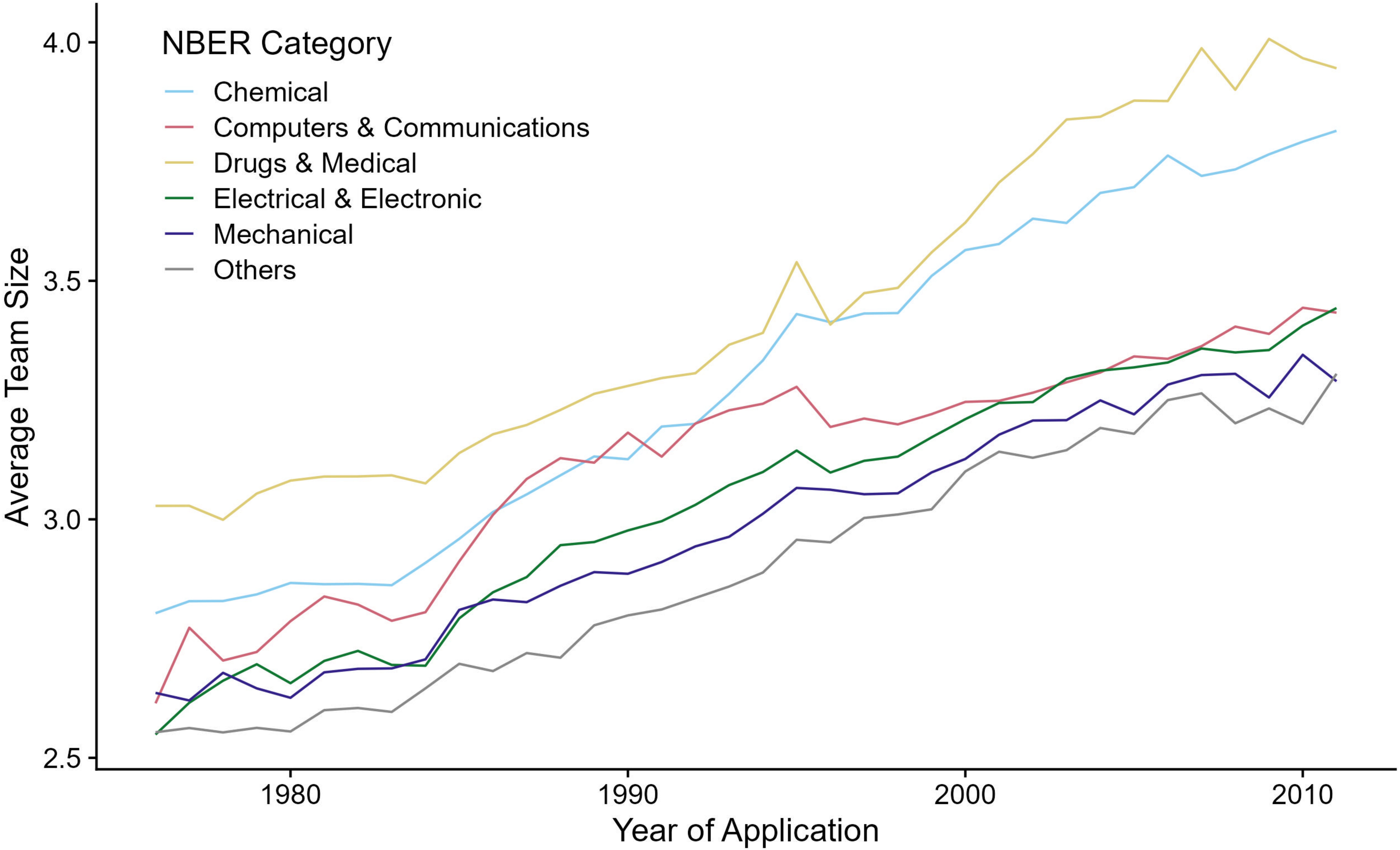
2,493,500 (2.5 million) observations


Frequency
150
100
50
0
1
10
100
1000
10000
Inventors in CPC Subclass

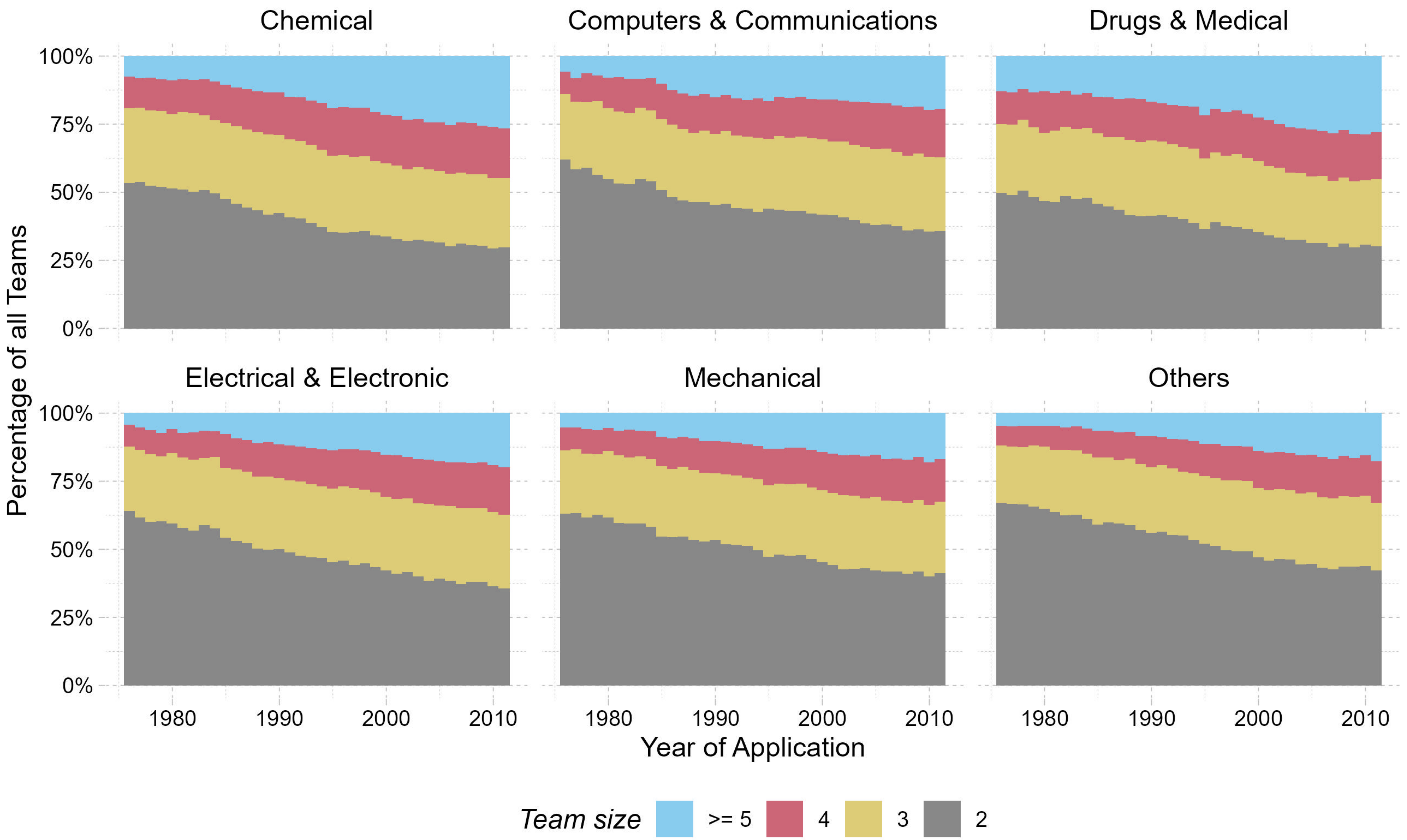

NBER Category
Chemical
Computers & Communications
Drugs & Medical
Electrical & Electronic
Mechanical
Others
30k
20k
10k
First Patenting Inventors
1980
1990
2000
Year of Application


Inventors
Patents
Total
400k
300k
200k
100k
1980
1990
2000
2010
Year of Application


Number of Authors
Team Size (w/o single authored)
3.5
3.0
2.5
2.0
1980
1990
2000
2010
2020
Year of Application



NBER Category
Chemical
Computers & Communications
Drugs & Medical
Electrical & Electronic
Mechanical
Others
Average Team Size
4.0
3.5
3.0
2.5
1980
1990
2000
2010
Year of Application


Chemical
Computers & Communications
Drugs & Medical
Electrical & Electronic
Mechanical
Others
Percentage of all Teams
100%
75%
50%
25%
0%
1980
