Who Becomes an Inventor in America?
The Importance of Exposure to Innovation

Alex Bell, Harvard
Raj Chetty, Stanford
Xavier Jaravel, London School of Economics
Neviana Petkova, Office of Tax Analysis
John Van Reenen, MIT

December 2017

The opinions expressed in this paper are those of the authors alone and do not necessarily reflect the views of the Internal Revenue Service or the U.S. Treasury Department.

Motivation: Determinants of Innovation

- Innovation is widely viewed as the engine of economic growth
  [Romer 1990, Aghion and Howitt 1992]

- Many policies used to spur innovation, ranging from tax cuts to investments in STEM education

- One approach to understanding effectiveness of such policies: study the determinants of who becomes an inventor
  - What types of people become inventors today?
  - What do their experiences teach us about who becomes a successful inventor?

This Paper

- We study the determinants of innovation using de-identified data on 1.2 million inventors from patent records linked to tax records

- Track inventors' lives from birth to adulthood to identify factors that determine who invents and policies that may be effective in increasing innovation

This Paper

- Main result: there are large gaps in innovation rates by parental income, gender, and race that are partly caused by differences in exposure to innovation
  - Substantial potential to increase innovation by bringing “lost Einsteins” into the pipeline through targeted efforts to increase exposure
  - In contrast, changes in financial incentives have less scope to increase innovation because high-impact inventors already earn high returns
- Findings contribute to nascent literature studying “supply of inventors” using administrative data from European countries [Toivanen & Vaananen 2012, 2015; Jung and Ejermo 2014; Depalo and Di Addario 2015; Bender et al. 2015; Aghion, Akcigit, Hyytinen, & Toivanen 2017]

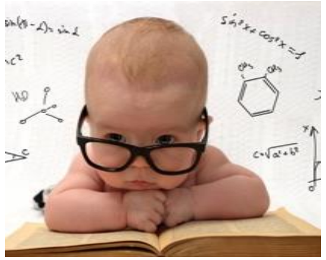
The Lifecycle of Inventors

- Organize analysis around the chronology of an inventor’s life

<u>Birth</u>
Parents
Gender
Ability

<u>Childhood</u>
Mentors
Neighborhood
College

<u>Career</u>
Earnings
Employers
Age Profile



Patent Data

- Patents granted between 1996-2014 from USPTO (Google XML files): 1.7 million patents
- Published applications between 2001-12 from Strumsky (2014): 1.6 million applications

(19) United States
(12) **Patent Application Publication**
Musabji et al.
(10) Pub. No.: US 2014/0244159 A1
(43) Pub. Date: Aug. 28, 2014

(54) **METHOD OF OPERATING A NAVIGATION SYSTEM USING IMAGES**

(71) Applicant: **Navteq North America, LLC**, Chicago, IL (US)

(72) Inventors: **Adil M. Musabji**, Glendale Heights, IL (US); **Jason Borak**, Lombard, IL (US); **James D. Lynch**, Chicago, IL (US); **Narayanan Alwar**, South Barrington, IL (US); **Jon D. Shutter**, Chicago, IL (US)

(73) Assignee: **Navteq North America, LLC**, Chicago, IL (US)

(21) Appl. No.: **14/272,045**

(22) Filed: **May 7, 2014**

Related U.S. Application Data

(63) Continuation of application No. 13/279,537, filed on Oct. 24, 2011, now Pat. No. 8,751,156, which is a continuation-in-part of application No. 12/879,178, filed on Sep. 10, 2010, now Pat. No. 8,301,372, which is a continuation of application No. 12/253,488, filed on Oct. 17, 2008, now Pat. No. 7,818,124, which is a continuation of application No. 10/880,815, filed on Jun. 30, 2004, now Pat. No. 7,460,953.

Publication Classification

(51) **Int. Cl.**
G01C 21/36 (2006.01)

(52) **U.S. Cl.**
CPC ***G01C 21/3647*** (2013.01)
USPC **701/428**

(57) **ABSTRACT**

A navigation system comprises a processor, a geographic database and a guidance application executable on the processor. The guidance application obtains data from the geographic database and obtains a photographic image. The guidance application overlays an advertisement route highlight on said photographic image. The advertisement route highlight graphically illustrates a path corresponding to a route and a direction of travel for the route. The advertisement route highlight includes a series of advertisement decals.

Income Tax Data

- Panel dataset covering U.S. population
  - Covers every person in the U.S. who appears on any tax form from 1996-2012
  - Includes non-filers through information returns (W-2's, 1099's, etc.)

Linked Patent-Tax Data

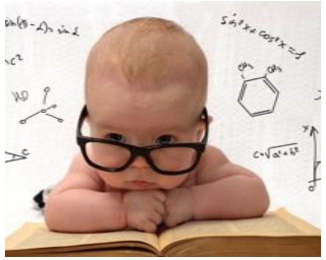
- Patent data were linked to tax data by inventor name, city, and state at time of patent application

- 86% of people in patent files linked to tax data

- 1,200,689 unique inventors in linked patent-tax data

The Lifecycle of Inventors

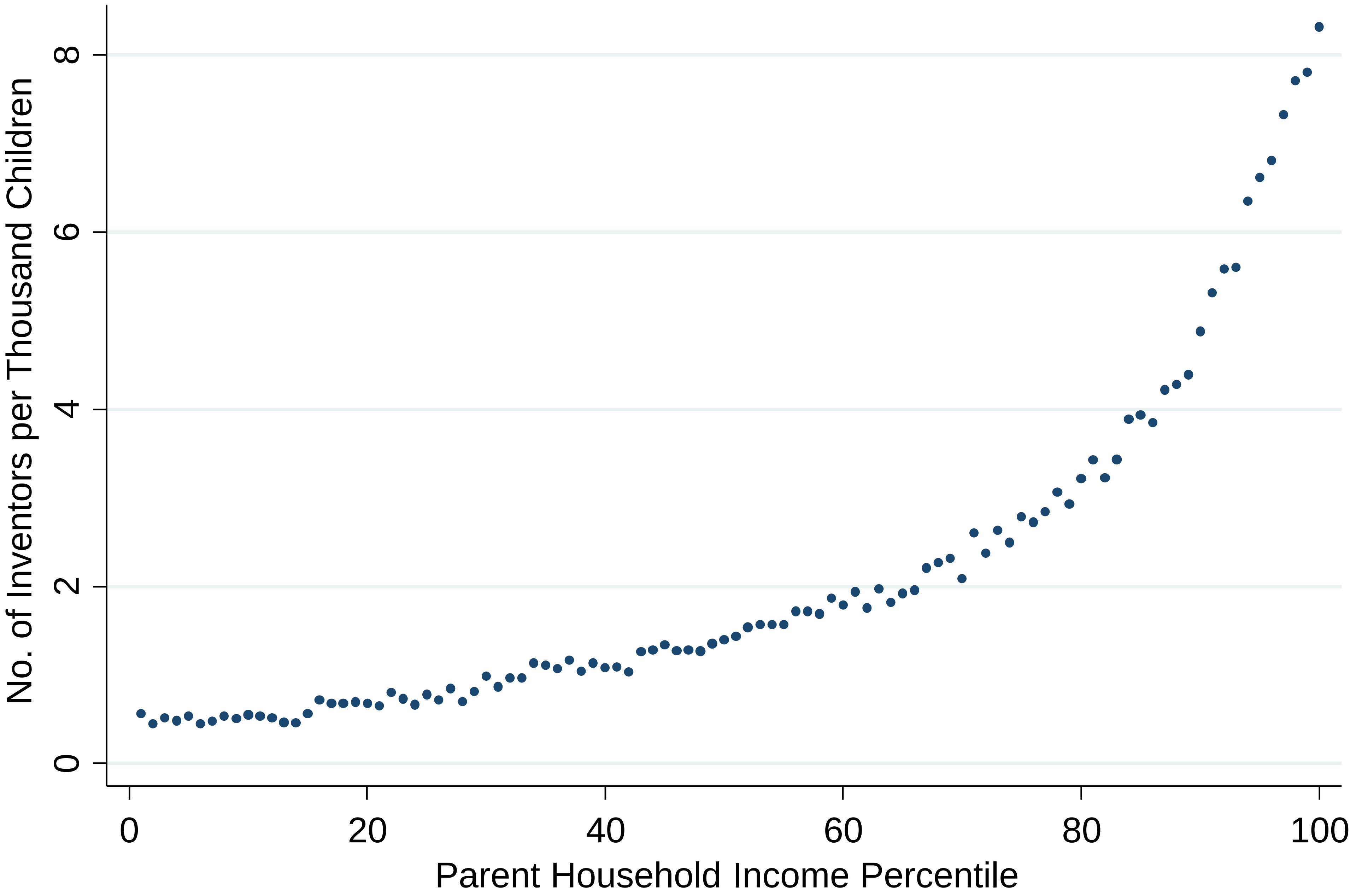
Birth
Parents
Gender
Ability



Parent Characteristics

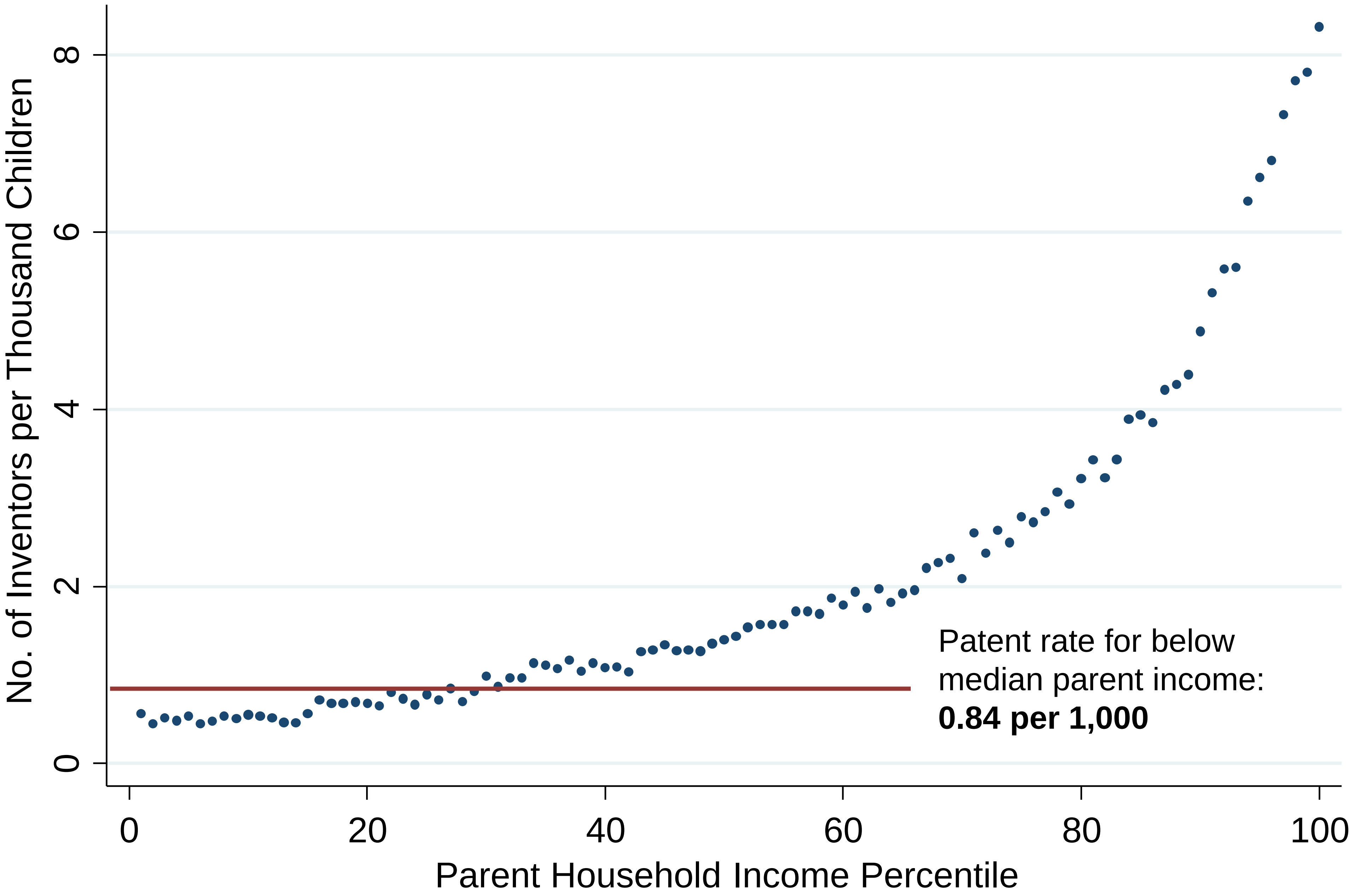
- Link parents to children based on dependent claiming
  [Chetty, Hendren, Kline, Saez 2014]
  - We can identify parents only for children born in or after 1980
  - Forces us to study young inventors: patents before age 32 (in 2012)
- Still a substantial sample: 34,973 inventors in our sample born between 1980-1984
  - 13% of (eventually granted) patents applied for in 2000 were from individuals aged under age 32
- Evaluate robustness of patterns using Statistics of Income 0.1% sample, which allows us to look at patenting up to age 40

Patent Rates vs. Parent Income Percentile

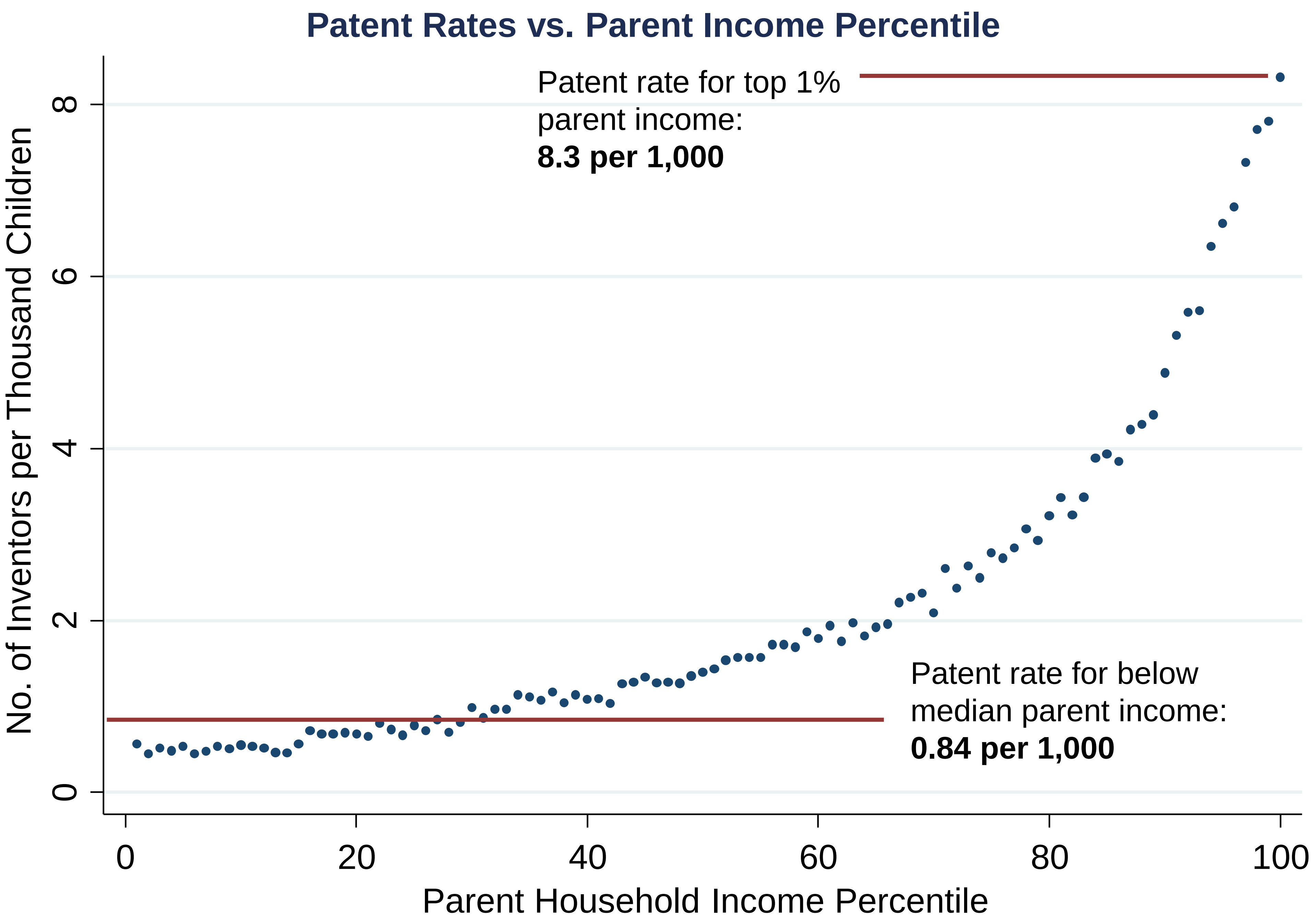


Notes: Sample of children is 1980-84 birth cohorts. Parent Income is mean household income from 1996-2000.

Patent Rates vs. Parent Income Percentile

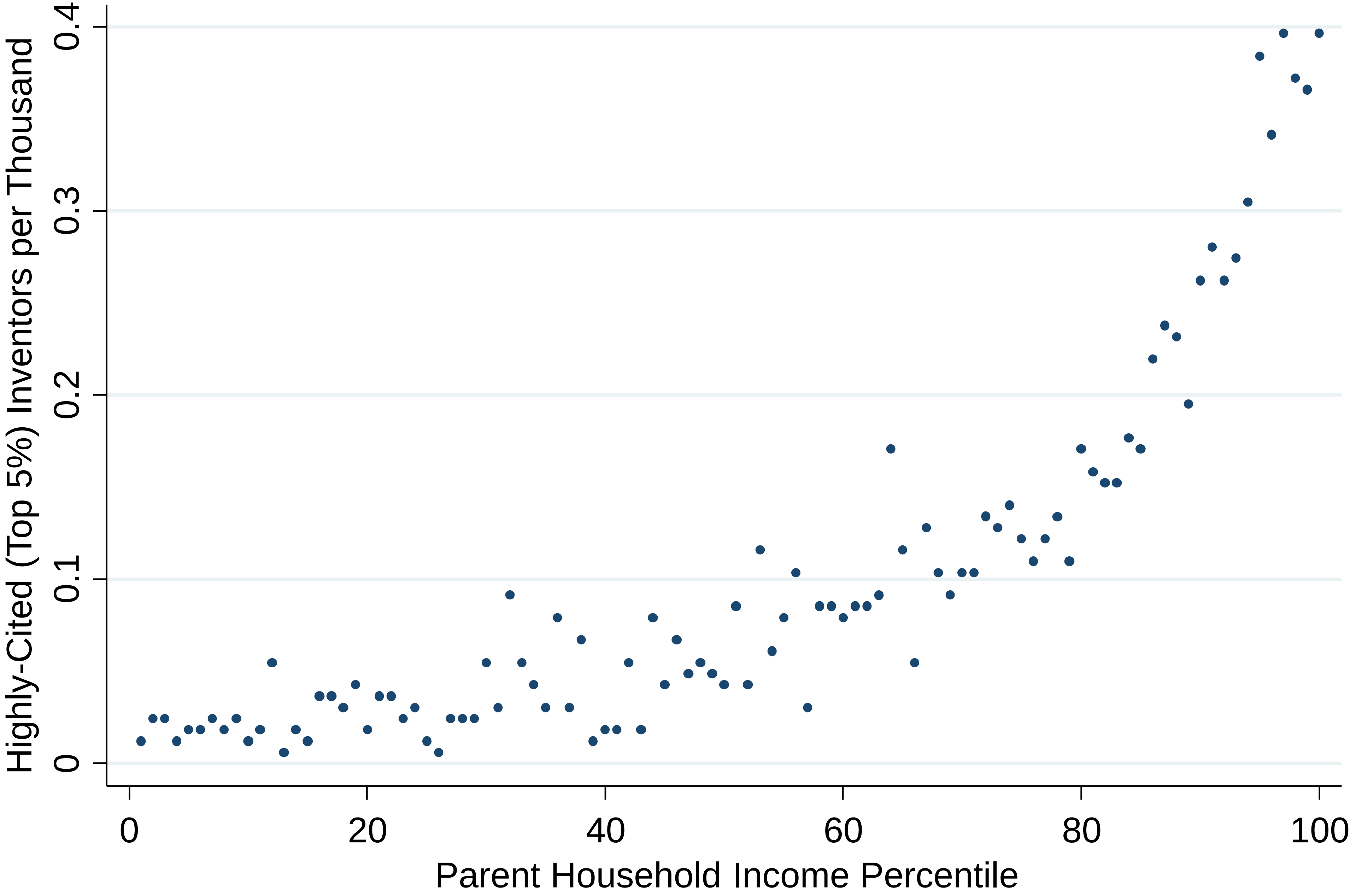


Notes: Sample of children is 1980-84 birth cohorts. Parent Income is mean household income from 1996-2000.

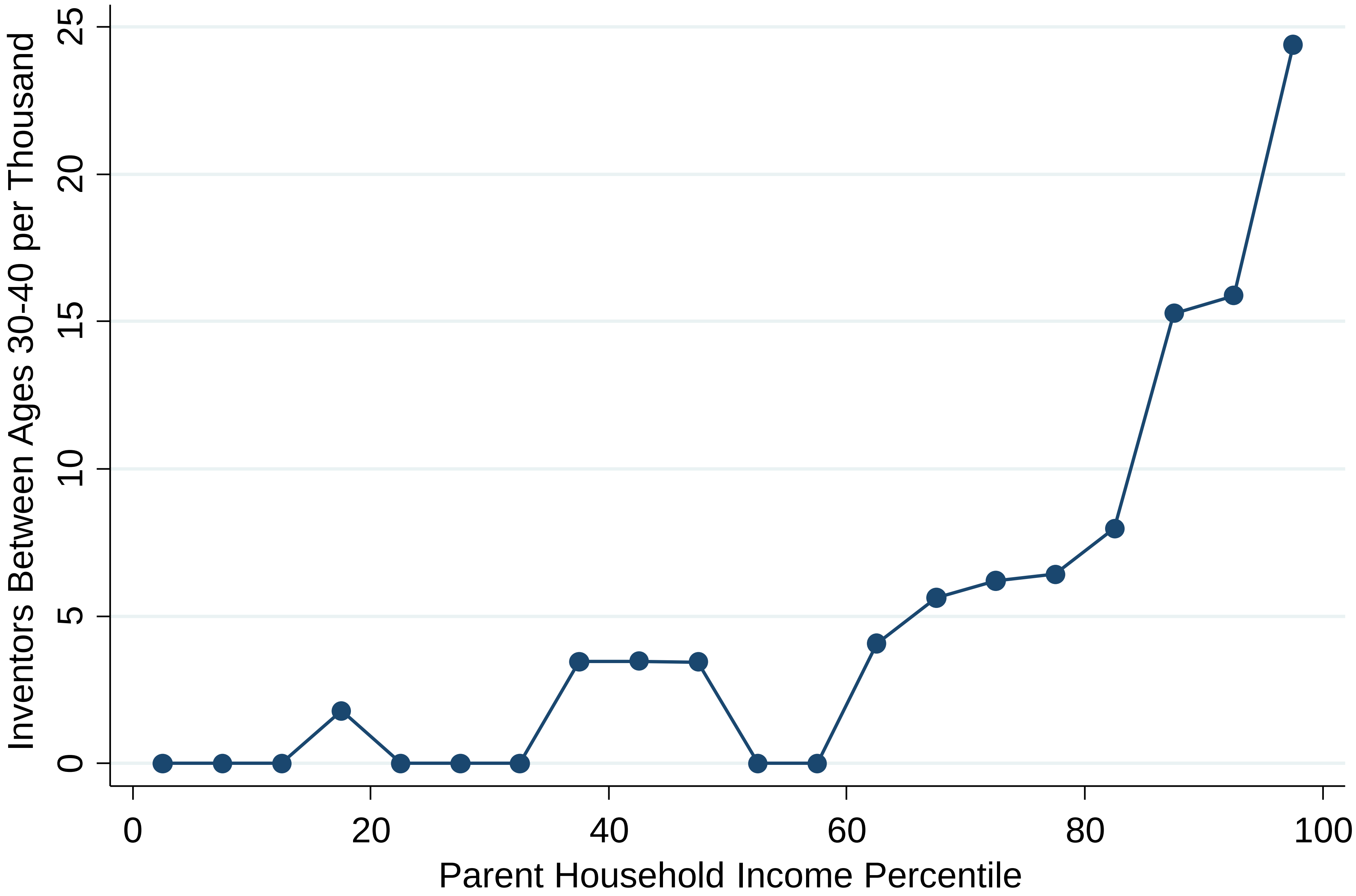


Notes: Sample of children is 1980-84 birth cohorts. Parent Income is mean household income from 1996-2000.

Highly-Cited Inventors vs. Parent Income Percentile



Patent Rates Between Ages 30-40 vs. Parent Income Percentile



Notes: Sample of children is birth cohorts 1971-72 from the Statistics of Income 0.1% Random Sample.

Why Do Patent Rates Vary with Parent Income?

- Correlation between parent income and children growing up to be inventors could be driven by three mechanisms:

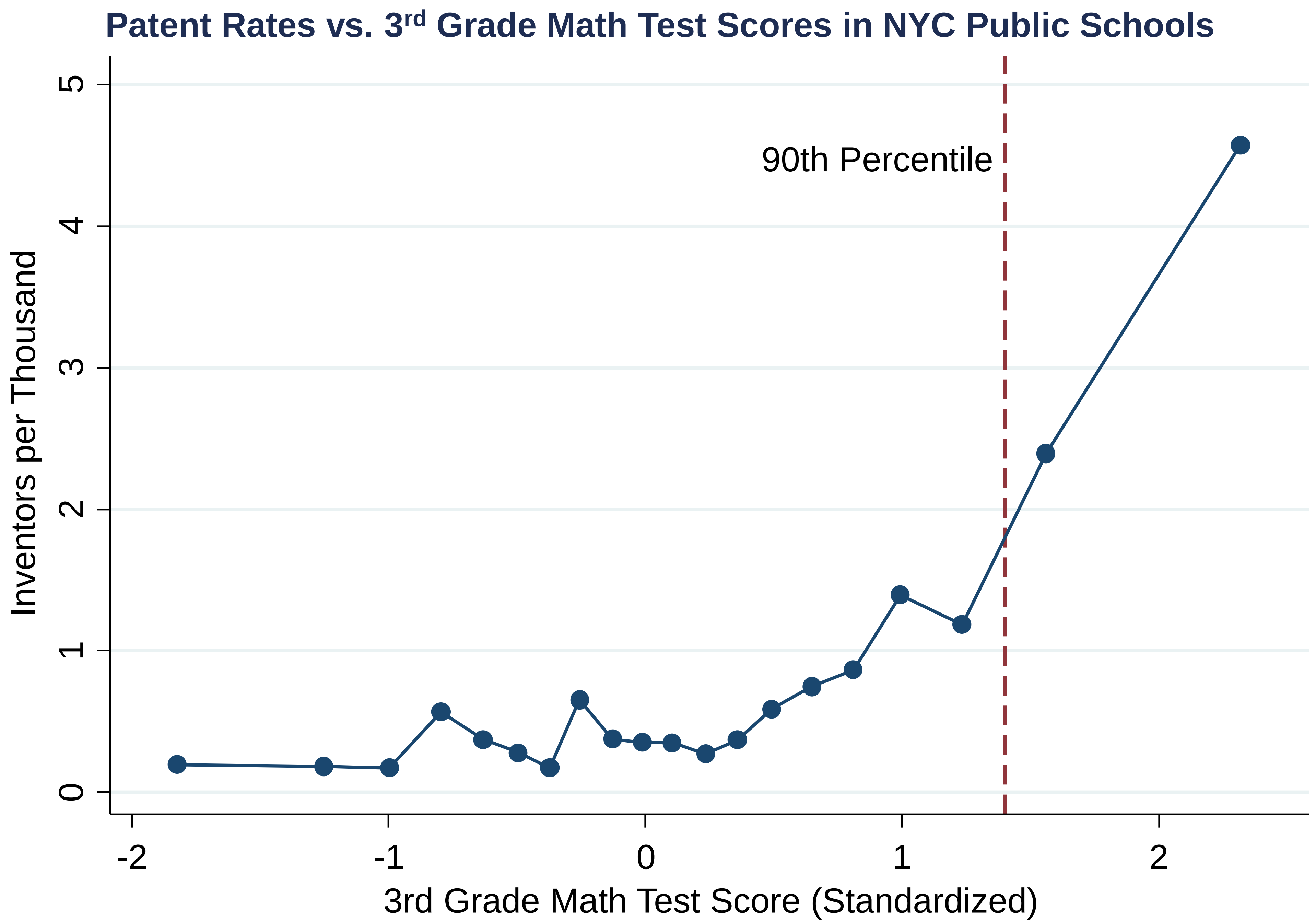
  1. **Endowments**: Children from high-income families may have greater ability to innovate

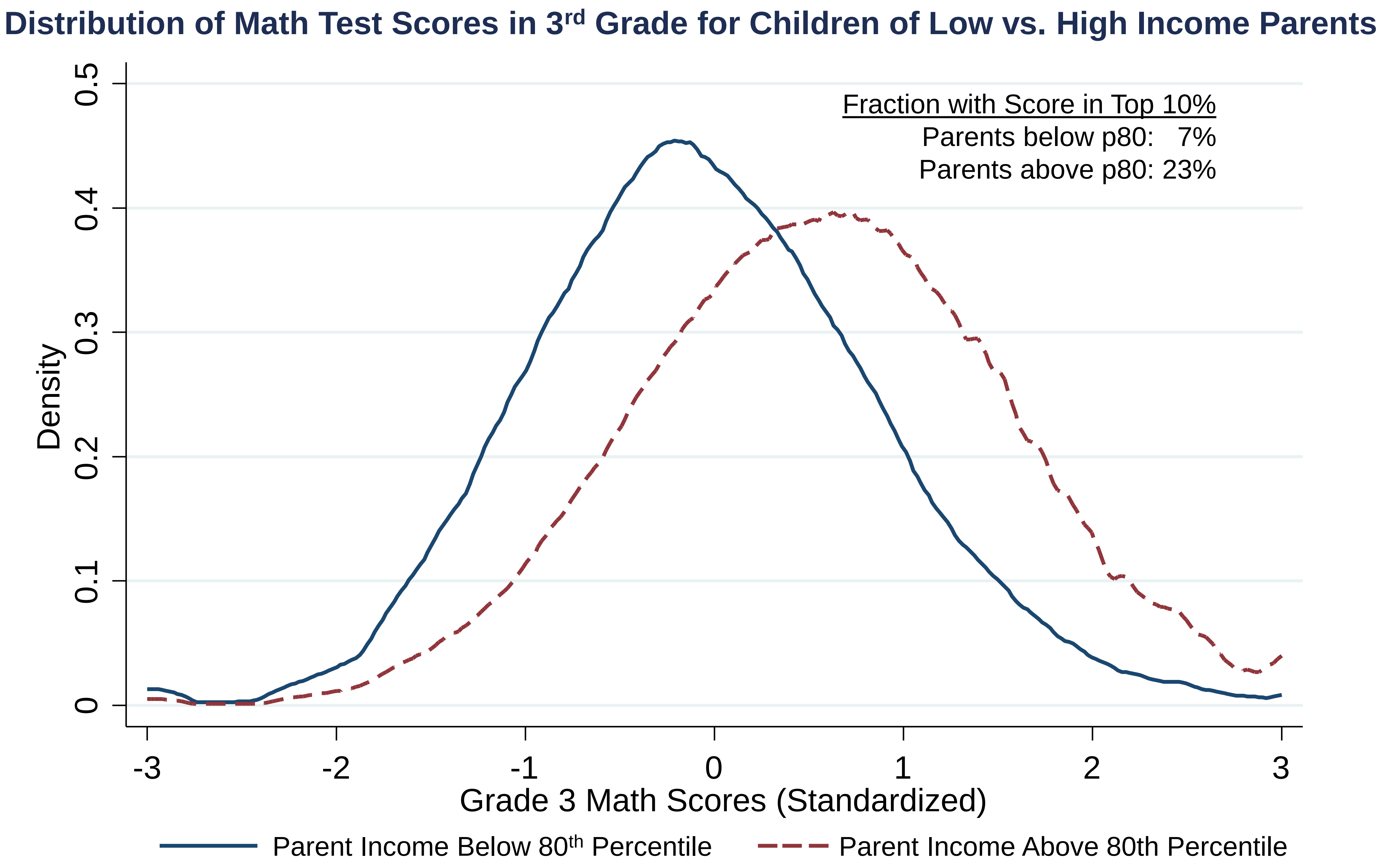
  2. **Preferences**: lower income children prefer other occupations (e.g., because of higher risk aversion due to financial constraints)

  3. **Constraints**: lower income children have comparable talent and preferences but face higher barriers to entry or lack exposure

Why Do Patent Rates Vary with Parent Income?

- First step to distinguish between these explanations: measure ability using data on test scores for all children in NYC public schools
[Chetty, Friedman, Rockoff 2014]
    - Math/reading scores from grades 3-8 on statewide standardized tests from 1989-2009
    - Use data for 430,000 children in 1979-85 birth cohorts for this analysis


Patent Rates vs. 3rd Grade Math Test Scores in NYC Public Schools
90th Percentile
Inventors per Thousand
0
1
2
3
4
5
-2
-1
0
1
2
3rd Grade Math Test Score (Standardized)



Distribution of Math Test Scores in 3rd Grade for Children of Low vs. High Income Parents
Fraction with Score in Top 10%
Parents below p80: 7%
Parents above p80: 23%
Density
0
0.1
0.2
0.3
0.4
0.5
-3
-2
-1
0
1
2
3
Grade 3 Math Scores (Standardized)
Parent Income Below 80th Percentile
Parent Income Above 80th Percentile

Patenting Gap Explained by Test Scores

- What fraction of the gap in patenting by parent income is explained by test scores?

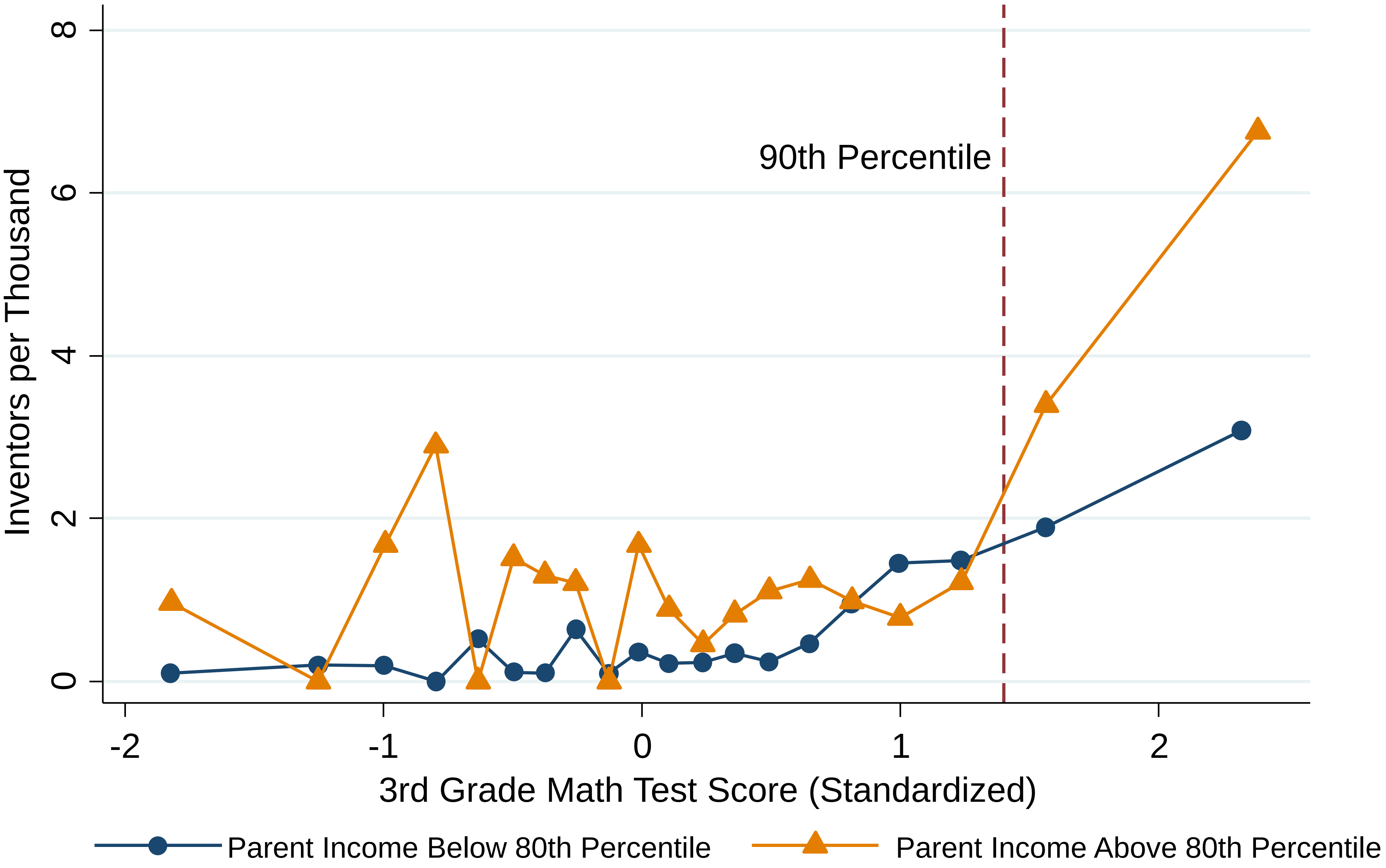
- Calculate this non-parametrically using a simple reweighting approach [Dinardo, Fortin, Lemieux 1996]

  - Estimate patent rate for low-income kids if they were to have the same 3rd grade math scores as high income kids

What Fraction of the Gap in Patenting by Parent Income is Explained by Differences in Test Scores?

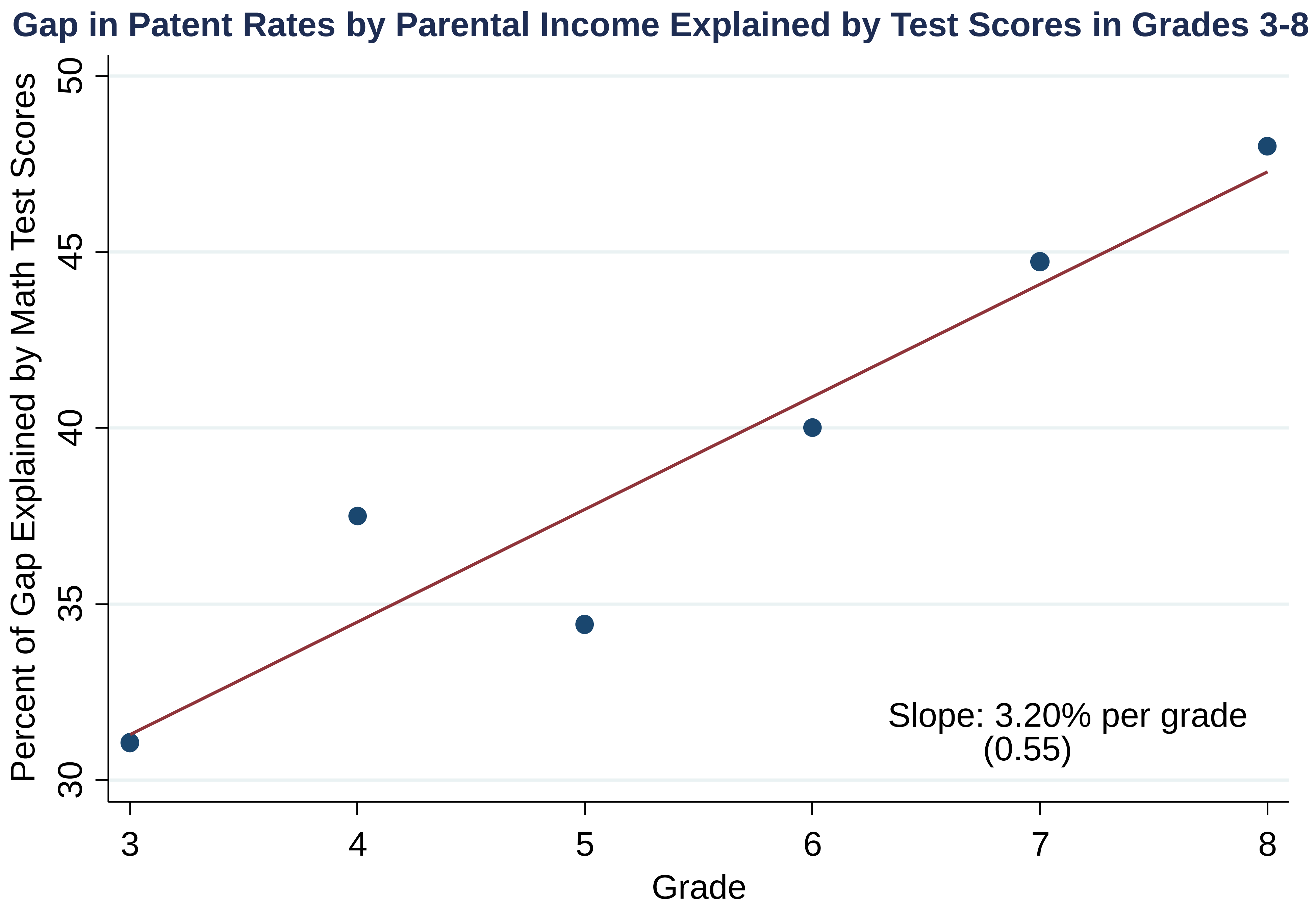
	Patent Rate (per 1000 Individuals)	Gap Relative to Above p80 Group
Above 80^{th} Pctile.	1.93	
Below 80^{th} Pctile.	0.52	1.41
Below 80^{th} Pctile. (Reweighting Scores)	0.95	0.97 (= 1.93 – 0.95)
% of gap accounted for by 3^{rd} grade scores		31.2% (s.e. = 6.8%)

Patent Rates vs. 3rd Grade Test Scores by Parental Income



Patenting Gap Explained by Test Scores

- Now repeat preceding analysis using test scores at later ages
- What fraction of innovation gap between low- and high-income children can be explained by test scores in 4^{th} grade, 5^{th} grade, etc.?