1990
2000
2010
Year of Application
Team size
>= 5
4
3
2

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A simple model

d	number of collaborators
$\Pr(d)$	prob. of success, increasing in collaborators d, concave
$\pi(d;c)$	profit per inventor if successful (0 if failed) decreasing in collaborators d, tends to 0, log concave decreasing in competition c
$\dfrac{\pi'(d;c)}{\pi(d;c)} < 0$	decreasing in collaborators d, competition c more competition leads to greater percentage decrease in profits from more collaborators

Profit maximization

$$\max_d \Pr(d)\pi(d;c)$$

FOC:

$$\underbrace{\frac{\overbrace{\Pr'(d)}^{-\text{ve}}}{\Pr(d)}}_{\text{decreasing in } d} = \underbrace{\overbrace{-\frac{\overbrace{\pi'(d;c)}^{-\text{ve}}}{\pi(d;c)}}^{+\text{ve}}}_{\text{increasing in } d,\ c}$$

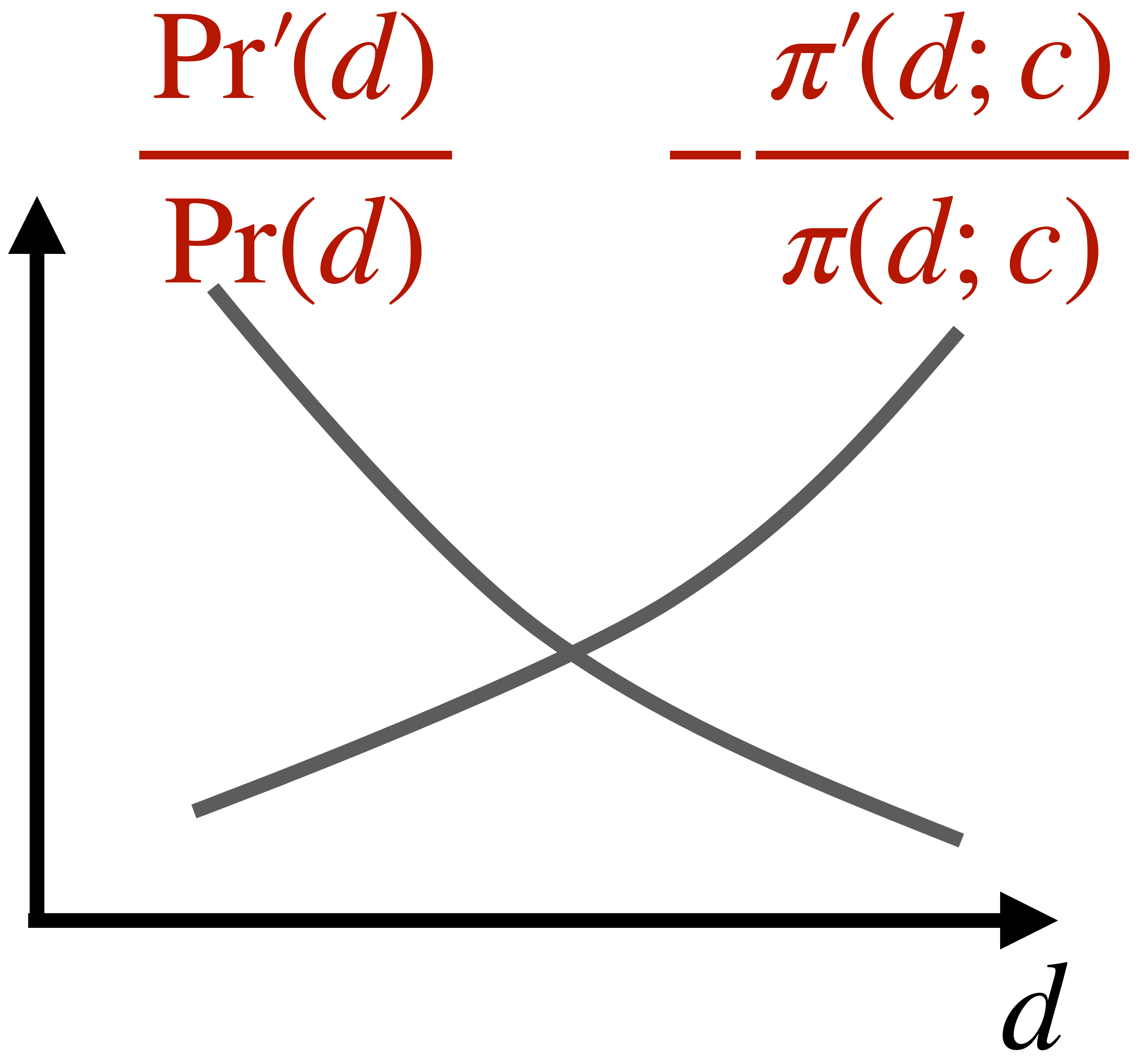
There exists a finite solution: profits go to 0 as d increases