Gap in Patent Rates by Parental Income Explained by Test Scores in Grades 3-8
Percent of Gap Explained by Math Test Scores
30
35
40
45
50
3
4
5
6
7
8
Grade
Slope: 3.20% per grade
(0.55)

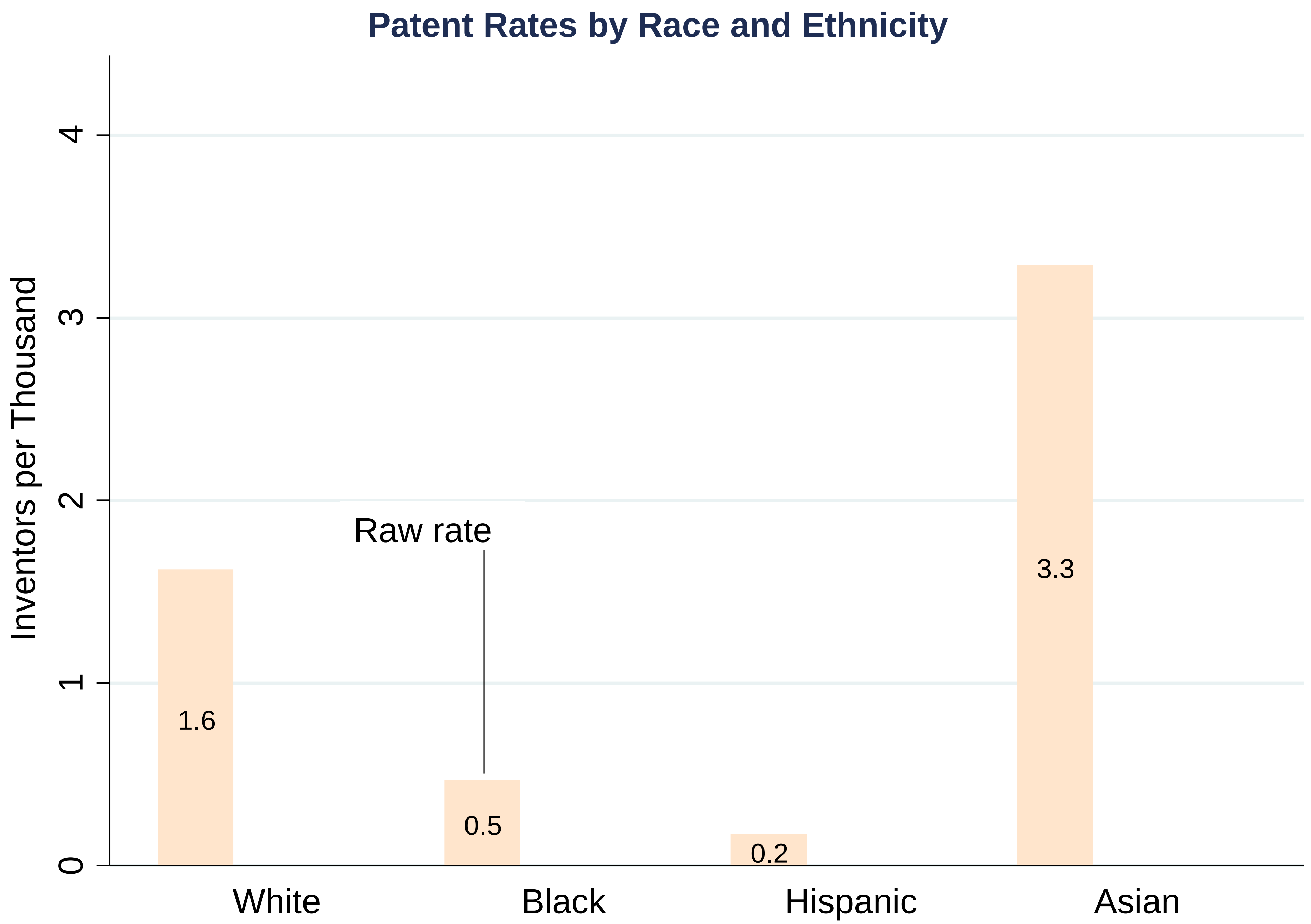
Expanding Gaps over Childhood

- Gap in innovation explained by test scores grows over time, consistent with low SES children falling behind over time
  [Fryer and Levitt 2006, Fryer 2014]

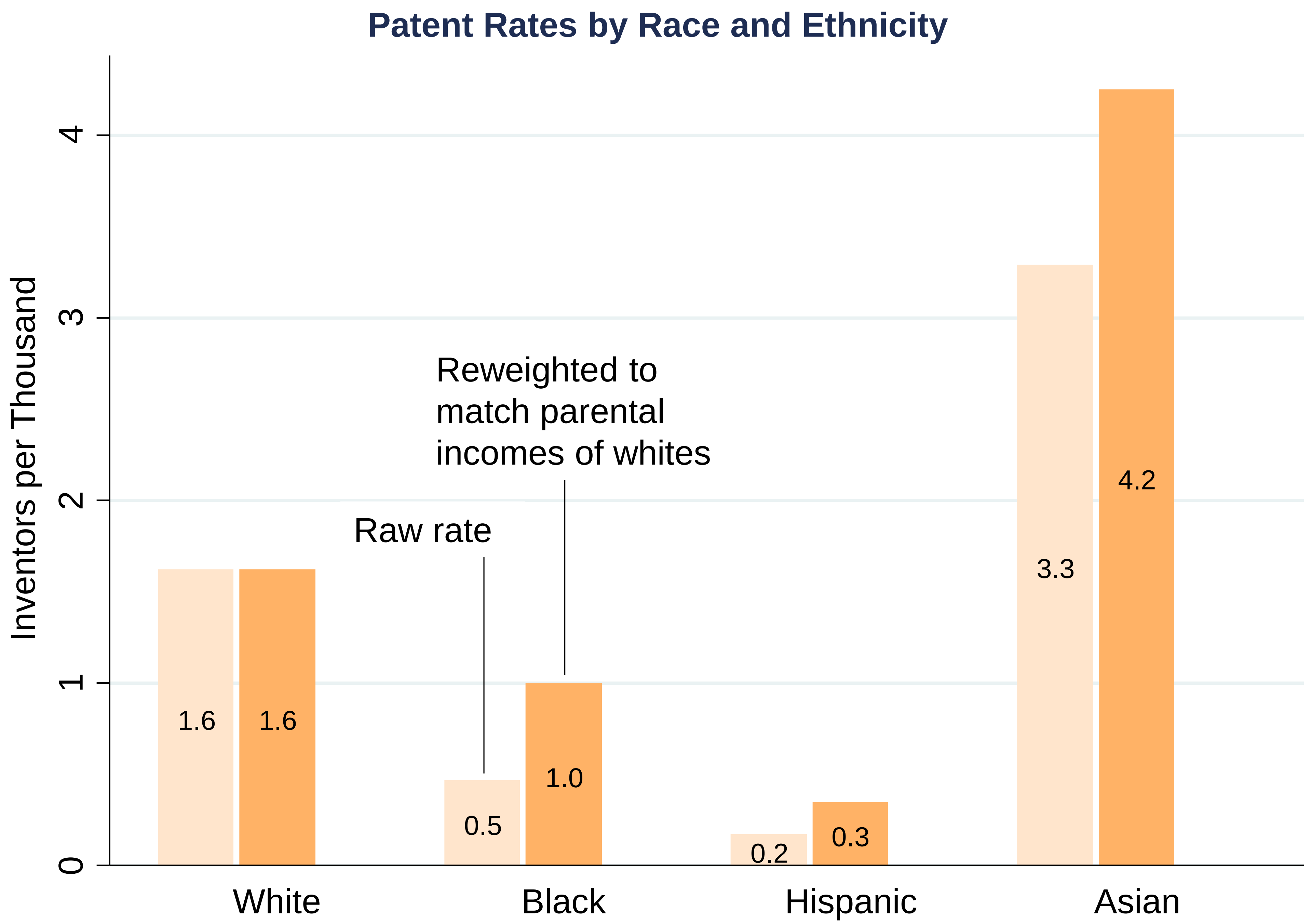
- Suggests that innovation may be driven by differences in childhood environment
  - However, not conclusive because latent genetic ability may be better manifested in tests at later ages
  - To evaluate whether environment matters, analyze importance of environmental exposure directly in next section

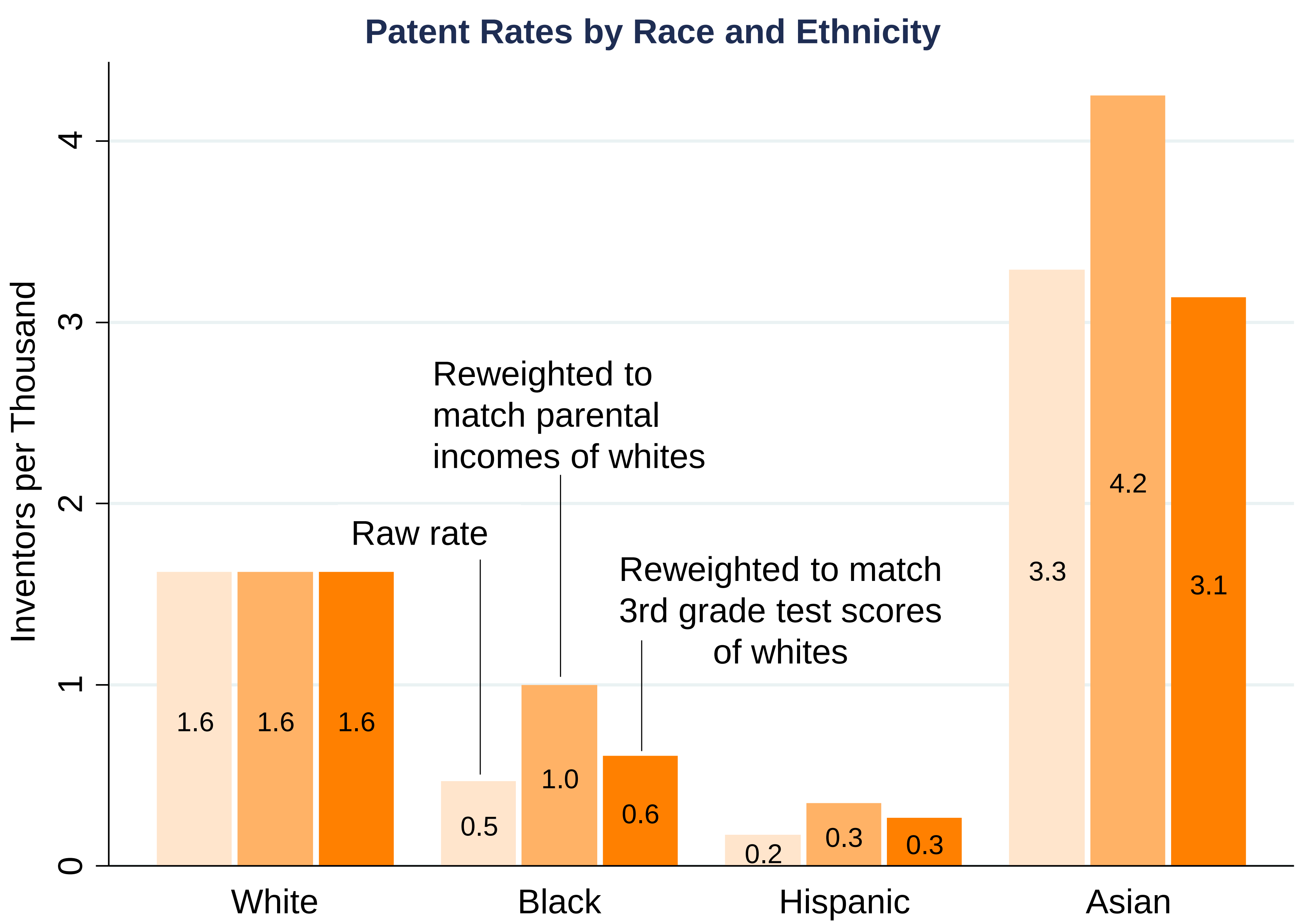
Racial Gaps in Patenting

- Next, replicate this analysis to evaluate gaps by race
  - Is there misallocation of talent by race in innovation?
    [Cook and Kongcharoen 2010]

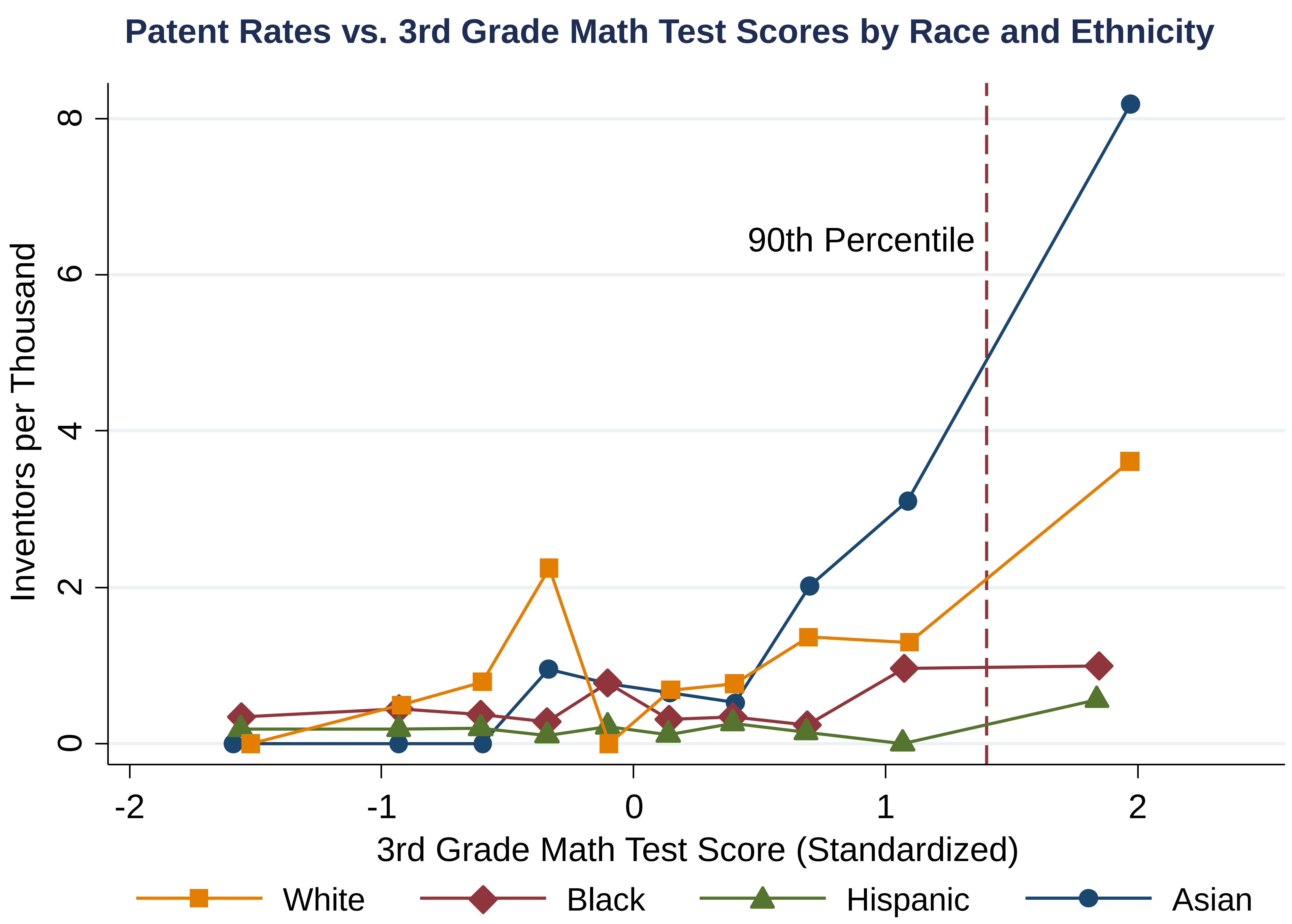


Patent Rates by Race and Ethnicity
Inventors per Thousand
0
1
2
3
4
Raw rate
1.6
0.5
0.2
3.3
White
Black
Hispanic
Asian


Patent Rates by Race and Ethnicity
Inventors per Thousand
0
1
2
3
4
Reweighted to match parental incomes of whites
Raw rate
1.6
1.6
0.5
1.0
0.2
0.3
3.3
4.2
White
Black
Hispanic
Asian

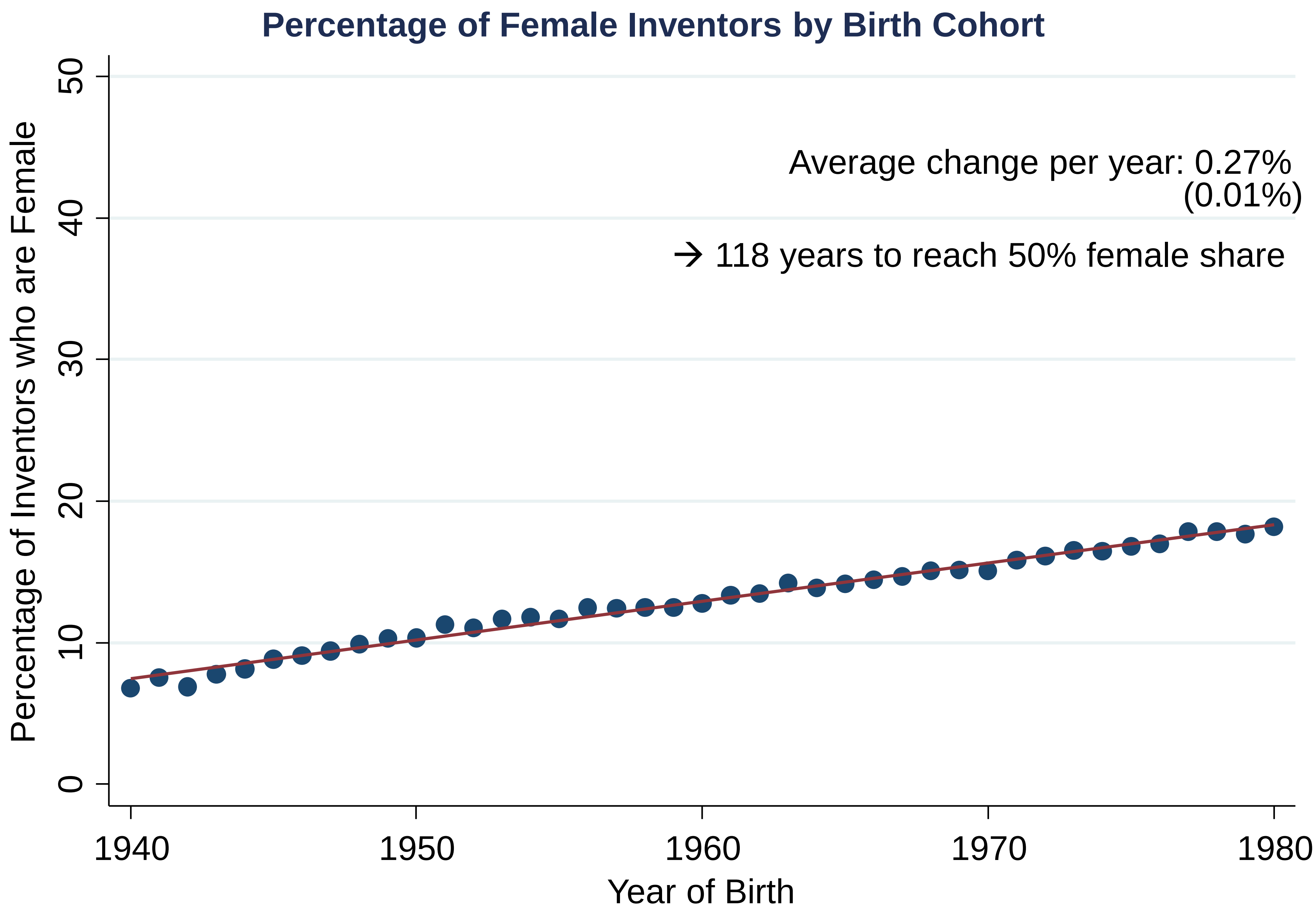


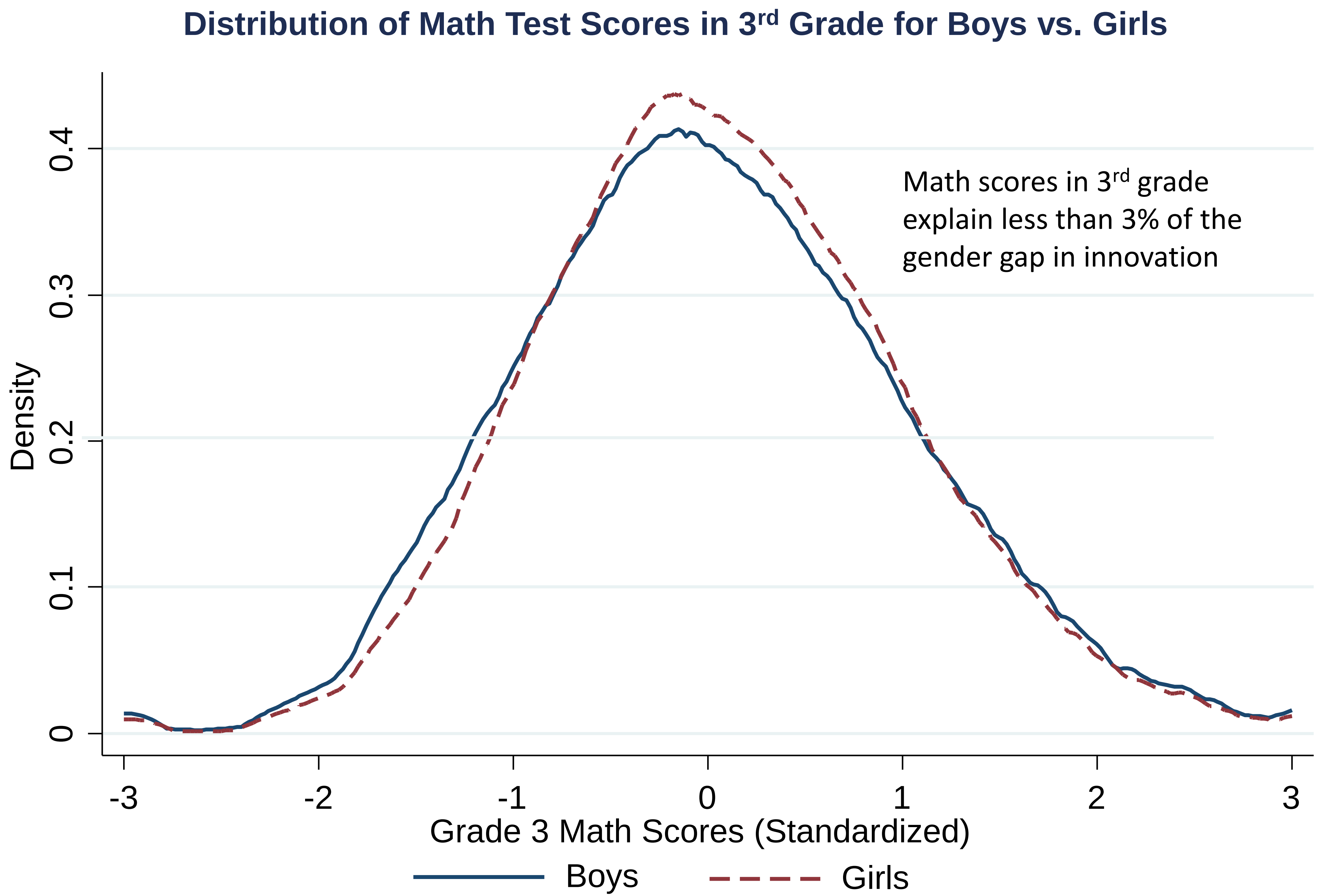
Patent Rates by Race and Ethnicity
Inventors per Thousand
0
1
2
3
4
Raw rate
Reweighted to match parental incomes of whites
Reweighted to match 3rd grade test scores of whites
1.6
1.6
1.6
0.5
1.0
0.6
0.2
0.3
0.3
3.3
4.2
3.1
White
Black
Hispanic
Asian