Profit maximization

$$\max_{d} \Pr(d)\pi(d; c)$$

FOC:

$$\underbrace{\frac{\overbrace{\Pr'(d)}^{-\text{ve}}}{\Pr(d)}}_{\text{decreasing in } d} = \underbrace{\overbrace{-\frac{\overbrace{\pi'(d; c)}^{-\text{ve}}}{\pi(d; c)}}^{+\text{ve}}}_{\text{increasing in } d,\ c}$$



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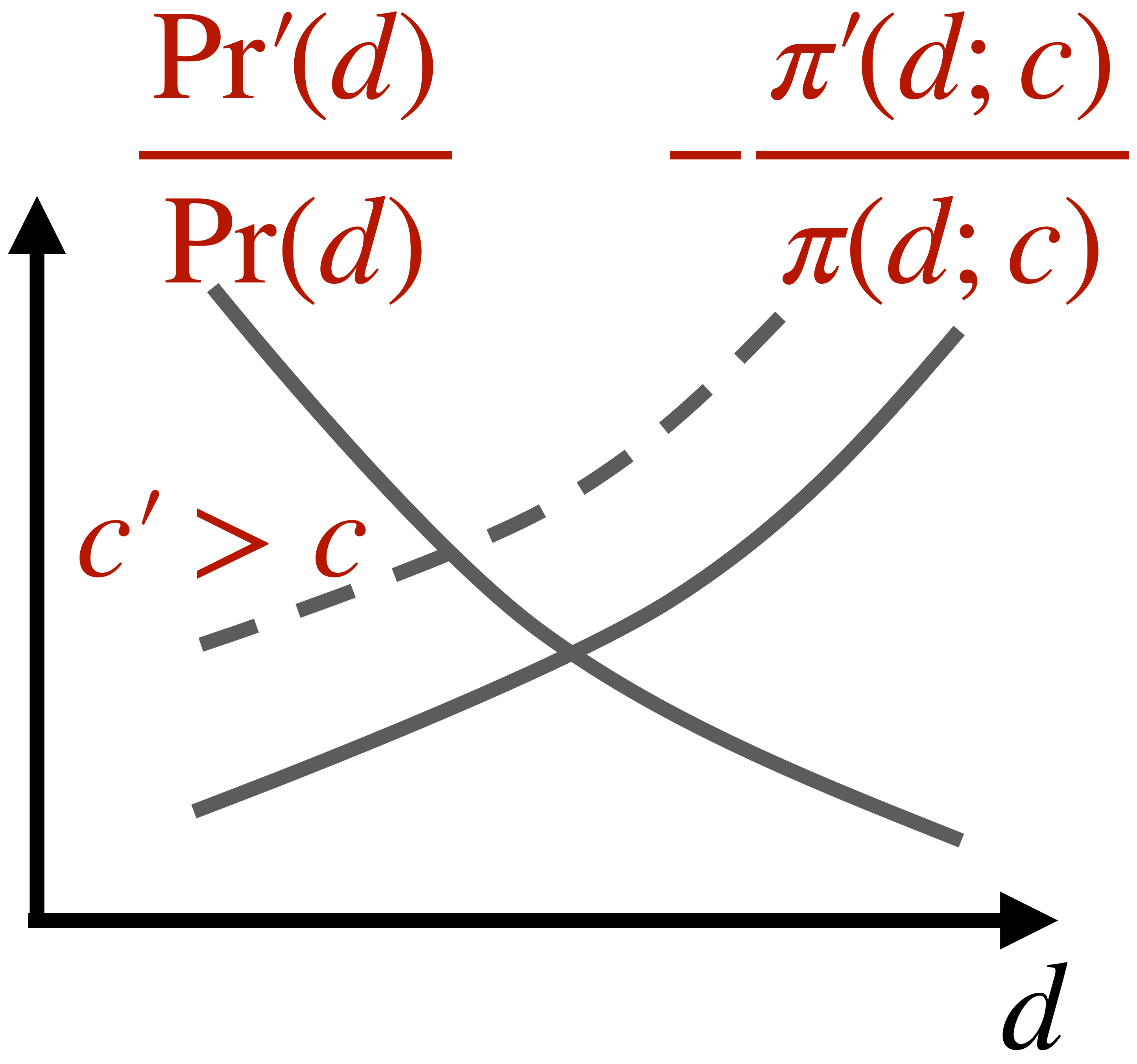
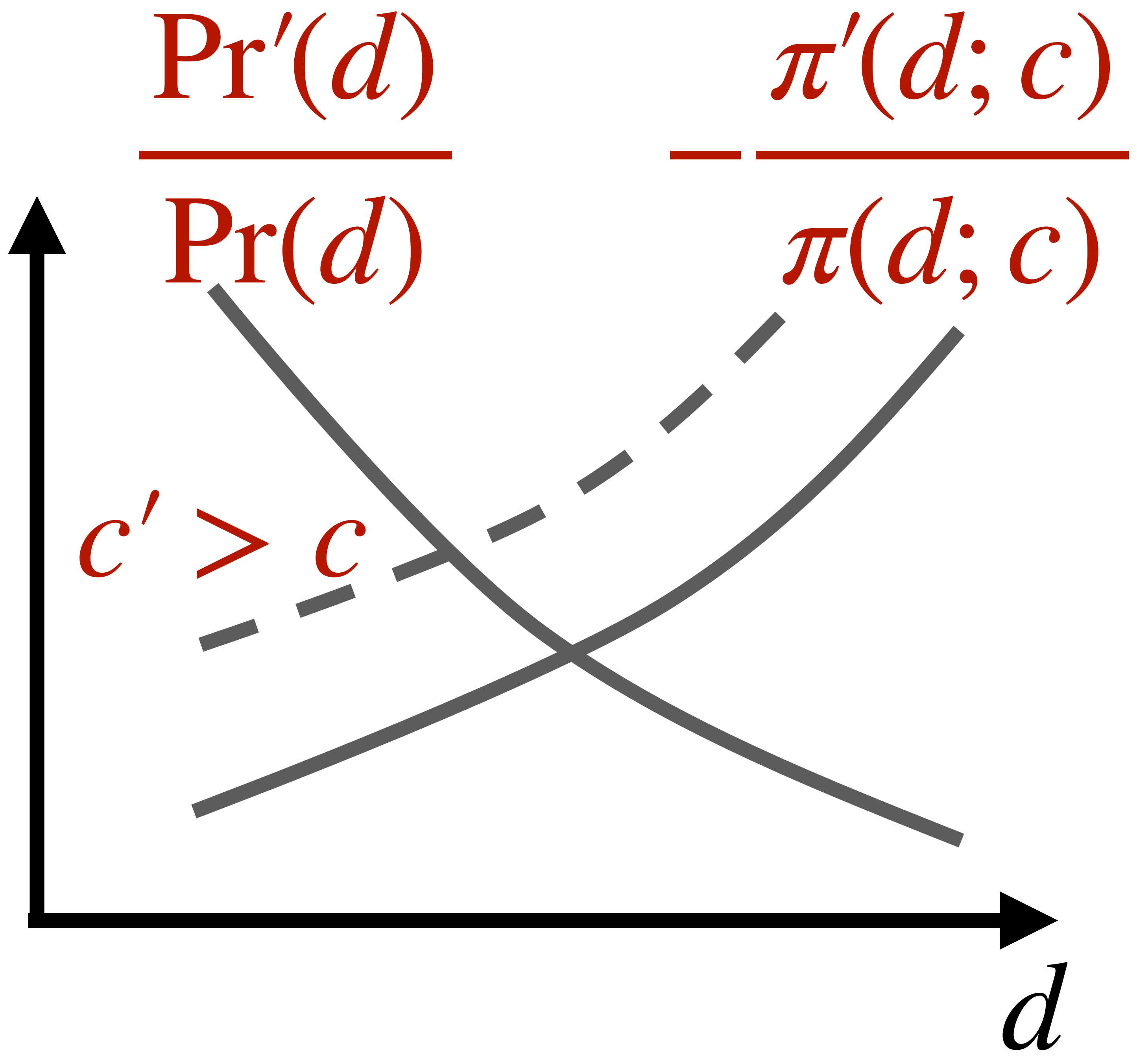


There exists a finite solution: profits go to 0 as d increases

An example profit function

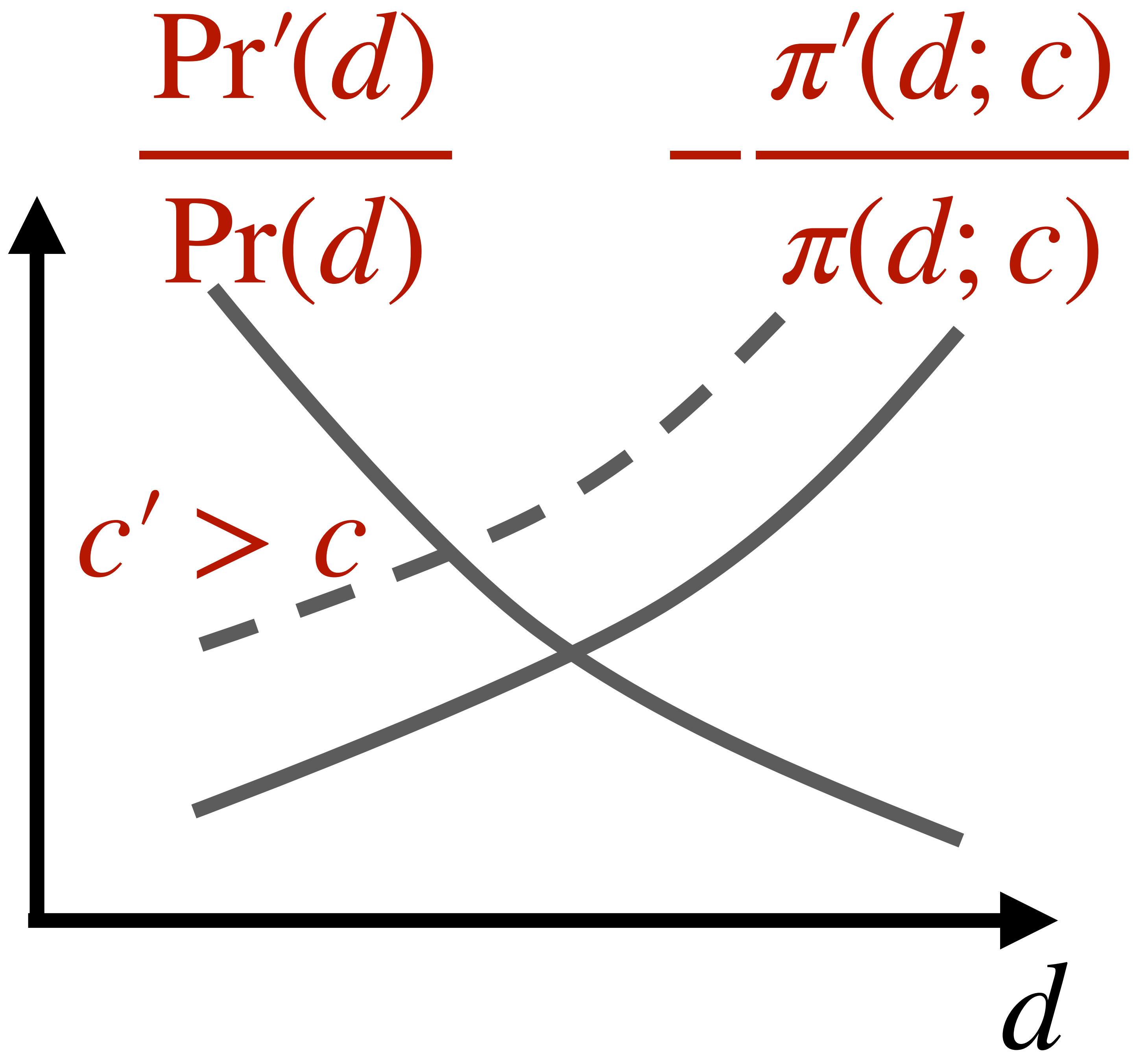
$$\Pr(d) = \min\{1,\ bd\}$$
$$\pi(d; c) = \max\{0,\ \pi_0 - cd\}$$



An example profit function

$$\Pr(d) = \min\{1,\ bd\}$$
$$\pi(d; c) = \max\{0,\ \pi_0 - cd\}$$

$$\frac{\Pr'(d)}{\Pr(d)} = \frac{1}{d} \qquad -\frac{\pi'(d;c)}{\pi(d;c)} = \frac{c}{\pi_0 - cd}$$