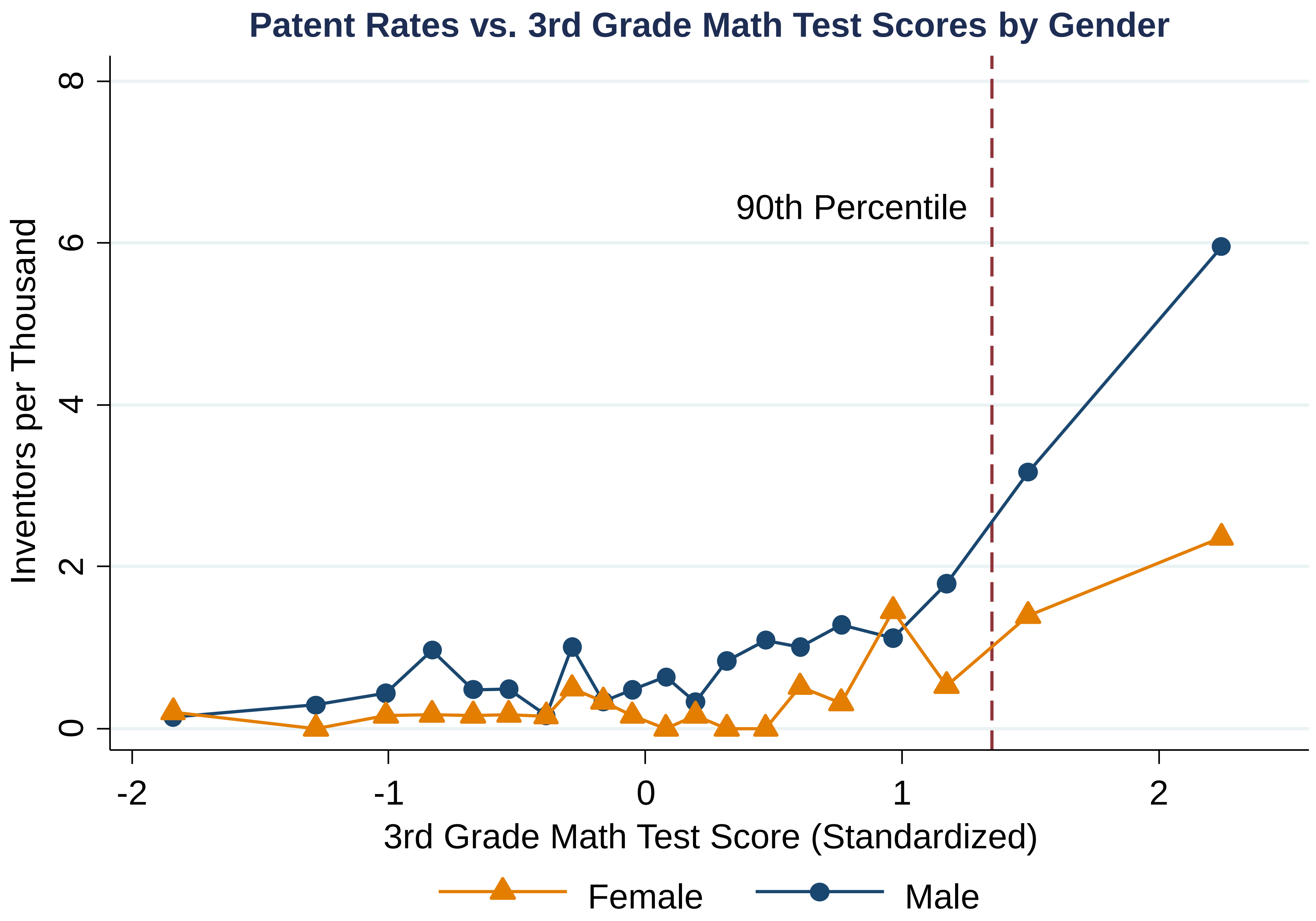

Patent Rates vs. 3rd Grade Math Test Scores by Race and Ethnicity
Inventors per Thousand
0
2
4
6
8
90th Percentile
-2
-1
0
1
2
3rd Grade Math Test Score (Standardized)
White
Black
Hispanic
Asian

Gender Gaps in Patenting

- Finally, characterize gaps in innovation by gender
  - Is there misallocation of talent by gender?
  - How has this changed over time?
    [Thursby and Thursby 2005, Ding, Murray, Stewart 2006, Jung and Ejermo 2014]


Percentage of Female Inventors by Birth Cohort
Percentage of Inventors who are Female
0
10
20
30
40
50
Average change per year: 0.27%
(0.01%)
→ 118 years to reach 50% female share
1940
1950
1960
1970
1980
Year of Birth


Distribution of Math Test Scores in 3rd Grade for Boys vs. Girls
Density
0
0.1
0.2
0.3
0.4
-3
-2
-1
0
1
2
3
Grade 3 Math Scores (Standardized)
Math scores in 3rd grade explain less than 3% of the gender gap in innovation
Boys
Girls



Patent Rates vs. 3rd Grade Math Test Scores by Gender
Inventors per Thousand
0
2
4
6
8
90th Percentile
-2
-1
0
1
2
3rd Grade Math Test Score (Standardized)
Female
Male

The Lifecycle of Inventors

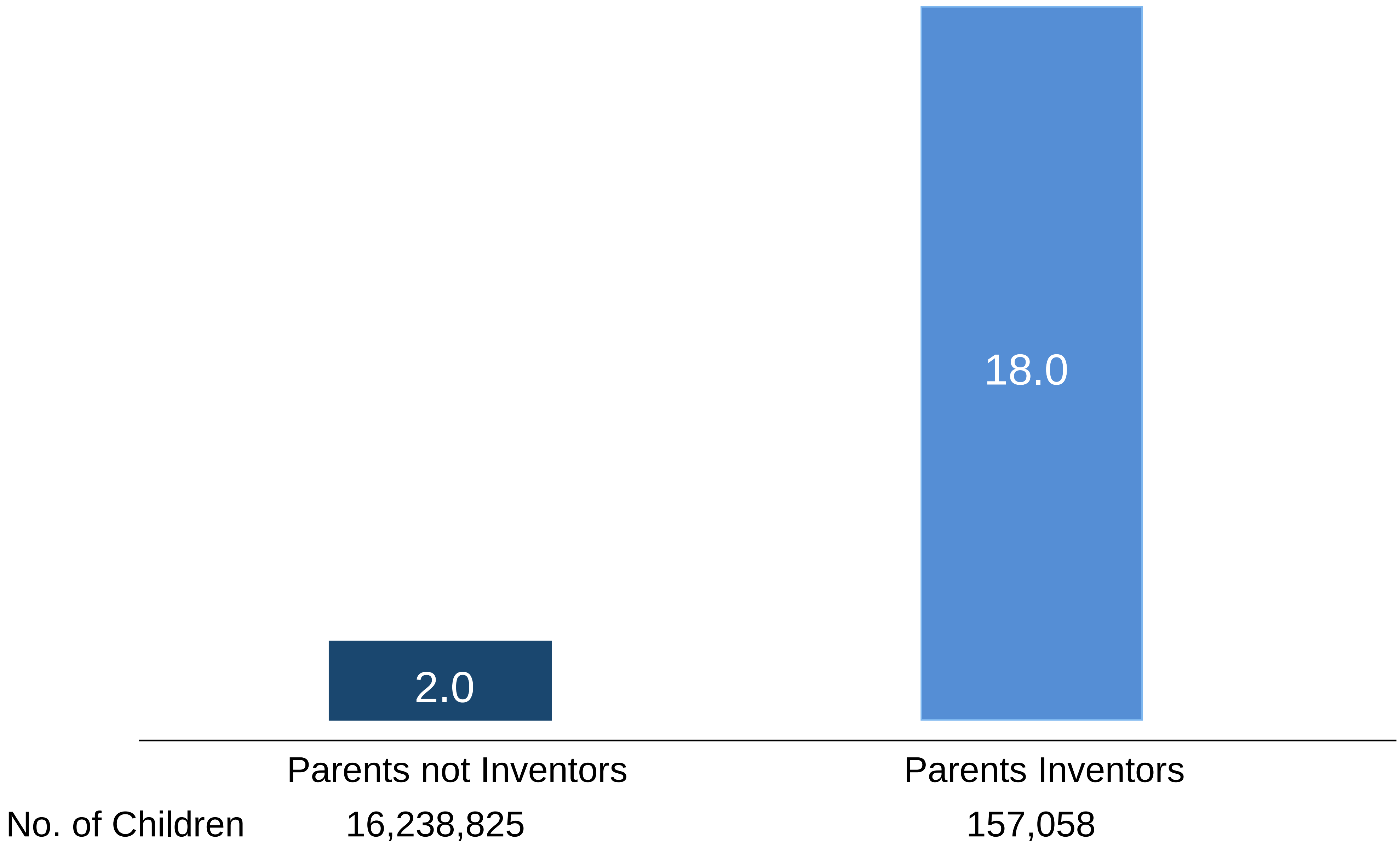
Birth
Parents
Gender
Ability

Childhood
Mentors
Neighborhood
College

Effects of Childhood Environment

- Begin by characterizing importance of exposure to innovation during childhood for propensity to innovate
  - Are children who are exposed to innovation through parents, friends, or neighbors more likely to patent?
- First analyze relationship between children’s and parents’ patent rates

Patent Rates for Children of Inventors vs. Non-Inventors



Exposure vs. Genetics

- Correlation between child and parent's propensity to patent could be driven by genetics or by environment

- To distinguish the two, analyze propensity to patent by narrow technology class

  - Intuition: genetic ability to innovate is unlikely to vary significantly across similar technology classes

- Define "similarity" of two technology classes based on the fraction of inventors who hold patents in both classes [Bloom et al. 2013]

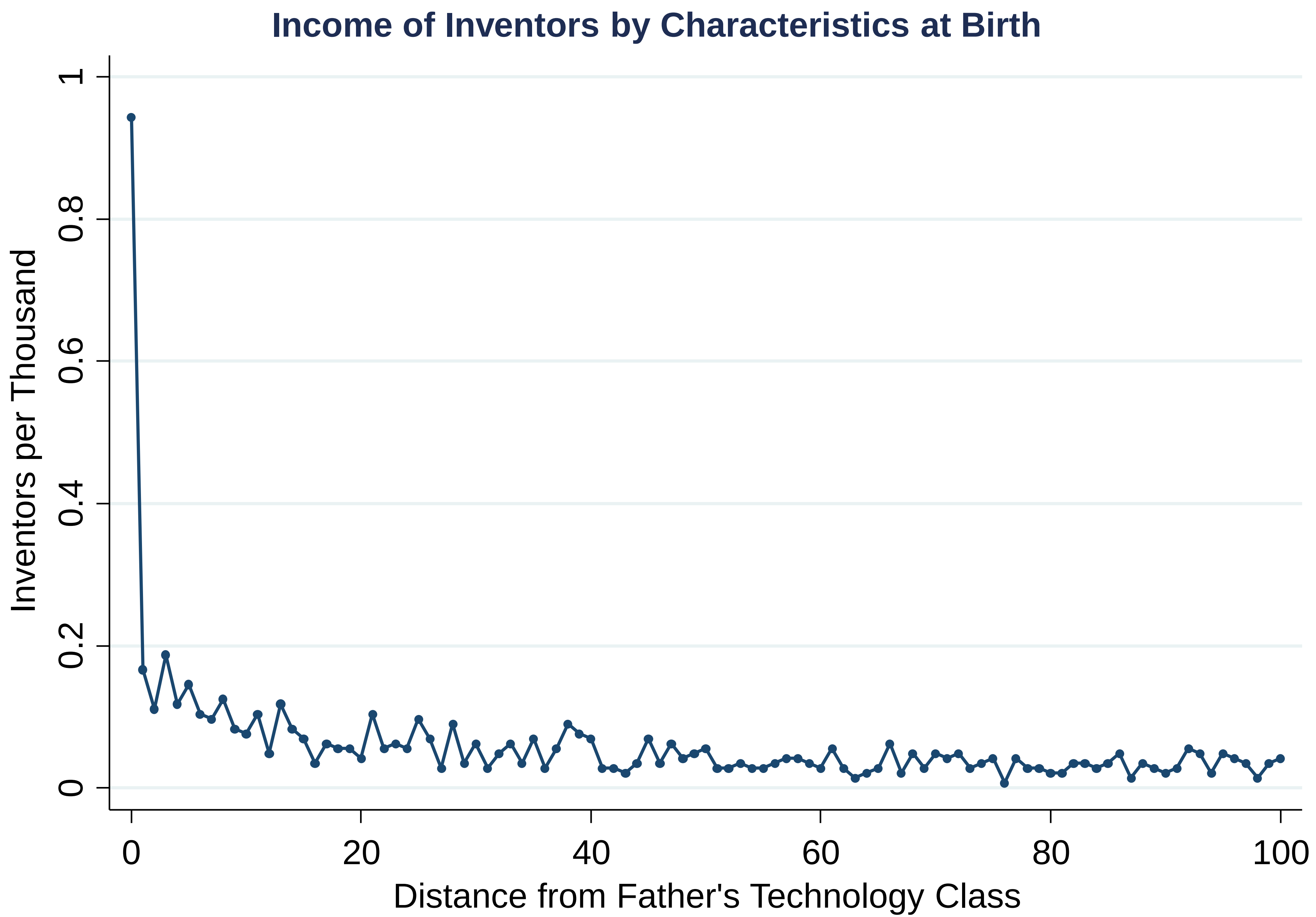
  - Other measures yield similar results

Illustration of Technology Classes and Distance

Category: Computers + Communications

Subcategory: Communications

Technology Class	Distance Rank
Pulse or digital communications	0
Demodulators	1
Modulators	2
Coded data generation or conversion	3
Electrical computers: arithmetic processing and calculating	4
Oscillators	5
Multiplex communications	6
Telecommunications	7
Amplifiers	8
Motion video signal processing for recording or reproducing	9
Directive radio wave systems and devices (e.g., radar, radio navigation)	10



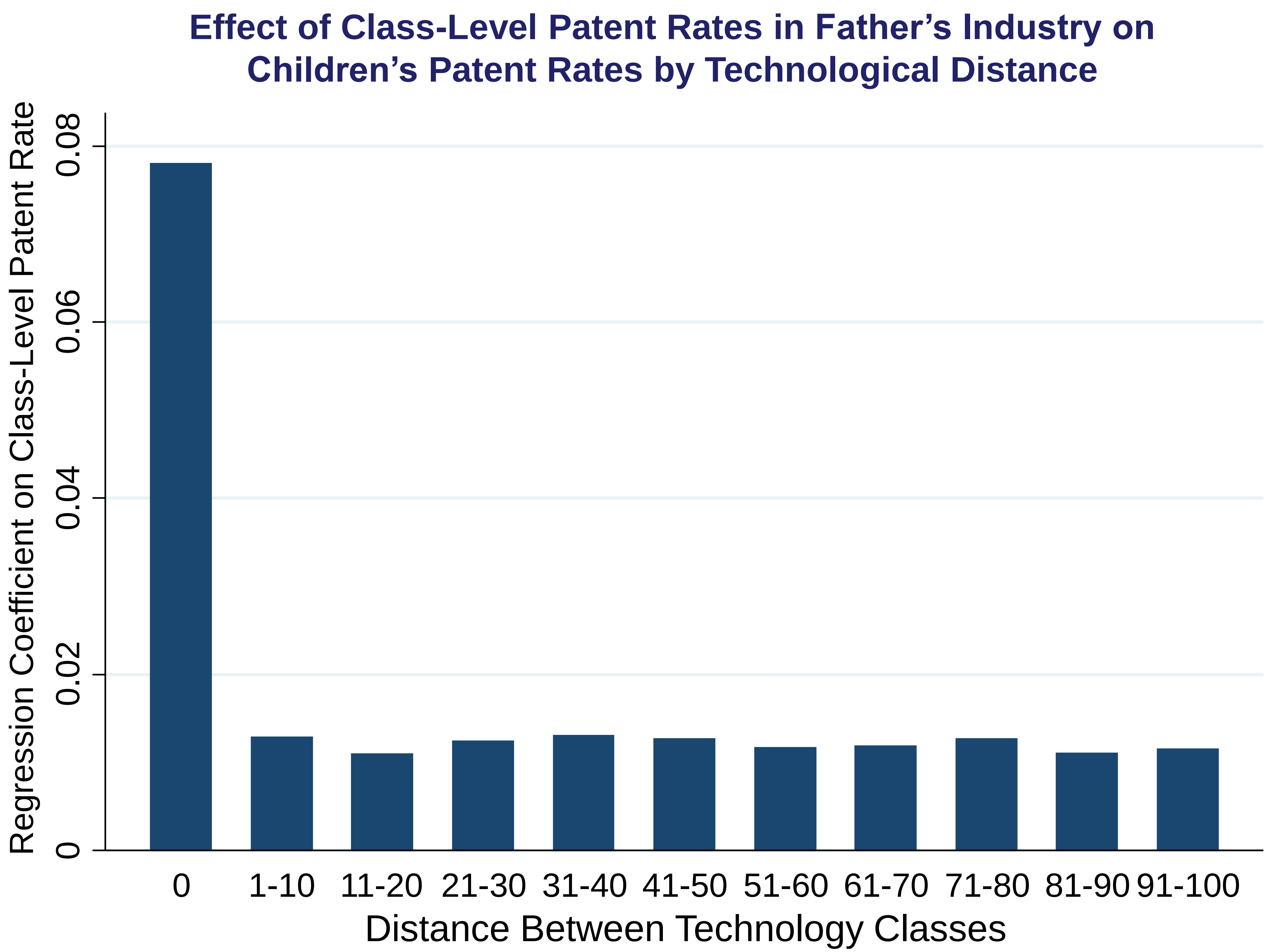
Income of Inventors by Characteristics at Birth
Inventors per Thousand
0
0.2
0.4
0.6
0.8
1
0
20
40
60
80
100
Distance from Father's Technology Class

Industry

- Now turn to a broader source of exposure: parent's "colleagues"

- Do children whose parents work in more innovative industries have higher patent rates?

  - Focus on children whose parents are *not* inventors themselves to eliminate direct effect of parent inventing



Effect of Class-Level Patent Rates in Father's Industry on
Children's Patent Rates by Technological Distance
Regression Coefficient on Class-Level Patent Rate
0
0.02
0.04
0.06
0.08
0
1-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
Distance Between Technology Classes

Children's Patent Rates vs. Patent Rates in Father's Industry: Regression Estimates

Dependent variable:	(1) Frac. Inventors	(2) Frac. Inventing in Category	(3) Frac. Inventing in Sub-Category	(4) Frac. Inventing in Class	(5) Frac. Inventing in Class
Frac. Inventors in Father's Industry	0.250*** (0.028)				
Frac. in Category in Father's Ind.		0.163*** (0.018)			
Frac. in S-Category in Father's Ind.			0.155*** (0.017)		
Frac. in Class in Father's Ind.				0.078*** (0.013)	0.0598*** (0.0125)
Frac. in same S-Cat but other Class					0.0044*** (0.0008)
Frac. in same Cat. but other S-Cat.					0.0001 (0.0004)
Frac. in other Cat.					0.0002*** (0.0000)
Observations	345	2,415	12,765	153,525	153,525

Notes: Std errors clustered by industry. Col. 2 includes Category FE; col. 3 includes sub-category FE; cols. 4-5 include class FE. Sample: 10.2 million children whose parents are not inventors.