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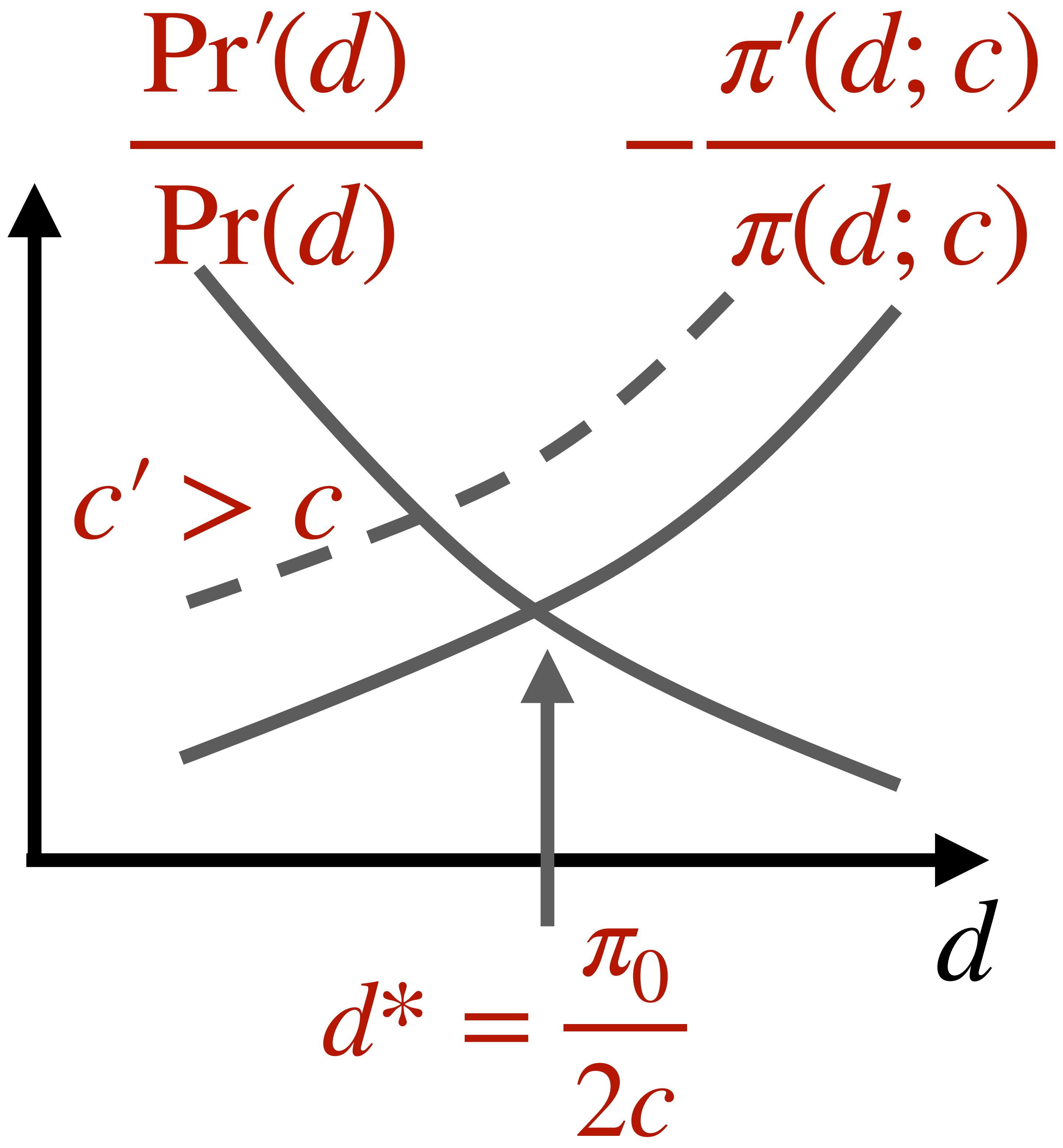
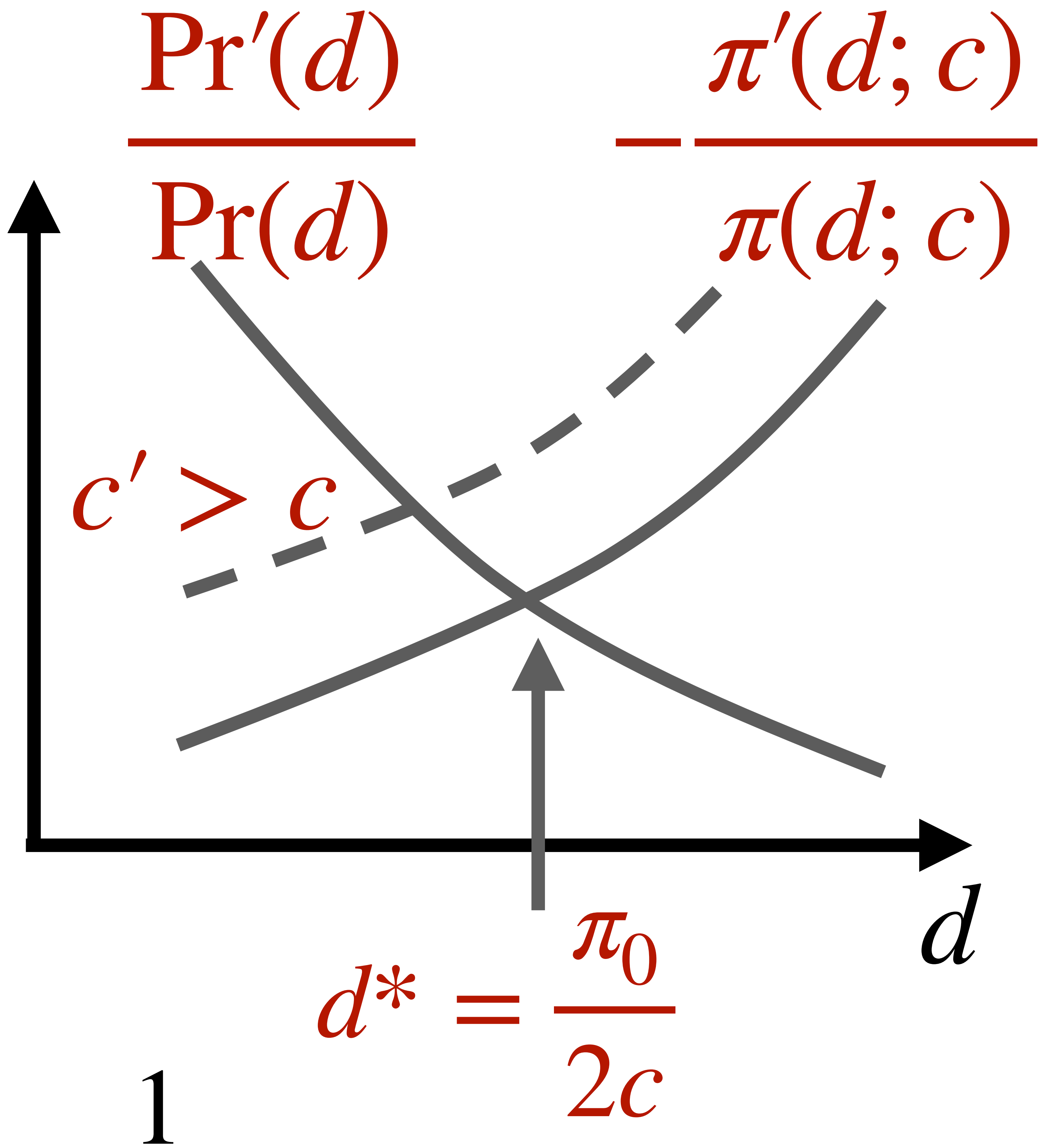
At intersection: $d^* = \dfrac{\pi_0}{2c}$



An example profit function

$\Pr(d) = \min\{1, bd\}$
$\pi(d; c) = \max\{0, \pi_0 - cd\}$

$$\frac{\Pr'(d)}{\Pr(d)} = \frac{1}{d} \qquad -\frac{\pi'(d;c)}{\pi(d;c)} = \frac{c}{\pi_0 - cd}$$

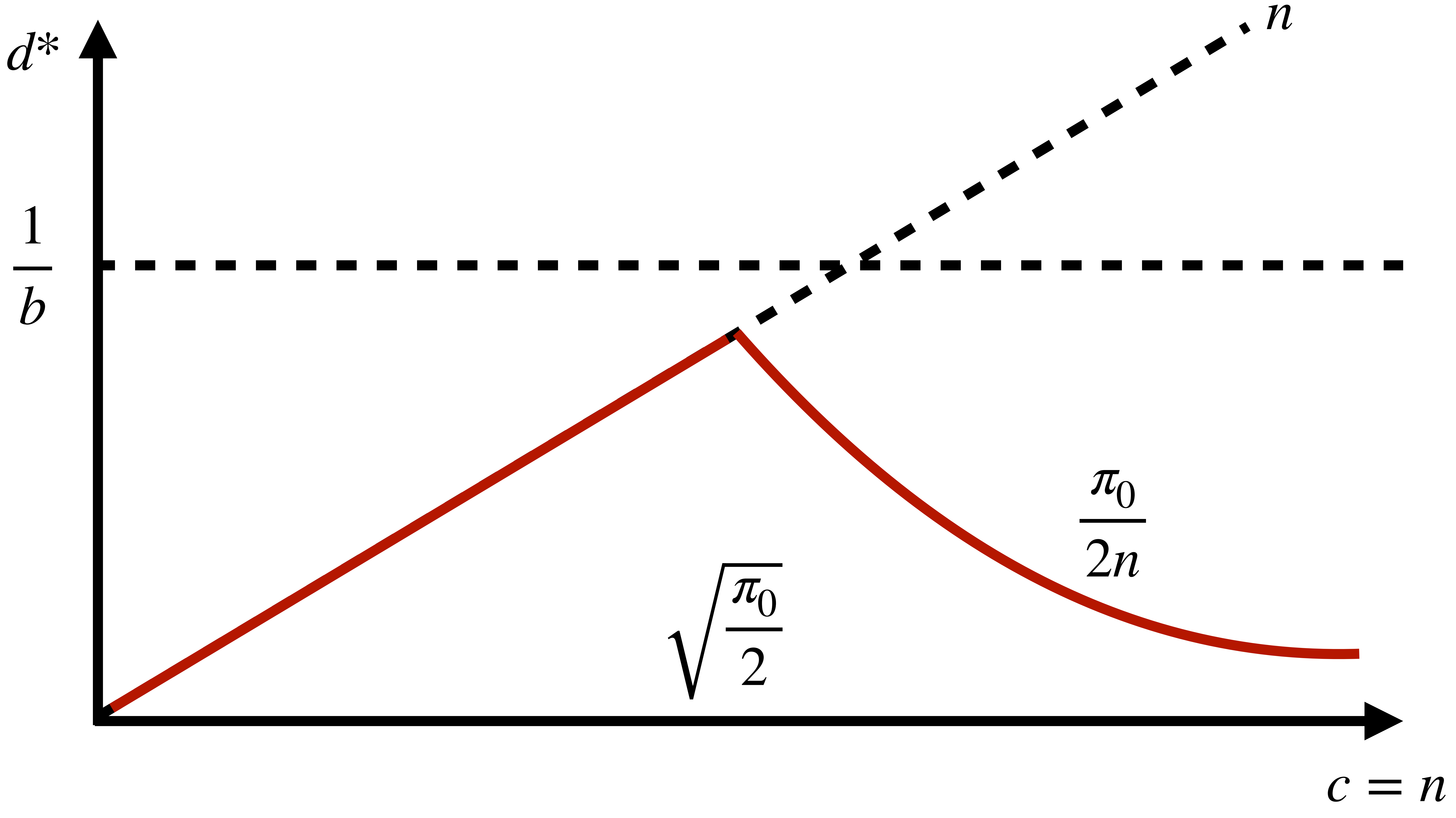


At intersection: $d^* = \dfrac{\pi_0}{2c}$

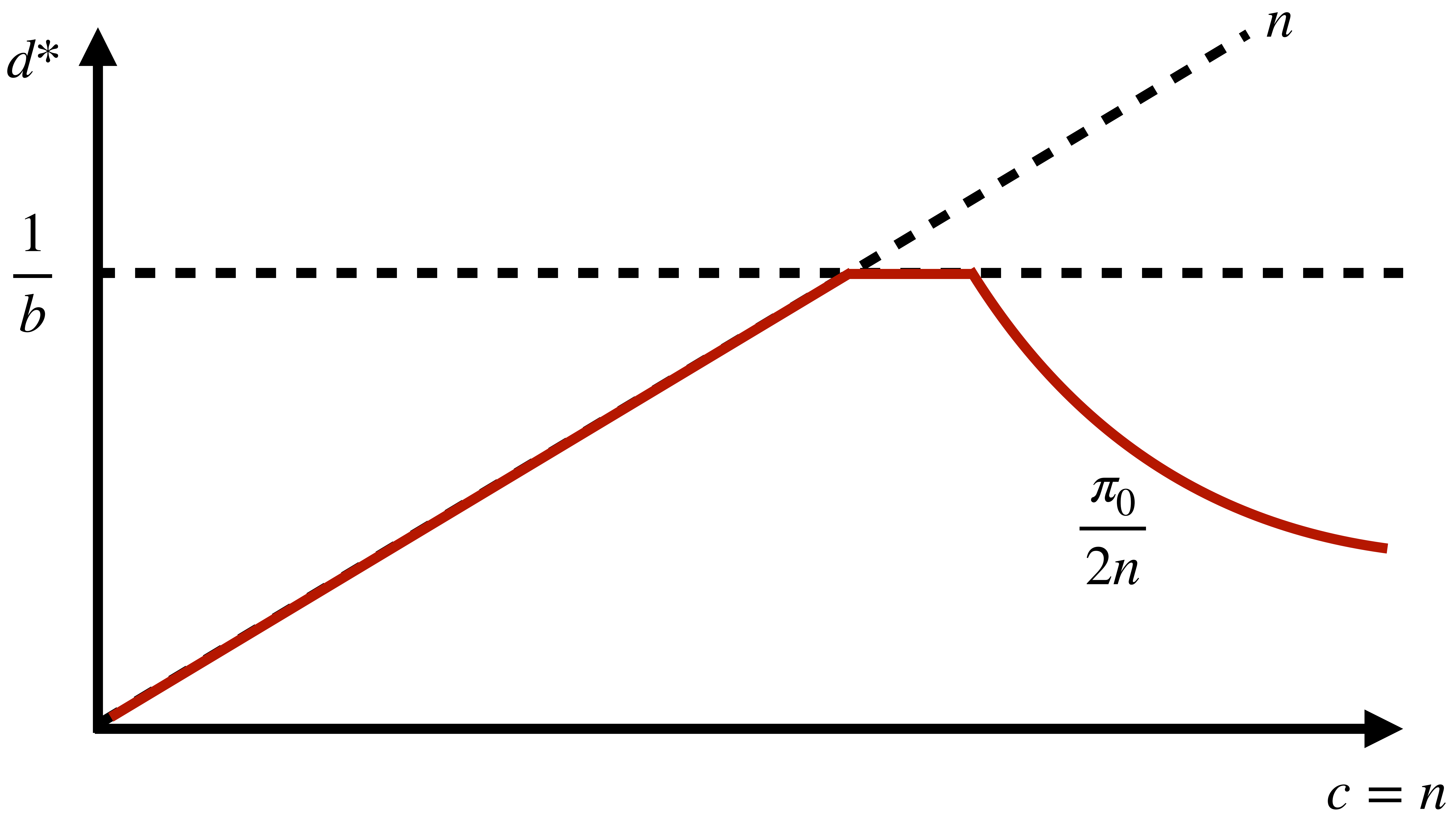
Before intersection: $d^* = n$ (expand). Max probability: $d^* = \dfrac{1}{b}$