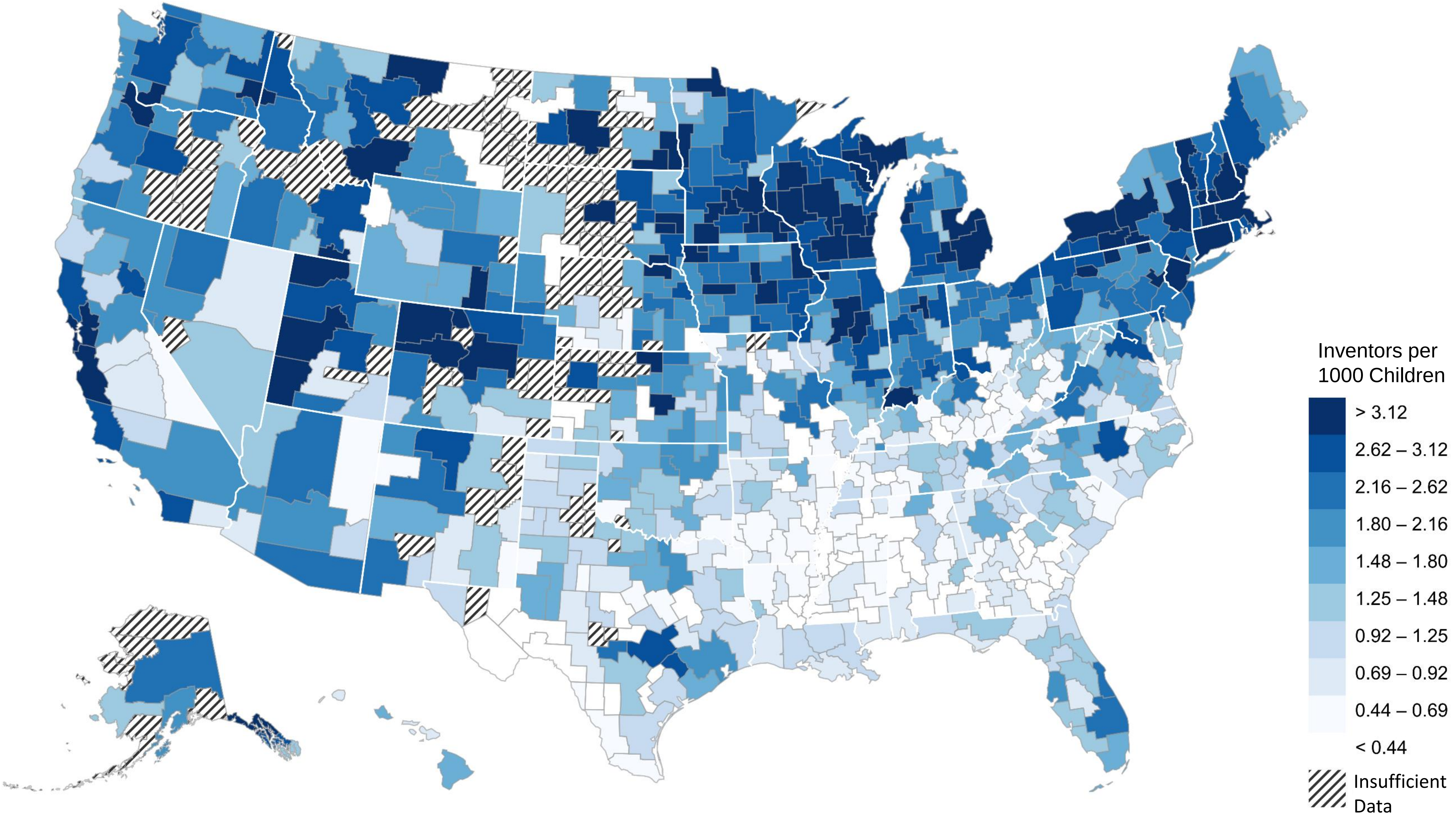
Neighborhoods

- Next, analyze influence of neighborhoods

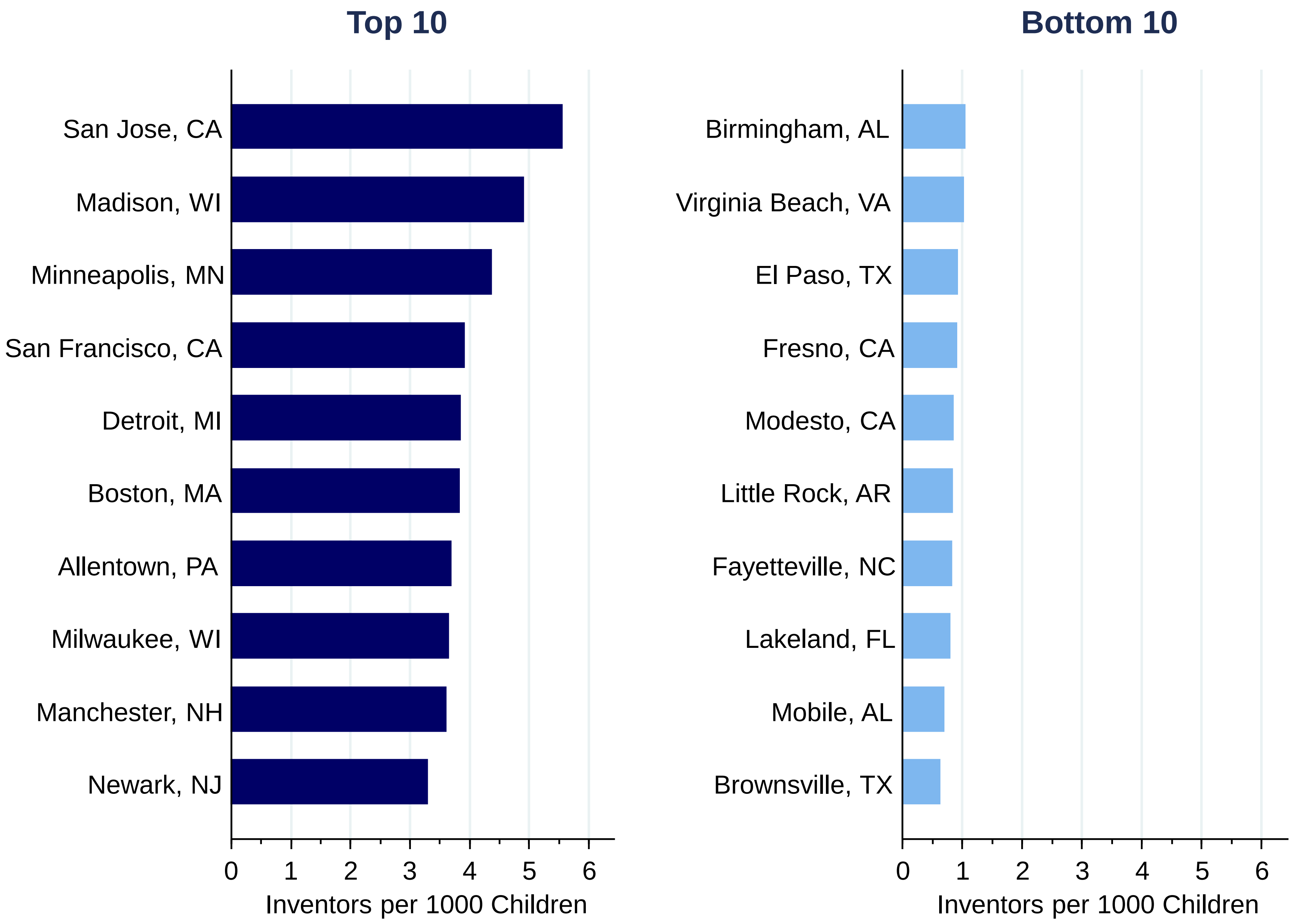
- Tabulate patent rates by commuting zone (aggregation of counties analogous to metro area) where child *grows up*

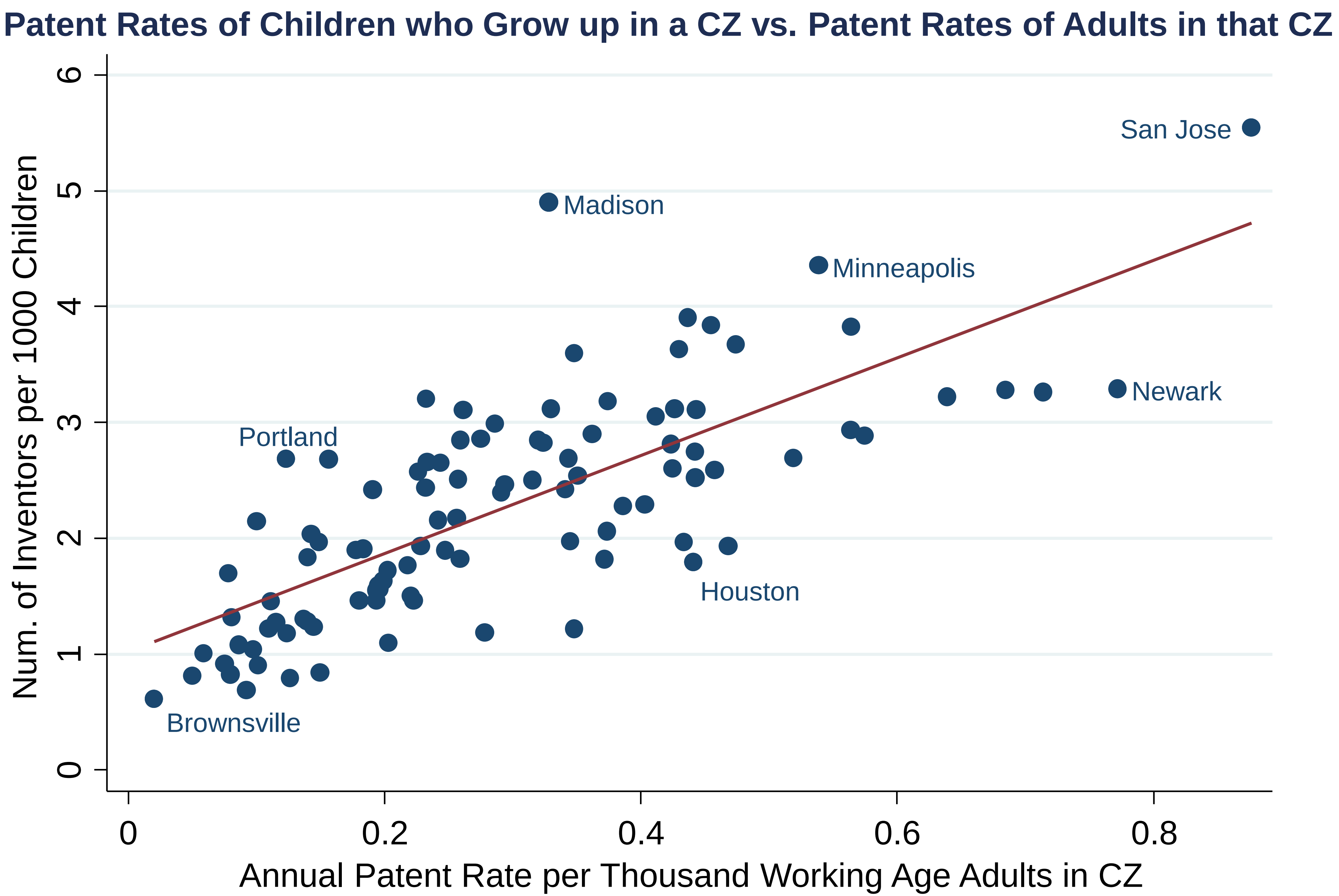
  - Differs from literature on clusters of innovation (e.g., Porter and Stern 2001), because this is not necessarily where they live as adults

The Origins of Inventors: Patent Rates by Childhood Commuting Zone



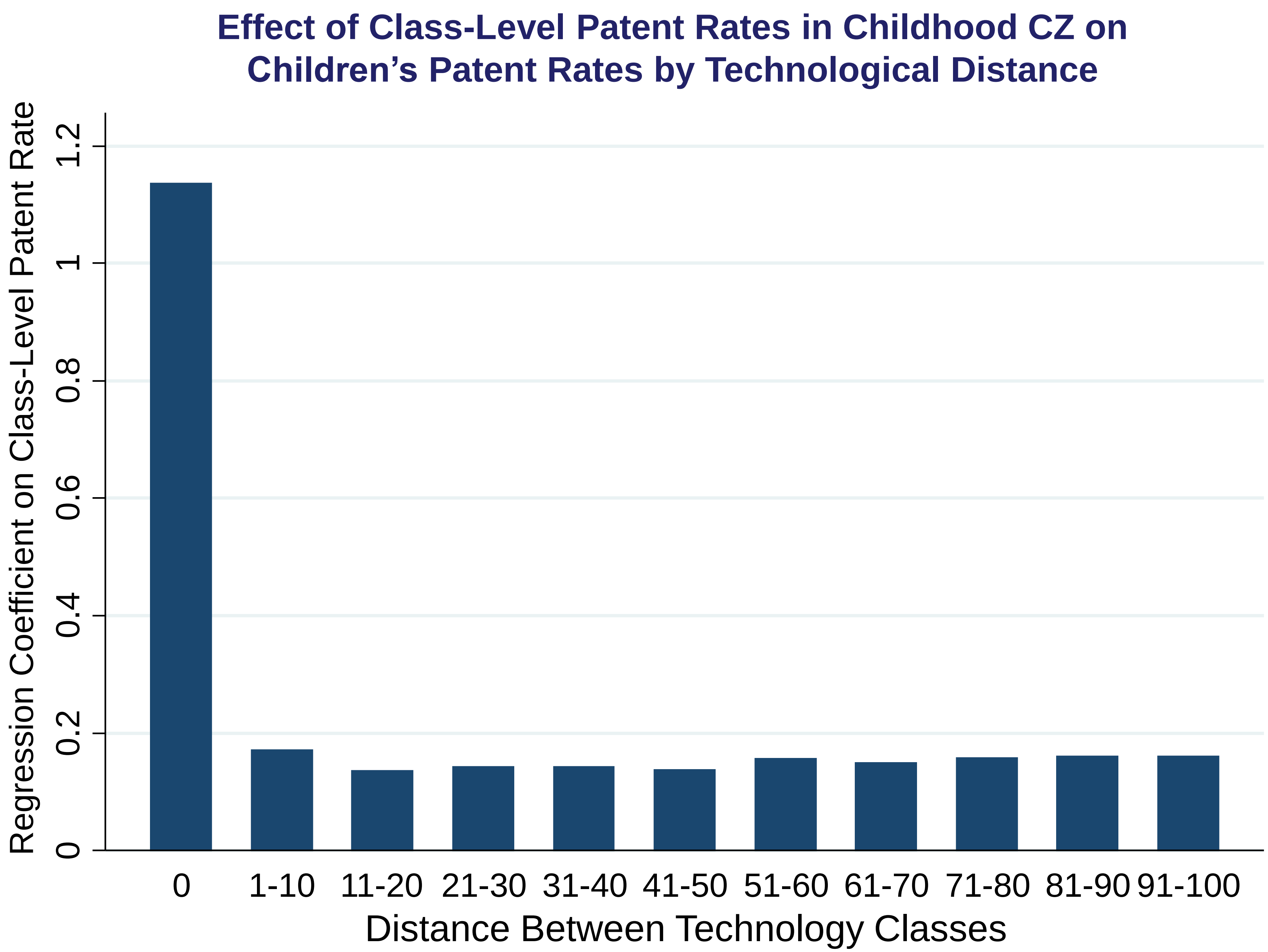
CZs with the Highest and Lowest Patent Rates among the 100 Largest CZs




Patent Rates of Children who Grow up in a CZ vs. Patent Rates of Adults in that CZ
Num. of Inventors per 1000 Children
Annual Patent Rate per Thousand Working Age Adults in CZ
0
1
2
3
4
5
6
0
0.2
0.4
0.6
0.8
San Jose
Madison
Minneapolis
Newark
Portland
Houston
Brownsville

Neighborhoods

- Children raised in areas with more inventors are more likely to be inventors themselves
- Could again be driven by genetics or exposure effects
- Once again, study patterns *within* technological class
  - Do children who grow up in Silicon Valley tend to become computing innovators?
  - Do children who grow up in Minnesota (with large medical device manufacturers) become medical innovators?


Effect of Class-Level Patent Rates in Childhood CZ on
Children's Patent Rates by Technological Distance
Regression Coefficient on Class-Level Patent Rate
0
0.2
0.4
0.6
0.8
1
1.2
0
1-10
11-20
21-30
31-40
41-50
51-60
61-70
71-80
81-90
91-100
Distance Between Technology Classes

Children's Patent Rates vs. Patent Rates in Neighborhood: Regression Estimates

Dep. Variable: Fraction Inventing in	(1) Any Category	(2) Any Category	(3) Patent Category	(4) Patent Category	(5) Patent Category	(6) Patent Sub-Category	(7) Patent Class	(8) Patent Class
Exposure (Childhood CZ): Invention rate	2.932*** (0.417)	**2.578*** (0.531)**						
Invention rate in same category			1.759*** (0.404)	1.114*** (0.341)	1.722*** (0.406)			
Invention rate in same sub-category						1.526*** (0.375)		
Invention rate in same technology class							1.108*** (0.181)	**1.050*** (0.173)**
Invention rate in same sub-category, but different technology class								-0.0003 (0.0063)
Invention rate in same category, but different sub-category								-0.0015 (0.0028)
Invention rate rate in different category in Childhood CZ								0.0054*** (0.0006)

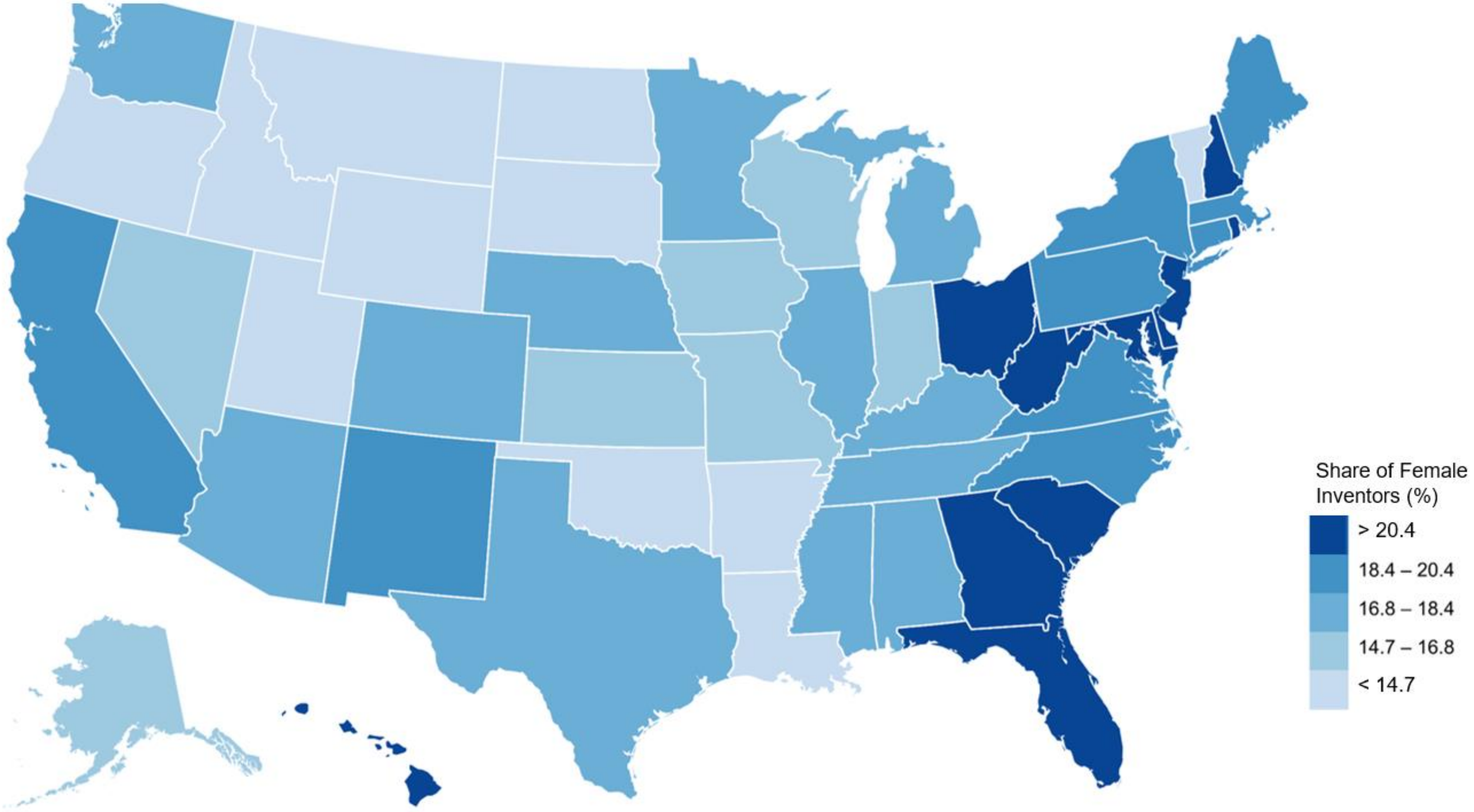
Notes: Std errors clustered by CZ. Cols. 3-5 include Category FE; col. 6 includes sub-category FE; cols. 7-8 include class FE. Sample: children whose parents are not inventors. Col. 2 and 4 based on movers only.