$$d^* = \min\left\{n, \frac{\pi_0}{2c}, \frac{1}{b}\right\}$$

An example profit function with $c = n$



An example profit function with $c = n$



Endogenous competition

Threat of business-stealing is endogenous	$b(d, n)$	$= c_0 + \delta n + \gamma d$
Probability of success	$\Pr(d)$	$= \min\{1,\ ad\}$
Profit	$\pi(d; b(d, n))$	$= \max\{0,\ \pi_0 - b(d, n)\}$
		$= \max\{0,\ \pi_0 - c_0 - \delta n - \gamma d\}$

Inventors maximize expected profit:

$$\max_d \Pr(d)\ \pi(d; b(d, n))$$

FOC:

$$\frac{1}{d} = -\frac{\gamma}{\pi_0 - c_0 - \delta n - \gamma d}$$

Solution gives an inverted-U:

$$d^* = \min\left\{n, \frac{\pi_0 - c_0 - \delta n}{2\gamma}, \frac{1}{a}\right\}$$

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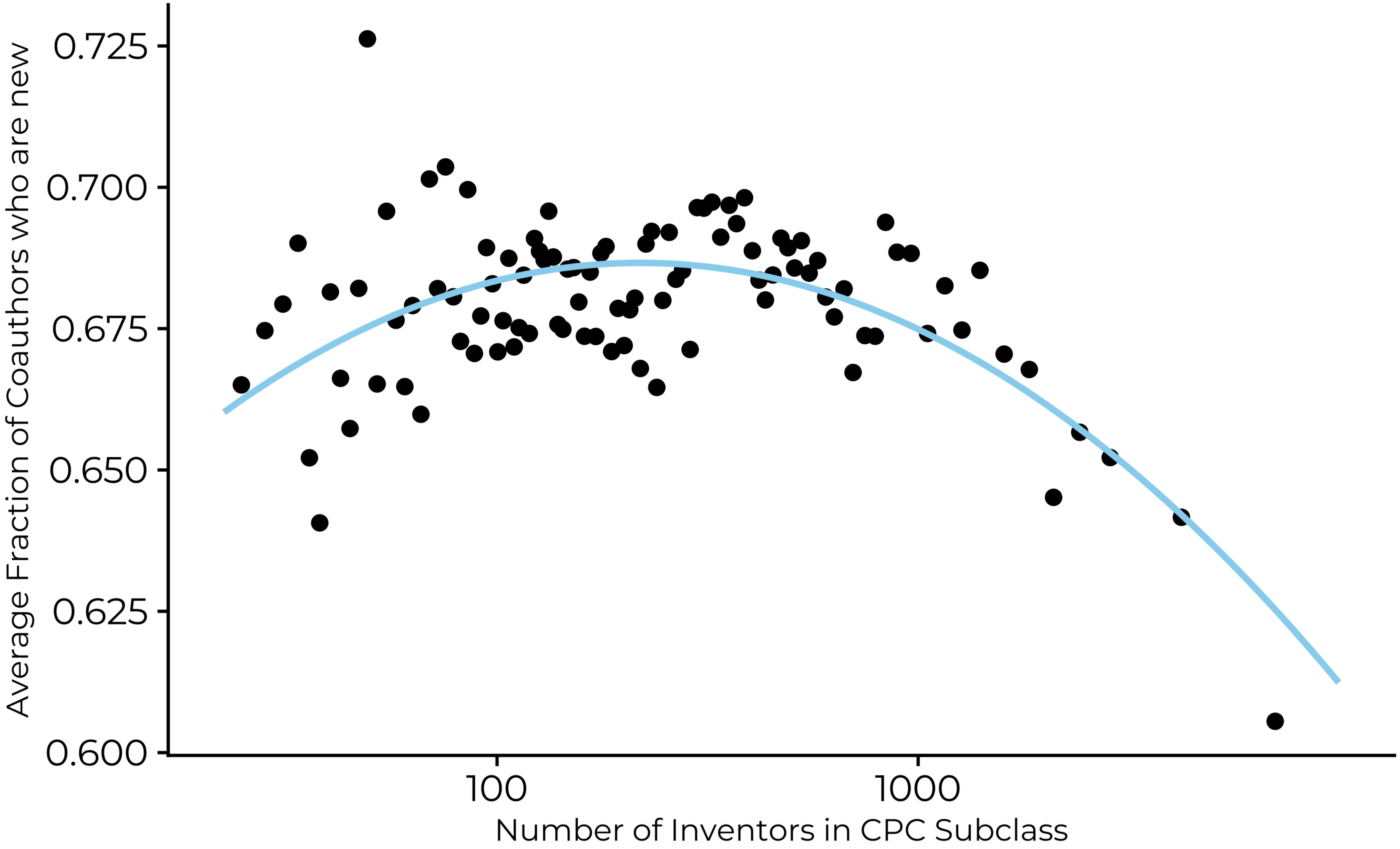
An event study: A drop in new coauthors after a breakthrough



The unit of observation is a CPC subclass. The solid line is a quadratic least squares fit.
Both variables are residualized by year and centered around the sample average.

The inverted-U in data

	(1)	(2)	(3)	(4)
(Intercept)	0.612***			
	(0.017)			
Log number of inventors	0.049***	0.054***	0.035***	-0.015*
	(0.006)	(0.005)	(0.005)	(0.008)
Log number of inventors squared	-0.005***	-0.005***	-0.003***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.001)
Year fixed effects	-	Yes	-	-
Year × CPC class fixed effects	-	-	Yes	-
CPC subclass fixed effects	-	-	-	Yes
Observations	17,842	17,842	17,842	17,842
R^2	0.020	0.402	0.626	0.631
Within R^2		0.011	0.005	0.026

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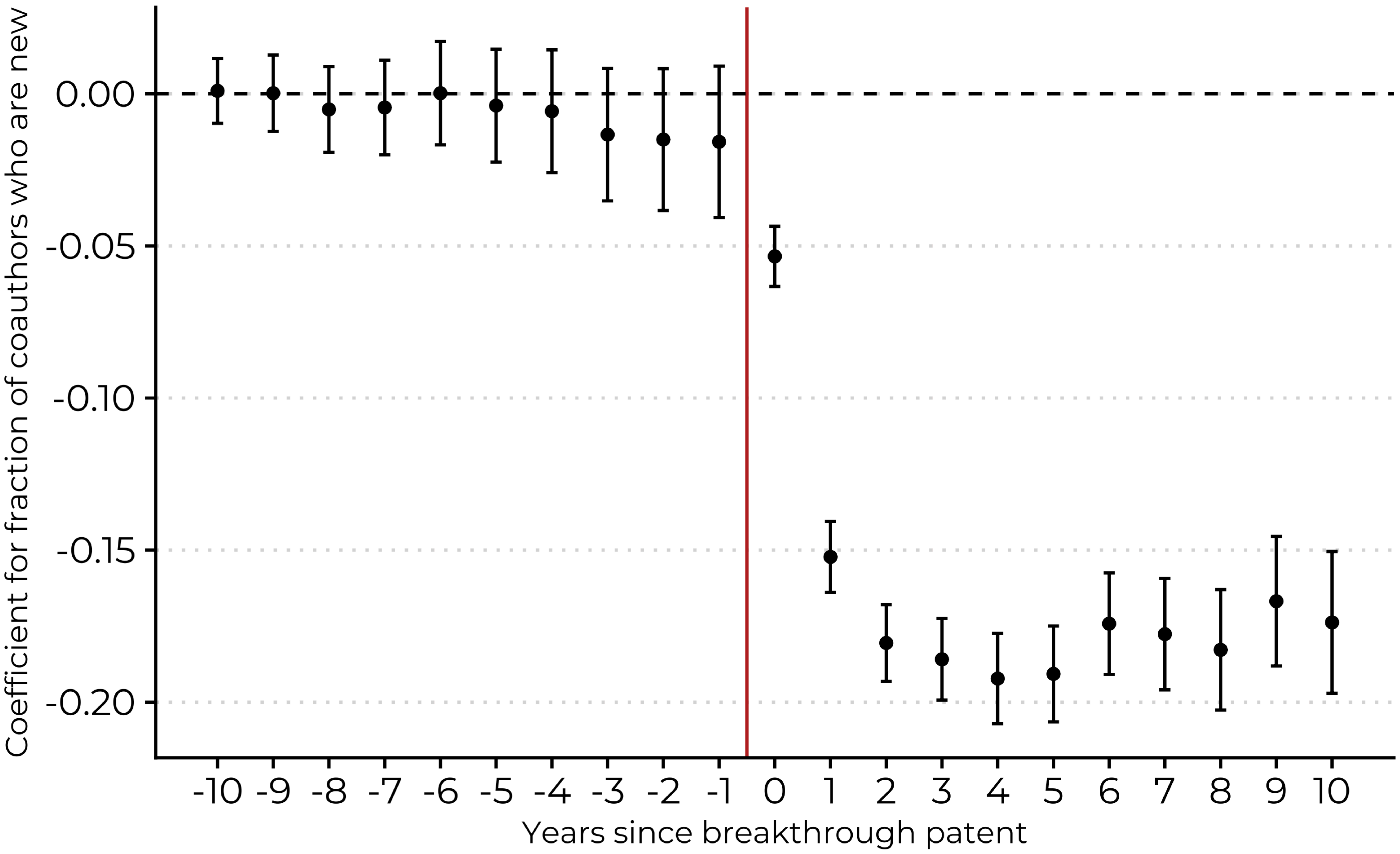
Event study on breakthroughs

Inventors find new coauthors in search of a gold mine of ideas

— Once they find a gold mine, they exploit

Predict a drop in new coauthors subsequent to a breakthrough

Breakthroughs and new co-authorships



Breakthroughs are defined as patents in top 2% of citations in its technological field (CPC subclass) within first 2 years of patent grant. Event is timed at the date of patent application.

Breakthroughs and new co-authorships

	Fraction of coauthors who are new				Growth rate in stock of coauthors			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Treated	-0.194***	-0.081***	-0.072***	-0.152***	-0.123***	-0.058***	-0.052***	-0.071***
	(0.003)	(0.005)	(0.005)	(0.006)	(0.003)	(0.003)	(0.004)	(0.004)
Inventor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year		Yes	Yes	Yes		Yes	Yes	Yes
Year × CPC sub × Country			Yes				Yes	
Experience				Yes				Yes
Wald statistic	137.139	10.470	4.305	1.055	127.816	4.346	1.591	2.030
Observations	349,130	343,816	326,066	349,130	343,816	326,066	349,130	343,816
Units	18,899	18,899	18,899	18,899	18,899	18,899	18,899	18,899

Event study on breakthroughs

Inventors find new coauthors in search of a gold mine of ideas

— Once they find a gold mine, they exploit

Predict a drop in new coauthors subsequent to a breakthrough

But this drop should depend on the value of ideas

— Value of ideas higher in more competitive fields

— Higher value = steeper drop to avoid sharing rents

Controlling for impact, differential drop by competition?

Event study on breakthroughs

	Fraction of coauthors who are new		Growth rate in stock of coauthors	
Level of competition:	Below median	Above median	Below median	Above median
Measure of competition:				
Density of inventors	**-0.135*** **	-0.162***	**-0.051*** **	-0.083***
	(0.009)	(0.007)	(0.006)	(0.005)
Sector markup	**-0.123*** **	-0.165***	**-0.045*** **	-0.082***
	(0.009)	(0.007)	(0.007)	(0.004)
Entry rate	**-0.104*** **	-0.203***	**-0.056*** **	-0.083***
	(0.007)	(0.007)	(0.005)	(0.005)
Similarity density	**-0.149*** **	-0.163***	**-0.038*** **	-0.106***
	(0.007)	(0.008)	(0.005)	(0.005)

Controls include inventor, inventor experience, year x CPC subclass x country fixed effects

In conclusion

Inventor networks respond to competitive forces

— Networks grow more slowly as competition goes up

— Business-stealing threats dominate

— Potential underinvestment in new partnerships, new combinations

Further: aggregate (this paper) vs competitive dynamics within firms

— Do firms in highly competitive areas restrict between team collaboration, firm size? (ex., Apple's famed secrecy, pharmaceutical, …)

Breakthroughs lead to new research advances

— Do they spur expansion of coauthorships in other innovators?

— Slowed growth among incumbents, vs new growth among entrants?