Variation by Gender across Neighborhoods

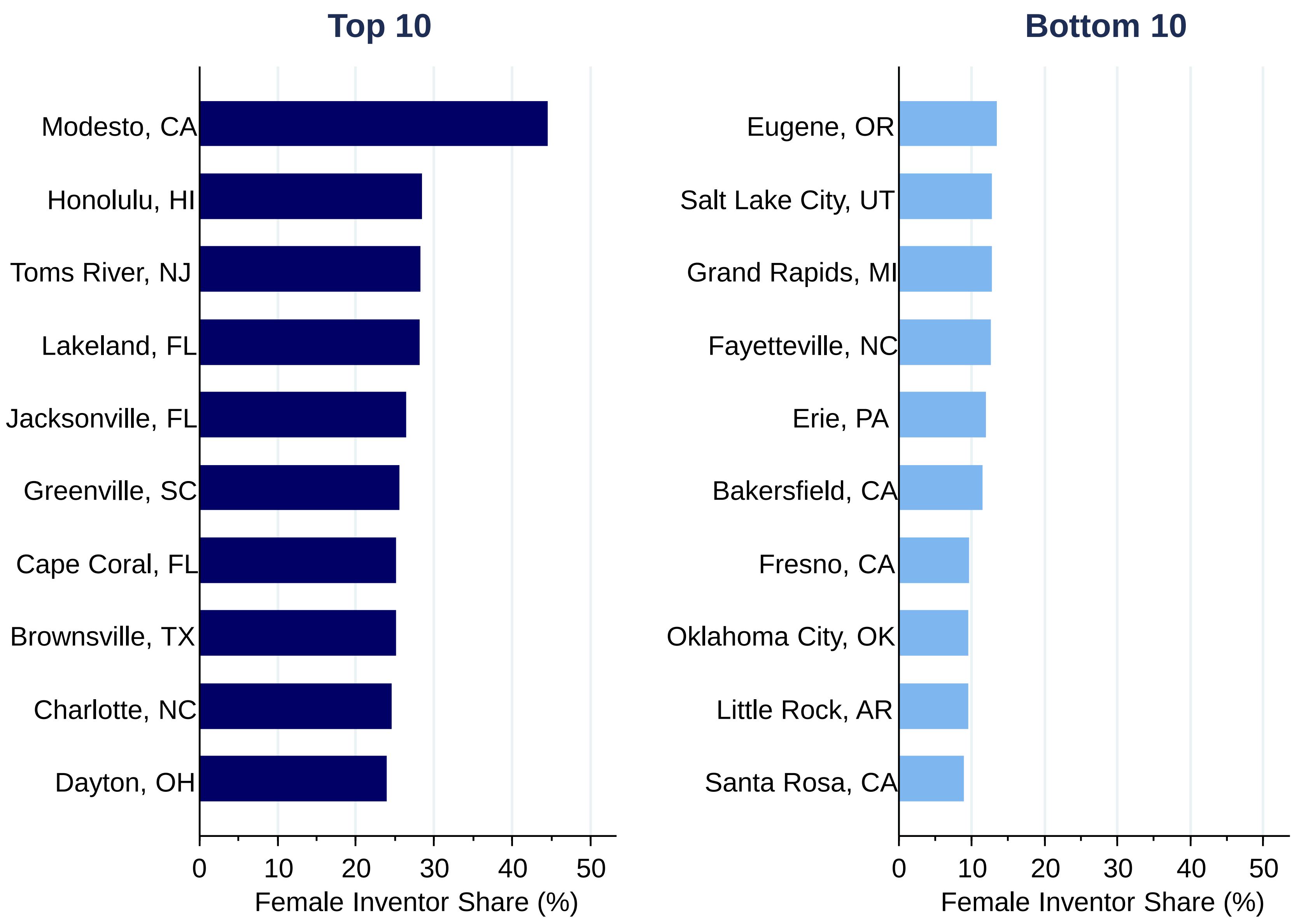
- Areas differ not just in overall rate of innovation but also in composition of inventors

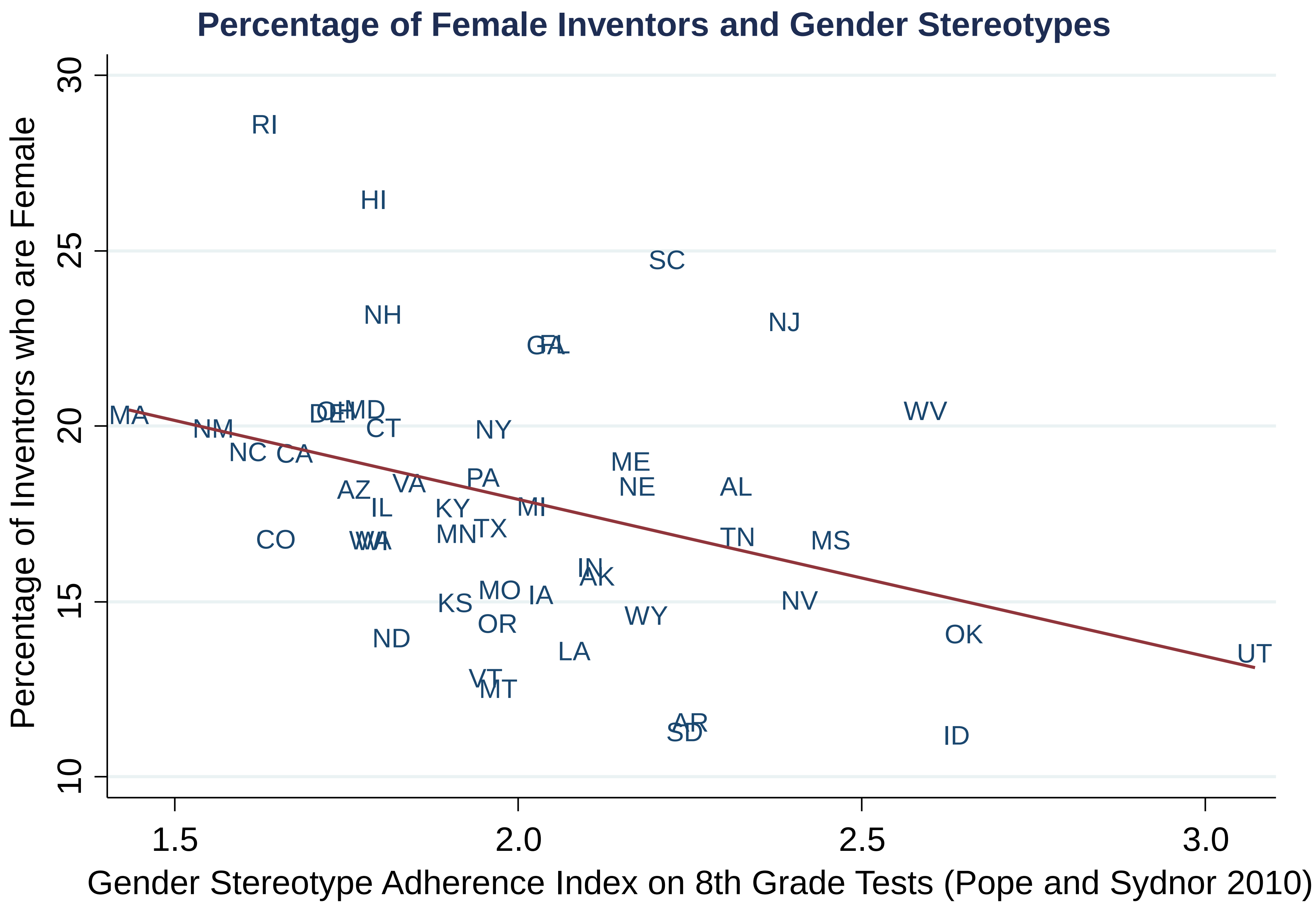
- Focus here on variation in fraction of inventors who are female by CZ where child grew up

Geographical Variation in Gender Gaps in Patent Rates
Percent of Inventors who are Female by State where Child Grew Up



Highest and Lowest Female Inventor Shares by CZ where Child Grew Up (100 Largest CZs)





Percentage of Female Inventors and Gender Stereotypes
Percentage of Inventors who are Female
Gender Stereotype Adherence Index on 8th Grade Tests (Pope and Sydnor 2010)
10
15
20
25
30
1.5
2.0
2.5
3.0
RI
HI
SC
NH
NJ
GA
FL
OH
MD
DE
MA
NM
CT
NY
WV
NC
CA
ME
PA
VA
NE
AL
AZ
IL
KY
MI
TX
MN
CO
WA
WI
TN
MS
IN
AK
MO
IA
KS
NV
WY
OR
OK
ND
LA
UT
VT
MT
AR
SD
ID

Children's Patent Rates vs. Patent Rates by Gender in Neighborhood

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	Fraction Inventing in CZ	Fraction of Women Inventing	Fraction of Men Inventing	Fraction of Women Inventing in Patent Category	Fraction of Men Inventing in Patent Category
Exposure: Invention Rate in Childhood CZ	0.986*** (0.145)				
Invention Rate of Women in Childhood CZ		2.408* (1.265)	-0.356 (4.398)	2.232*** (0.607)	-2.157* (1.300)
Invention Rate of Men in Childhood CZ		0.174 (0.154)	1.784*** (0.625)	0.102 (0.062)	1.693*** (0.295)
Fixed Effects	None	None	None	Category	Category
Unit of Observation	Childhood CZ	Childhood CZ	Childhood CZ	Childhood CZ by Category	Childhood CZ by Category
Number of Cells	741	741	741	5,188	5,188
p-value from F-test for Equality of Coefficients		0.113	0.667	0.001	0.015

Notes: Std. errors clustered by CZ. Sample of children whose parents are not inventors.
* denotes p<0.1, *** denotes p<0.01

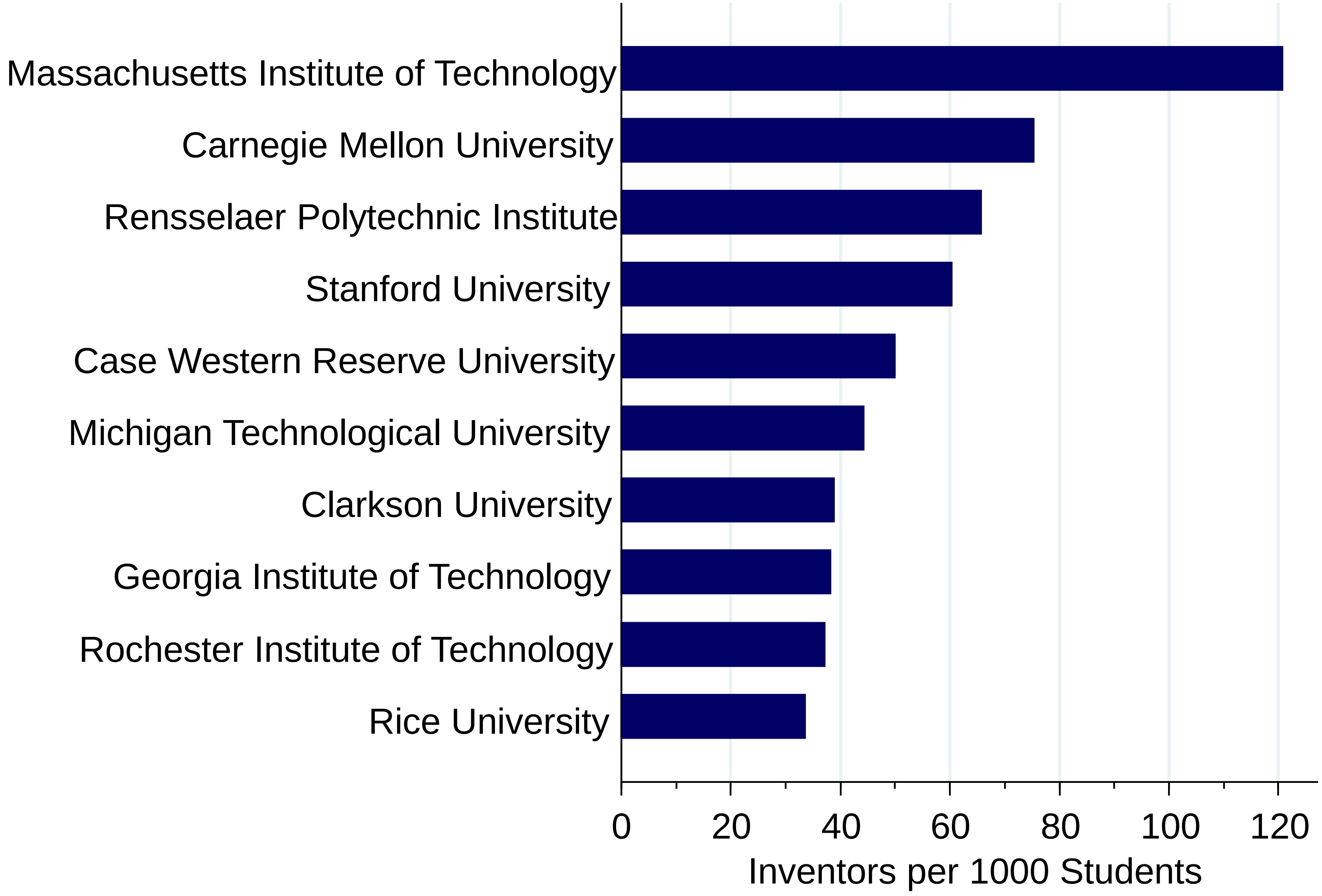
College Attendance and Innovation

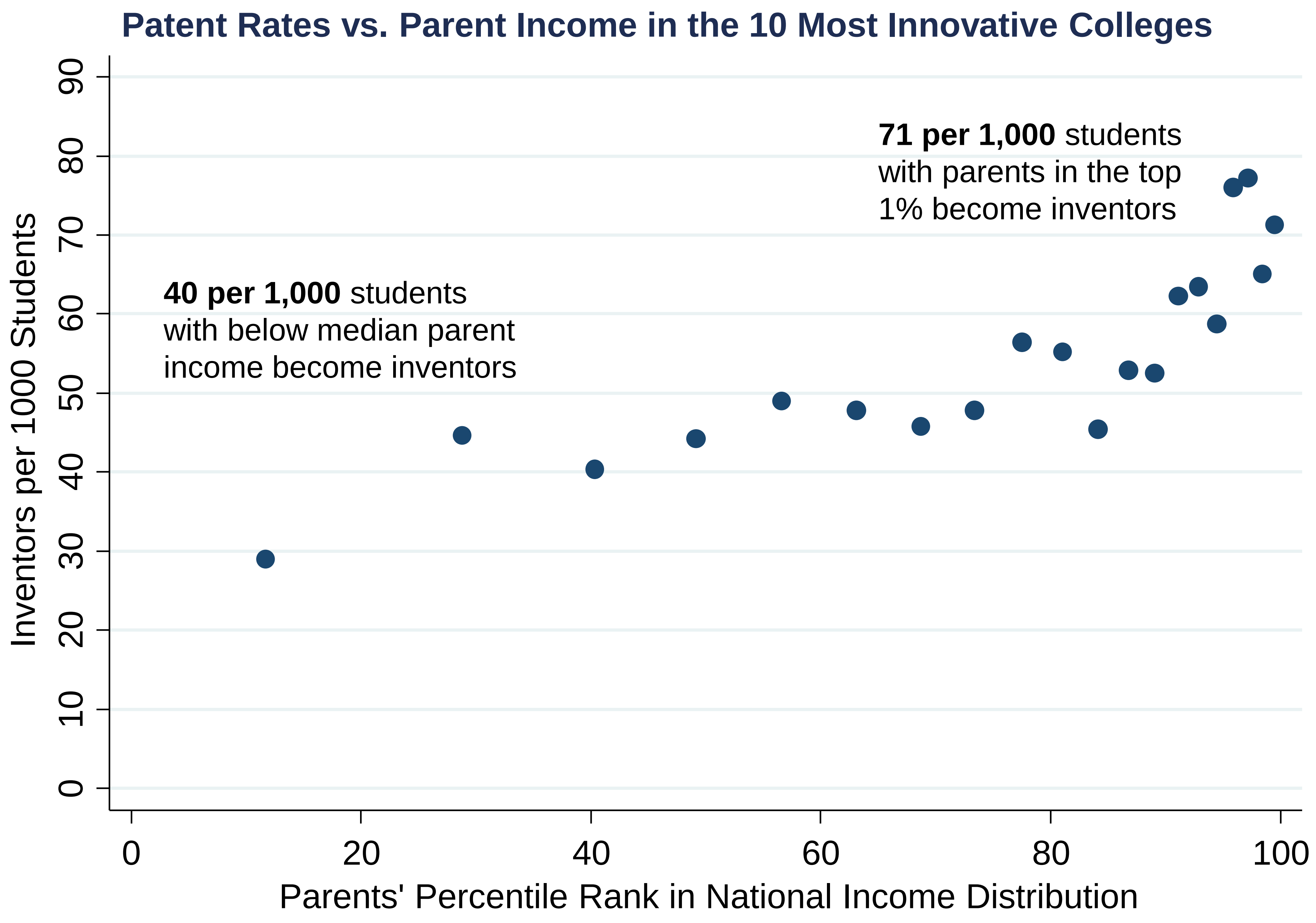
- Finally, examine college as a pathway to innovation

- What fraction of variation in innovation is accounted for by college that a child attends?

- How much variation is left to be explained by labor market choices after college?

Colleges with the Highest Share of Inventors per Student




Patent Rates vs. Parent Income in the 10 Most Innovative Colleges
71 per 1,000 students with parents in the top 1% become inventors
40 per 1,000 students with below median parent income become inventors
Inventors per 1000 Students
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
Parents' Percentile Rank in National Income Distribution

The Lifecycle of Inventors

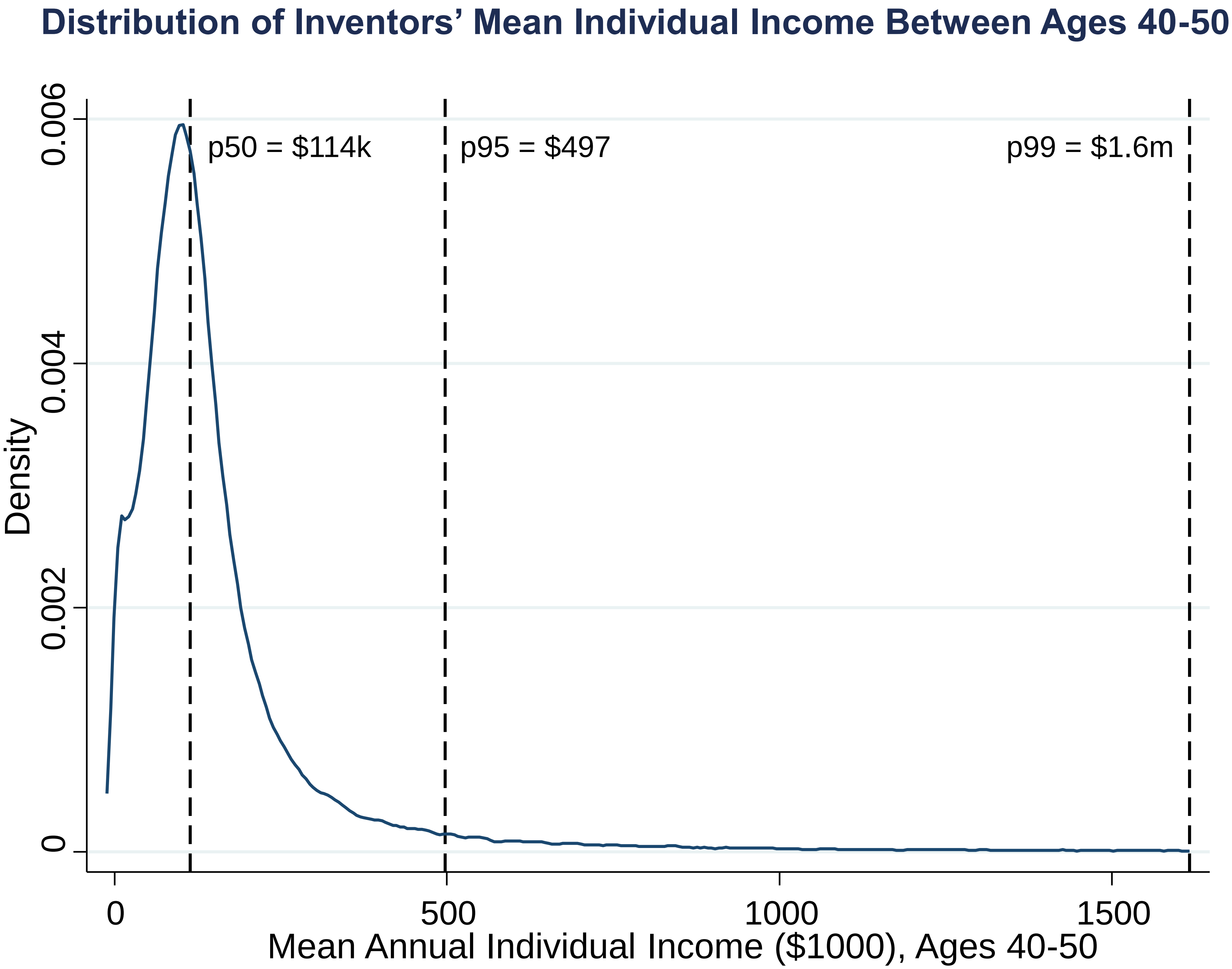
Birth
Parents
Gender
Ability

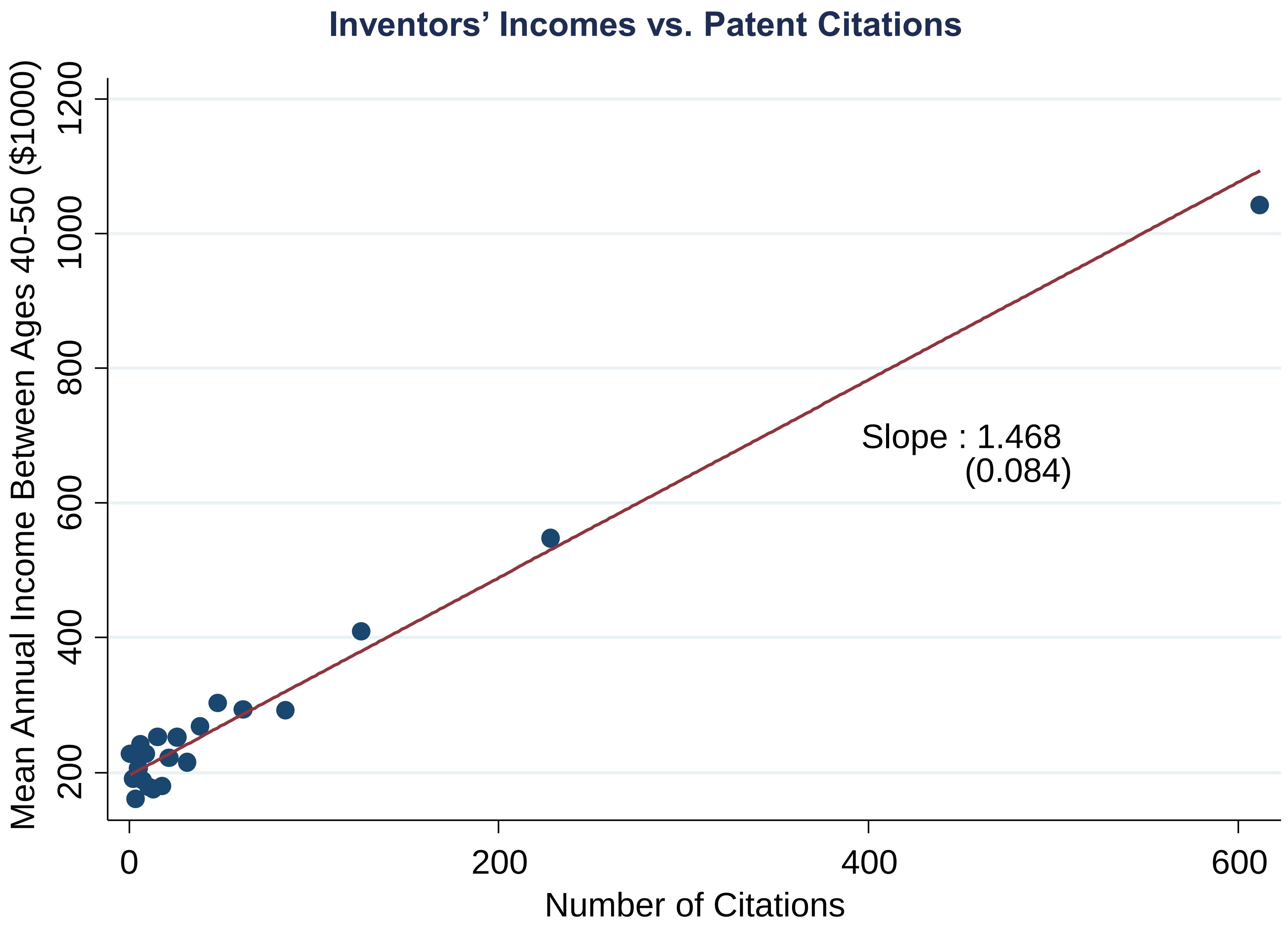
Childhood
Mentors
Neighborhood
College

Career
Earnings
Dynamics

Income Distribution of Inventors

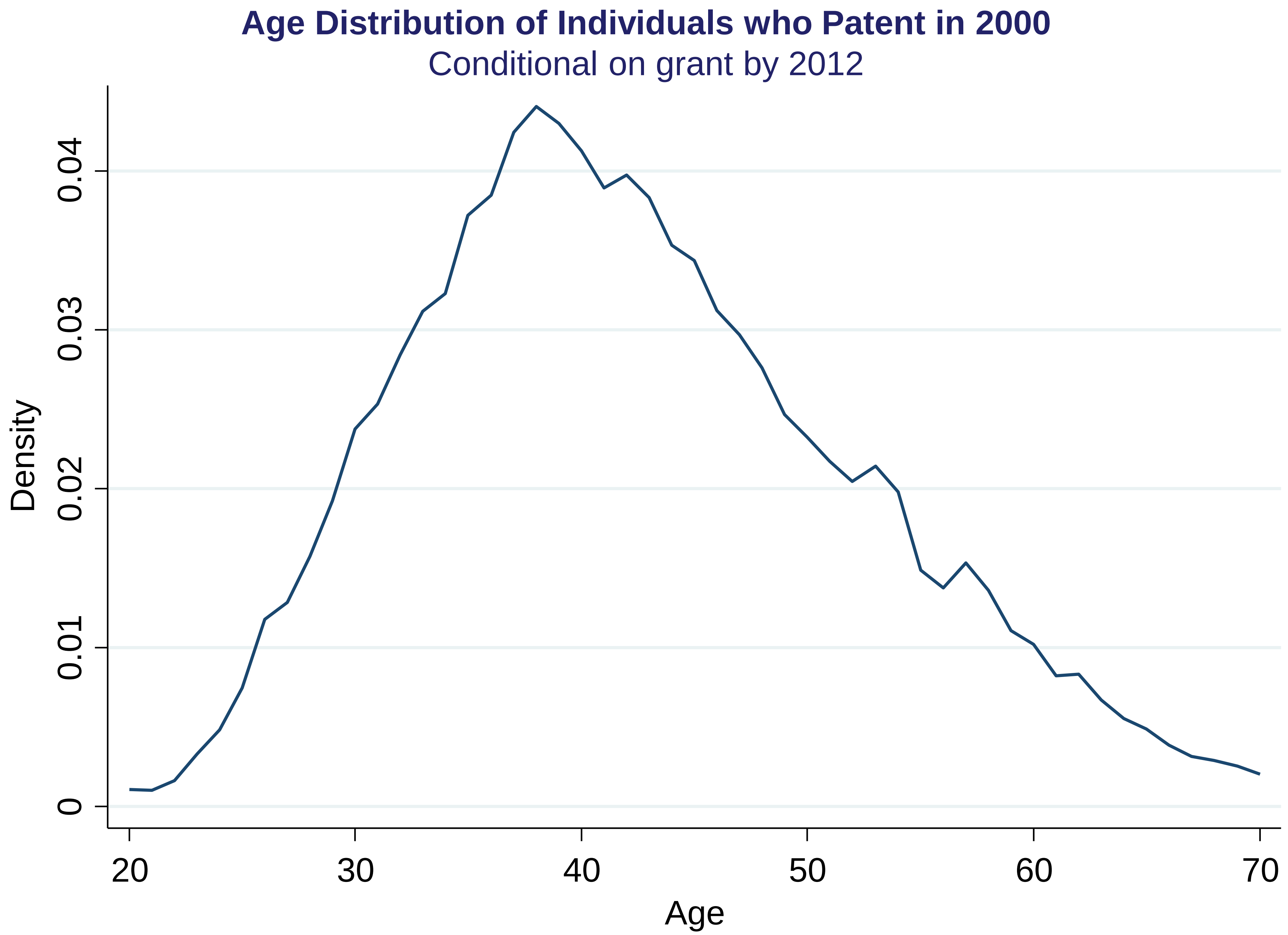
- Characterize careers of inventors to shed light on how financial incentives may affect individuals' decisions to pursue innovation
- First analyze cross-sectional distribution of mean income between ages 40-50 and covariance with scientific impact of patents
- Then characterize earnings dynamics over lifecycle


Distribution of Inventors' Mean Individual Income Between Ages 40-50
Density
0.006
0.004
0.002
0
p50 = $114k
p95 = $497
p99 = $1.6m
0
500
1000
1500
Mean Annual Individual Income ($1000), Ages 40-50

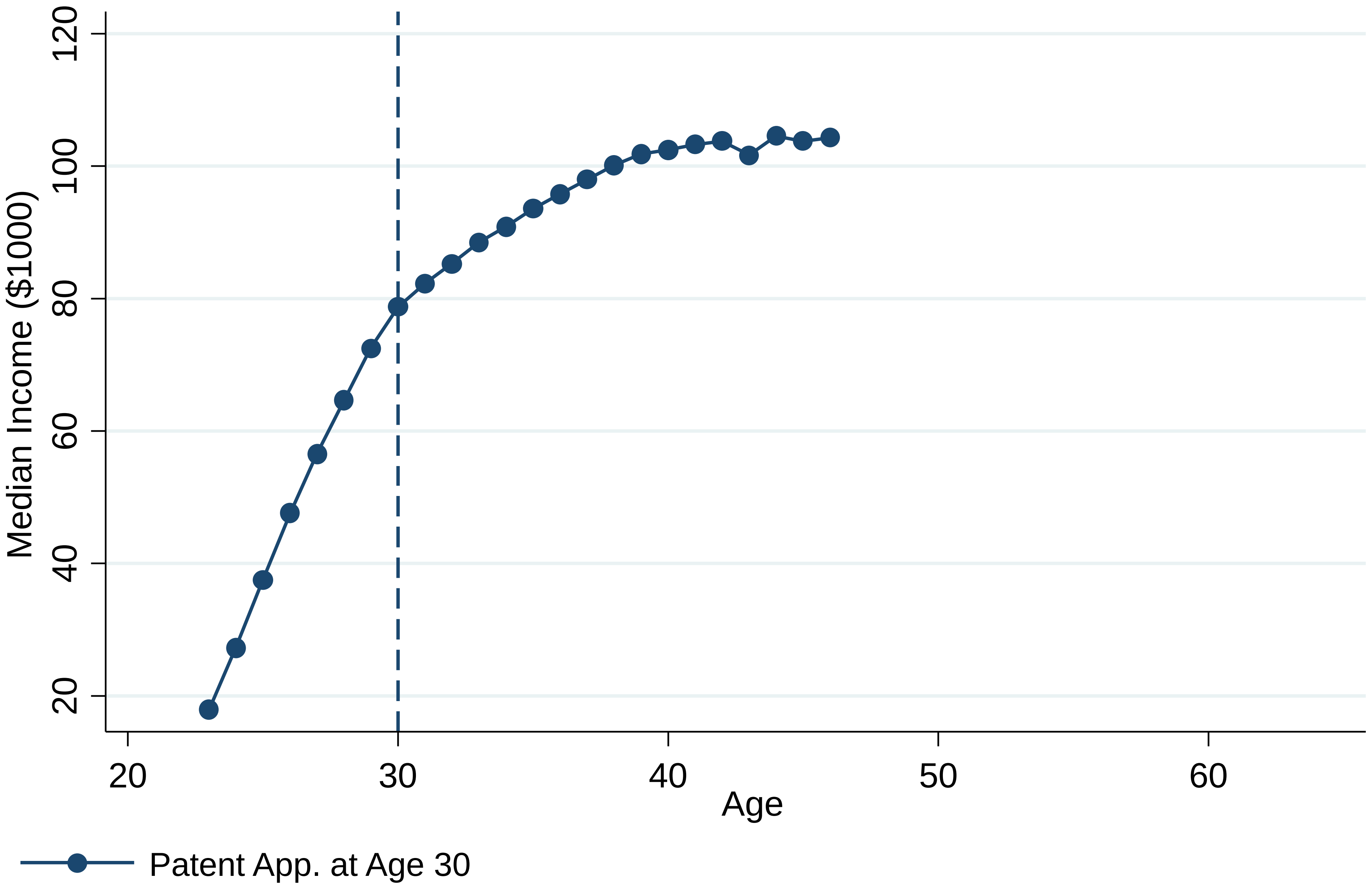

Inventors' Incomes vs. Patent Citations
Mean Annual Income Between Ages 40-50 ($1000)
1200
1000
800
600
400
200
0
200
400
600
Number of Citations
Slope : 1.468
(0.084)

Earnings Dynamics

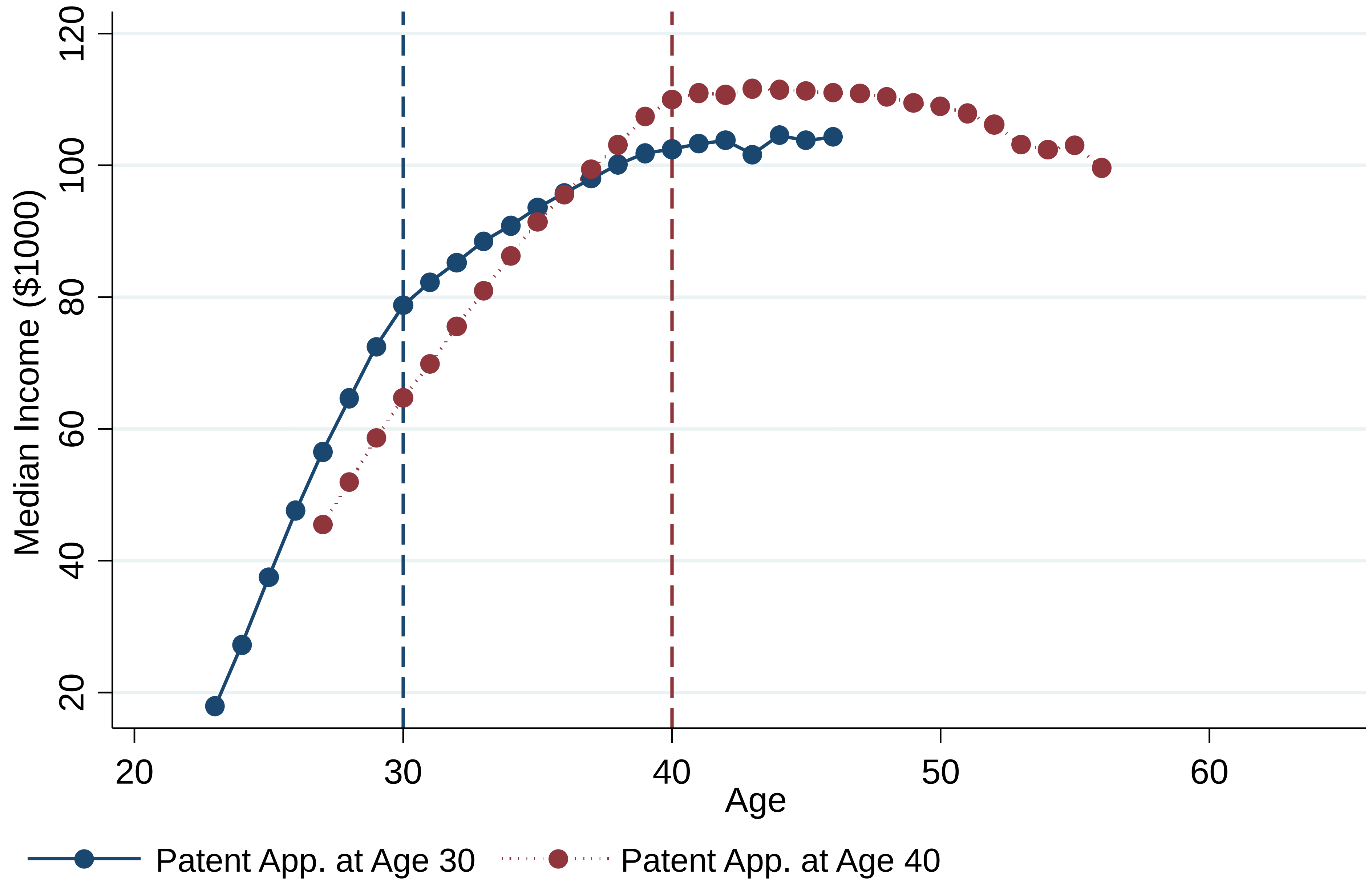
- Now turn to earnings dynamics
- General pattern: increase in earnings largely *precedes* patent application, consistent with Depalo and Addario (2014)
  - Private return to innovation appears to be earned largely before patent application itself
  - Change in income from grant of patent is small relative to earnings change prior to application
- Begin by examining age profile of innovation as background


Age Distribution of Individuals who Patent in 2000
Conditional on grant by 2012
Density
0
0.01
0.02
0.03
0.04
20
30
40
50
60
70
Age

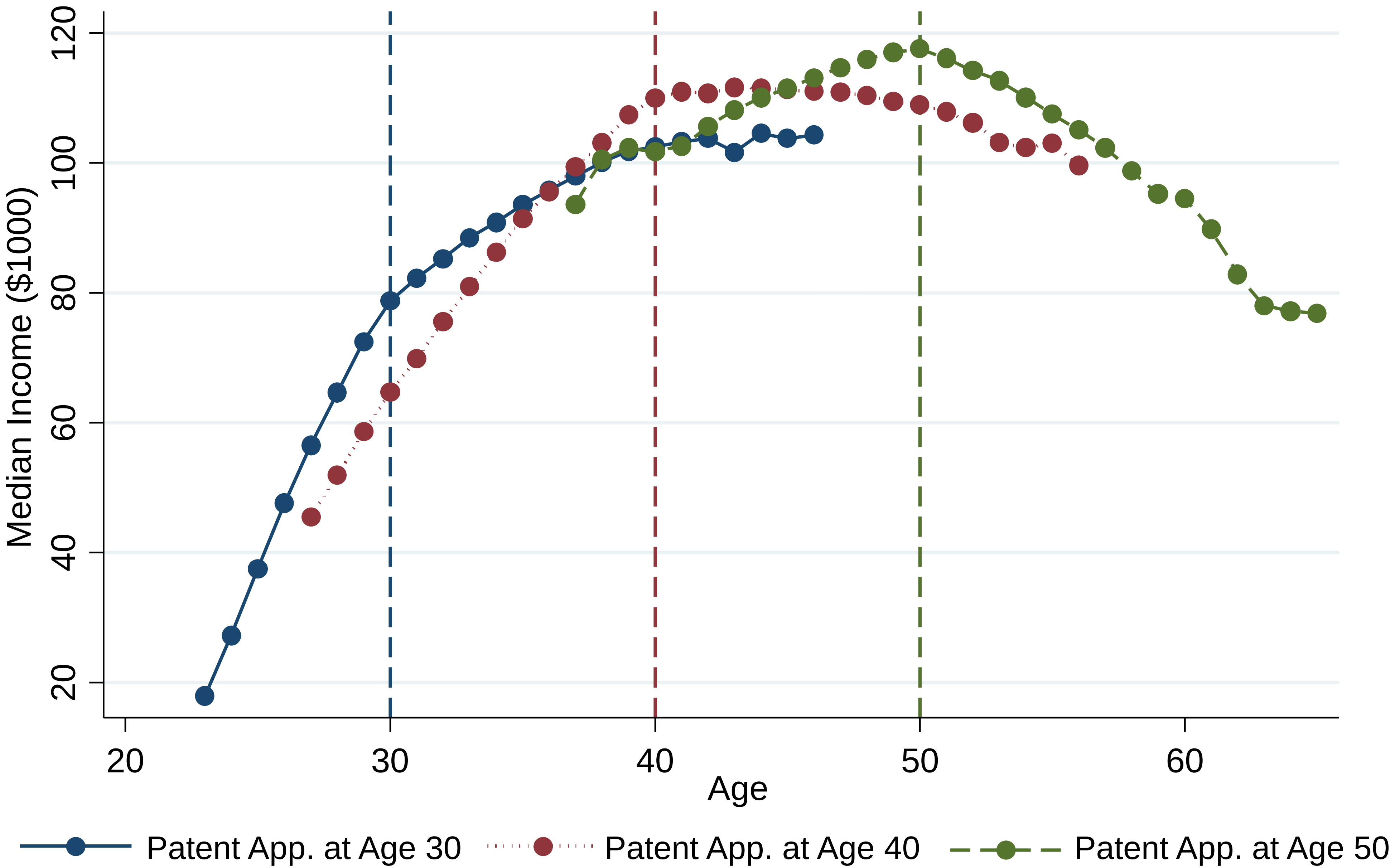
Median Income of Inventors by Age

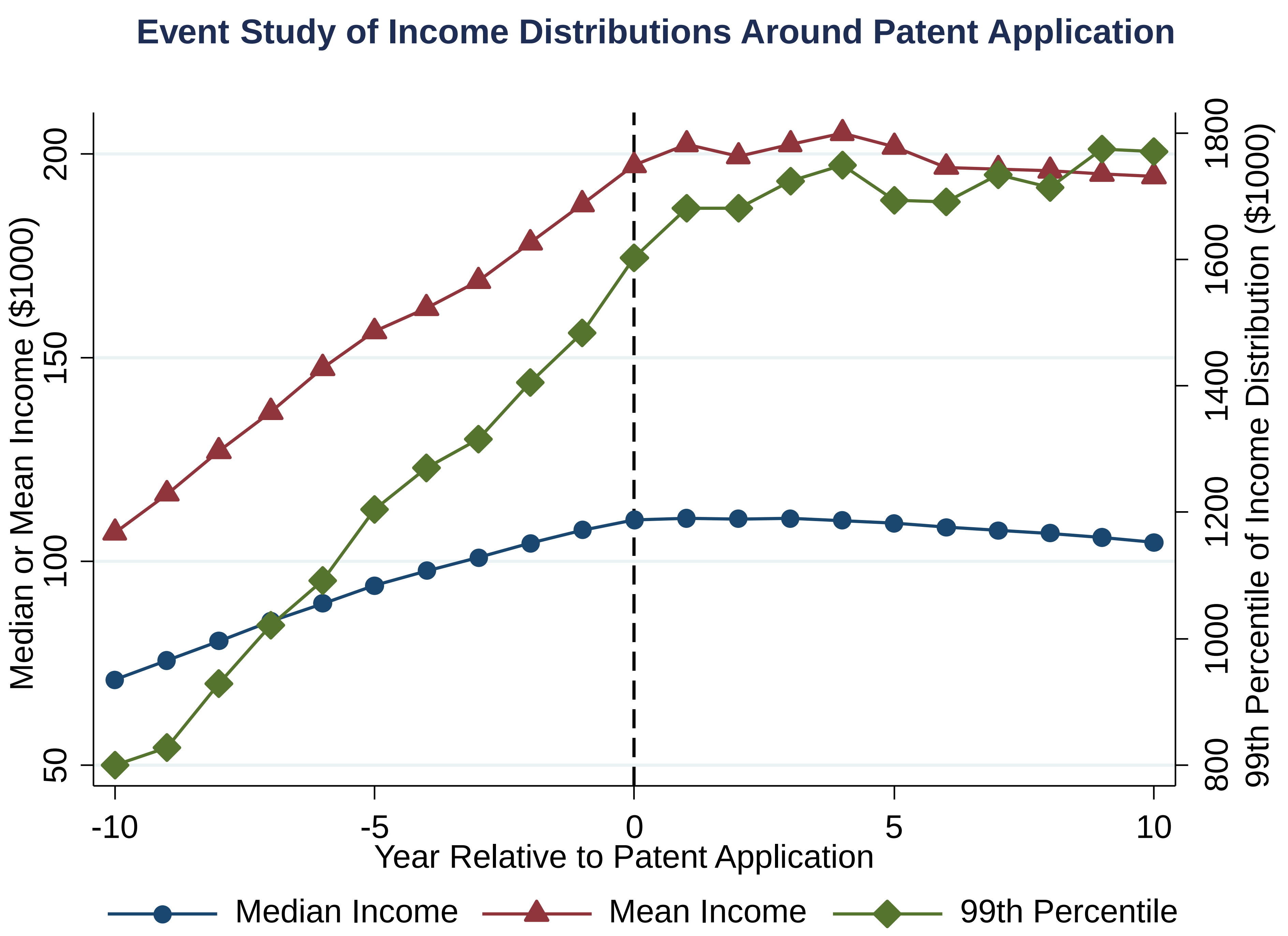


Median Income of Inventors by Age

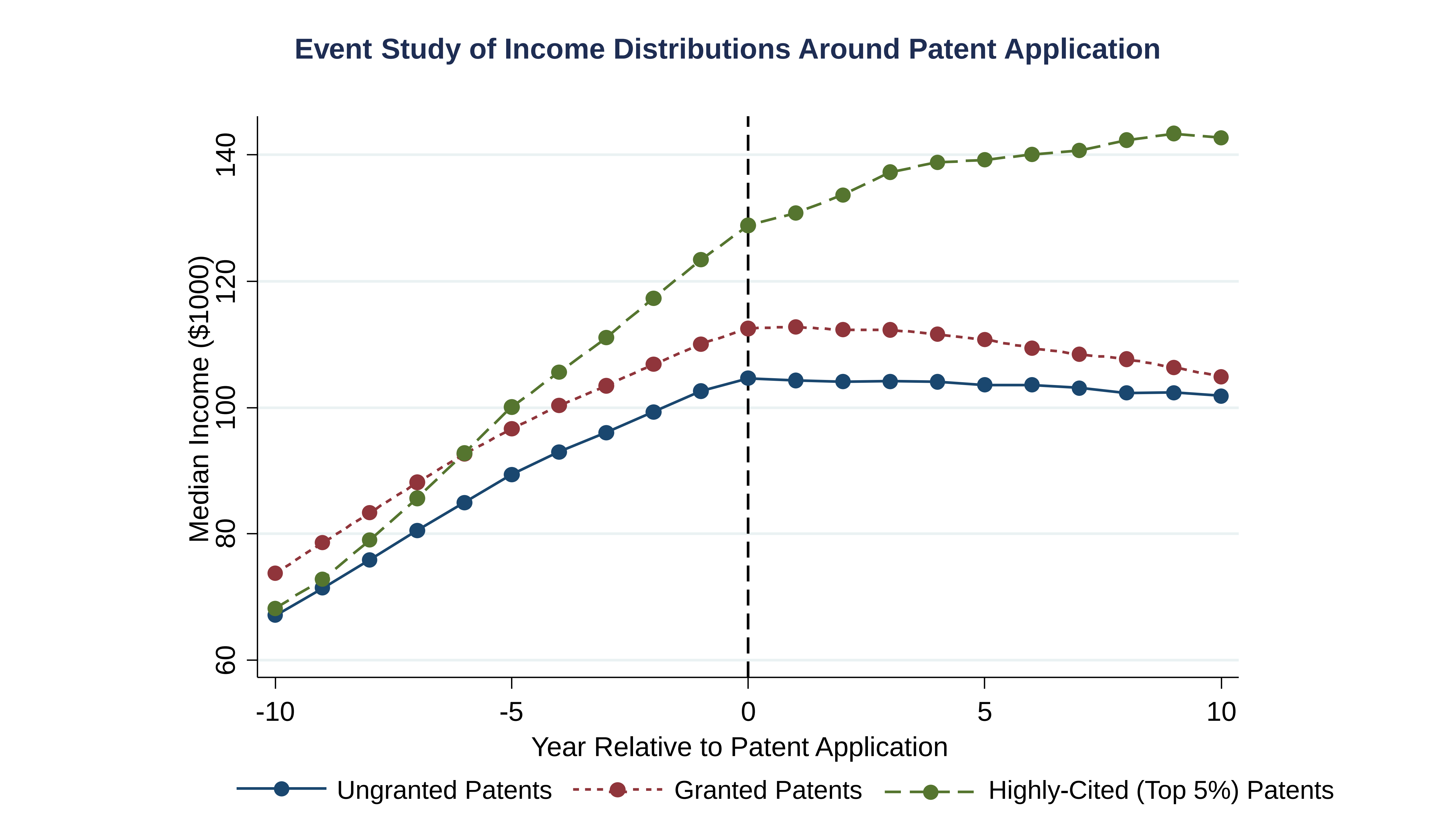


Median Income of Inventors by Age





Event Study of Income Distributions Around Patent Application
Median or Mean Income ($1000)
200
150
100
50
99th Percentile of Income Distribution ($1000)
1800
1600
1400
1200
1000
800
-10
-5
0
5
10
Year Relative to Patent Application
Median Income
Mean Income
99th Percentile



Event Study of Income Distributions Around Patent Application
Median Income ($1000)
60
80
100
120
140
-10
-5
0
5
10
Year Relative to Patent Application
Ungranted Patents
Granted Patents
Highly-Cited (Top 5%) Patents

Implications for Models of Innovation

- Three key facts about returns to innovation:

  1. Returns are extremely skewed: small chance of a very large payoff

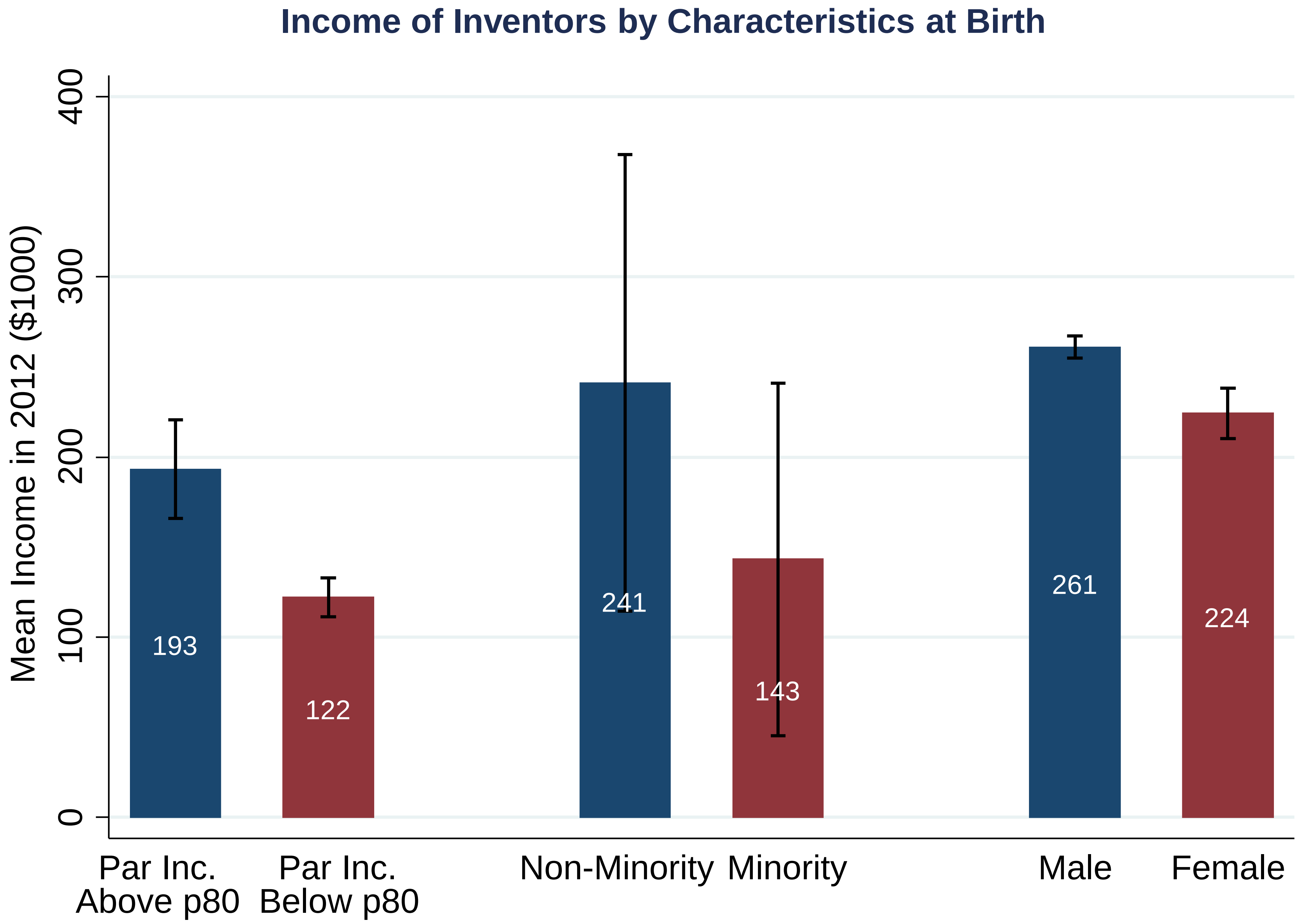
  2. Private financial returns are highly correlated with scientific impact: highly-cited inventors earn more than $1 million on average

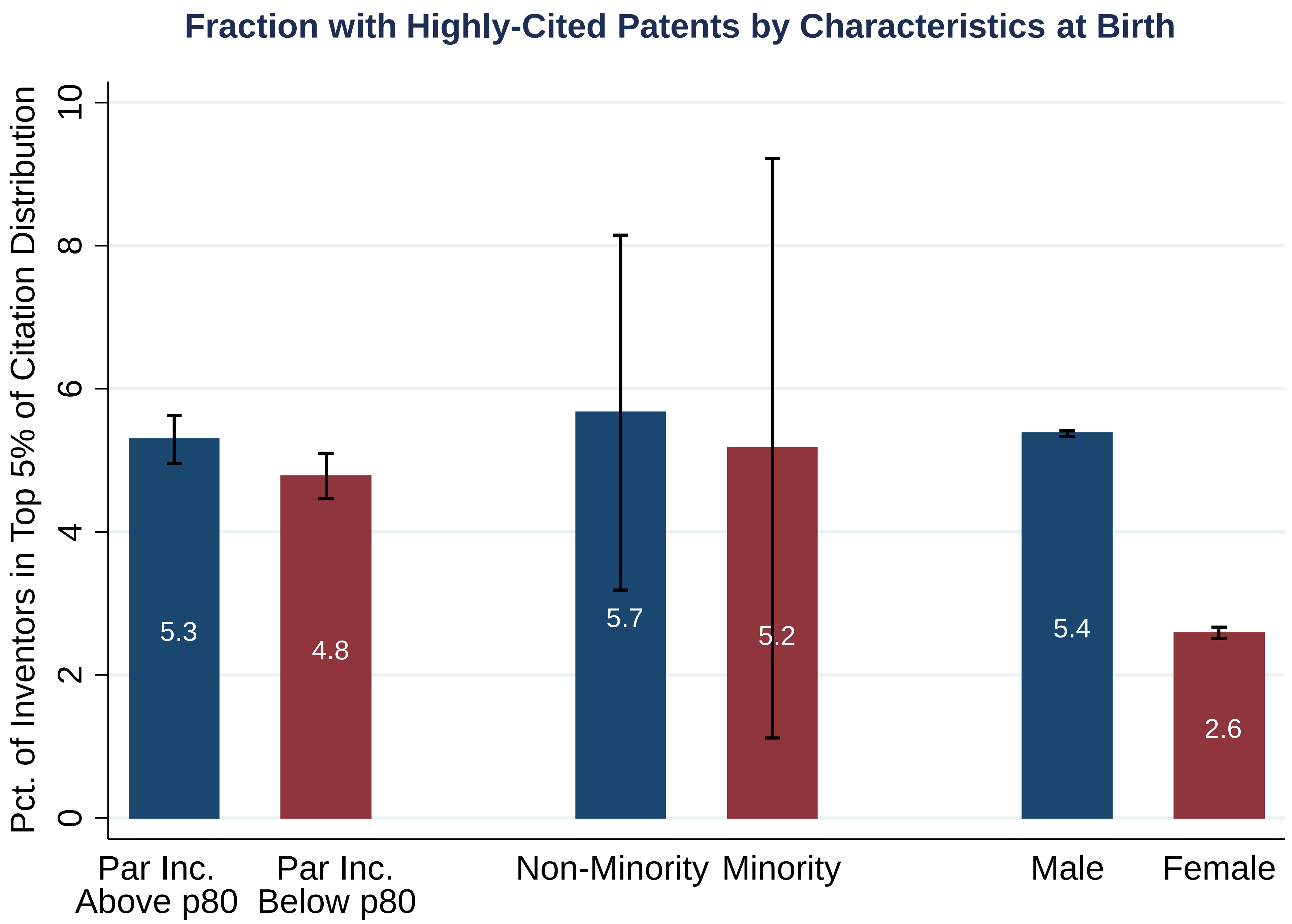
  3. Returns are often obtained late in an inventor’s career → payoffs may be uncertain when individuals make initial career choice

- We show below that these facts imply that changes in tax rates will have small effects on rates of innovation in a standard expected utility model

Income and Citations by Characteristics at Birth

- Finally, examine how income and citations vary with characteristics at birth
- Sheds further light on mechanisms that drive differences in innovation rates across subgroups
- Models of barriers to entry predict that inventors from under-represented groups will have *higher* ability on average [Hsieh et al. 2013]
    - Top inventors (“Einsteins”) make it through pipeline regardless of their parent’s income, race, gender


Income of Inventors by Characteristics at Birth
Mean Income in 2012 ($1000)
0
100
200
300
400
193
122
241
143
261
224
Par Inc. Above p80
Par Inc. Below p80
Non-Minority
Minority
Male
Female


Fraction with Highly-Cited Patents by Characteristics at Birth
Pct. of Inventors in Top 5% of Citation Distribution
0
2
4
6
8
10
5.3
4.8
5.7
5.2
5.4
2.6
Par Inc.
Above p80
Par Inc.
Below p80
Non-Minority
Minority
Male
Female

Implications for Models of Innovation

- Data are inconsistent with simple barriers to entry models
- But are consistent with exposure effects model
- Regardless of the explanation, key implication is that we are not just losing inventors of marginal ability
  - There are many “lost Einsteins” in under-represented groups
- Implies that costs of misallocation of talent might be even *larger* than predicted by existing models such as Hsieh et al. (2013)

How Many Lost Einsteins?

- White men from high-income (top-quintile) families comprise approximately 10% of US population

- Innovation rate for this group is about 4 times higher than in population as a whole

→ If women, minorities, and low-income children invented at same rate as high-income white men, would have four times as many inventors

Career Choice Model

- Analyze implications of findings for policies to increase innovation using a stylized model of career choice
- Two sectors: non-innovation (fixed salary) and innovation, which has payoffs that vary with ability and stochastic shock (Pareto distributions)
- Individuals choose careers by maximizing expected utility
- Decisions depend upon financial payoffs to innovation, tax rates/barriers to entry, and exposure (binary variable)

Career Choice Model: Results

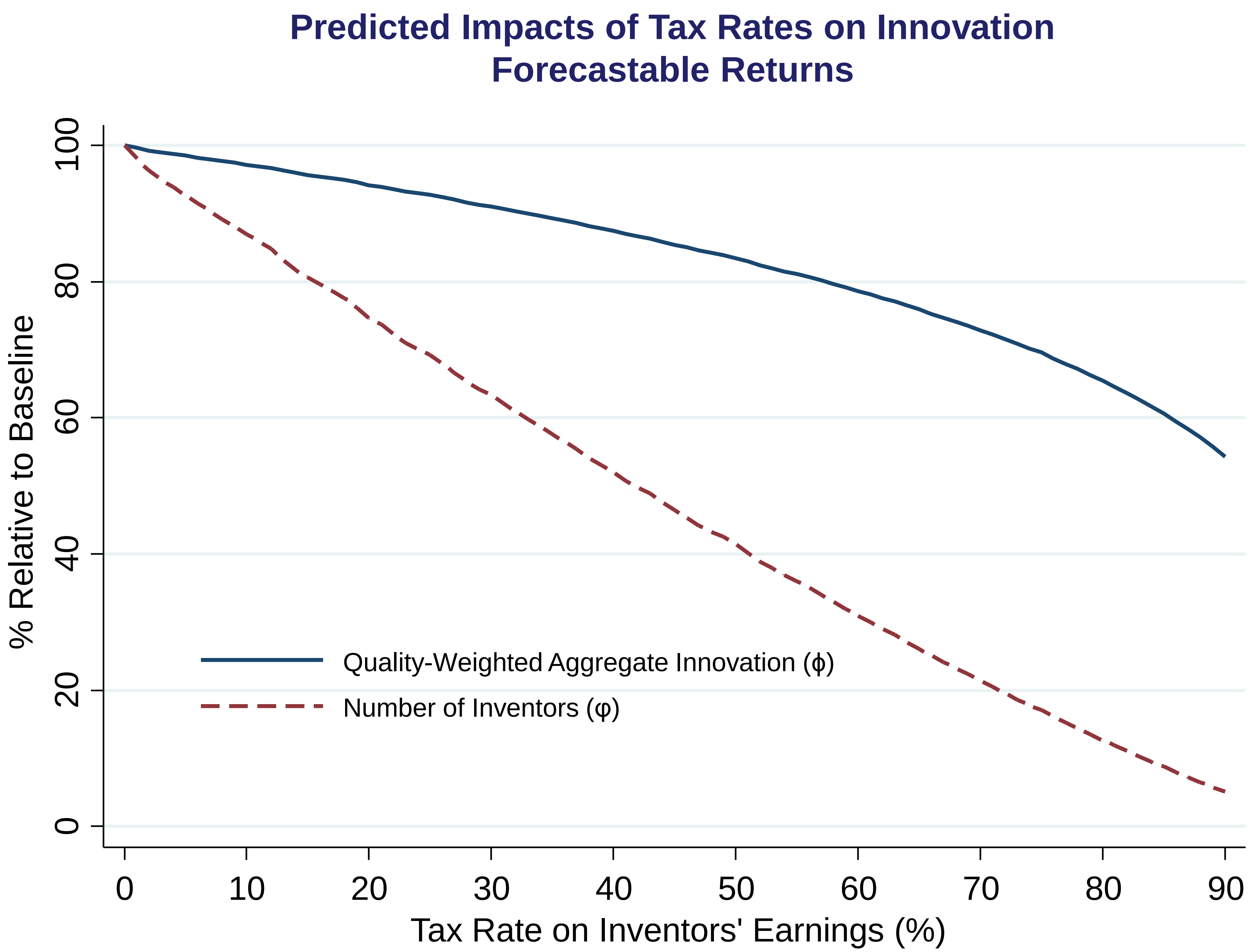
- Key result: changes in financial incentives have less potential to increase quality-weighted innovation than changes in exposure, for three reasons:

  1. [Exposure dampening] Taxes only affect those exposed to innovation

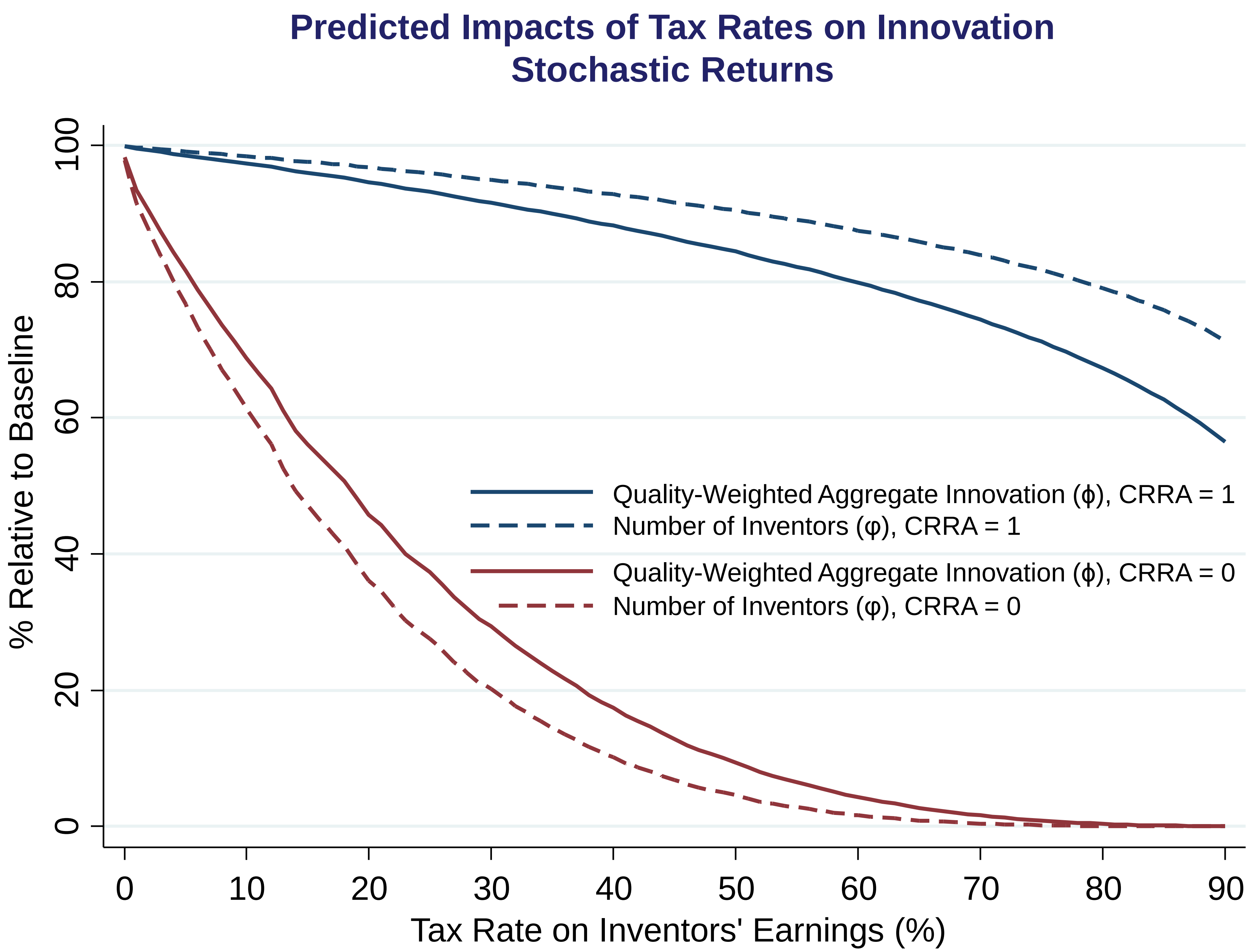
  2. [Forecastable returns] With highly skewed abilities, marginal inventor influenced by tax change has little impact on aggregate innovation [Jaimovich and Rebelo 2016]

  3. [Stochastic returns] With highly uncertain returns, changes in top tax rates do not affect marginal utility in "good" state significantly

- Calibrate distributions of ability and stochastic shocks to match empirical distribution of earnings to assess magnitudes of tax elasticities in practice



Predicted Impacts of Tax Rates on Innovation
Forecastable Returns
% Relative to Baseline
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80
90
Tax Rate on Inventors' Earnings (%)
Quality-Weighted Aggregate Innovation (ϕ)
Number of Inventors (φ)


Predicted Impacts of Tax Rates on Innovation
Stochastic Returns
% Relative to Baseline
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80
90
Tax Rate on Inventors' Earnings (%)
Quality-Weighted Aggregate Innovation (ϕ), CRRA = 1
Number of Inventors (φ), CRRA = 1
Quality-Weighted Aggregate Innovation (ϕ), CRRA = 0
Number of Inventors (φ), CRRA = 0

Impacts of Taxes with Stochastic Returns: Intuition

- Suppose an inventor makes $0 if his invention is unsuccessful and $10 million if invention succeeds
- Suppose he would make a fixed salary of $200K in an alternative career
- Consider an increase in income tax rate from 30 to 40%
  - If innovation fails, this has no impact on payoff (zero)
  - In innovation succeeds, net-of-tax payoff falls from $6m to $5m
- Fraction of individuals deterred from going into innovation sector will be small in a standard expected utility model
  - With diminishing marginal utility, value of extra $1m conditional on earning $5m is low

Tax Incentives for Innovation: Results

- Key result: when returns to innovation are calibrated to match empirical distribution, top tax elasticities are small regardless of other parameters

- Caveats

  1. This is *not* an empirical result: no direct evidence that tax elasticities are small

  2. Taxes may affect innovation through other channels, such as behavior of firms, other salaried workers, or through GE effects

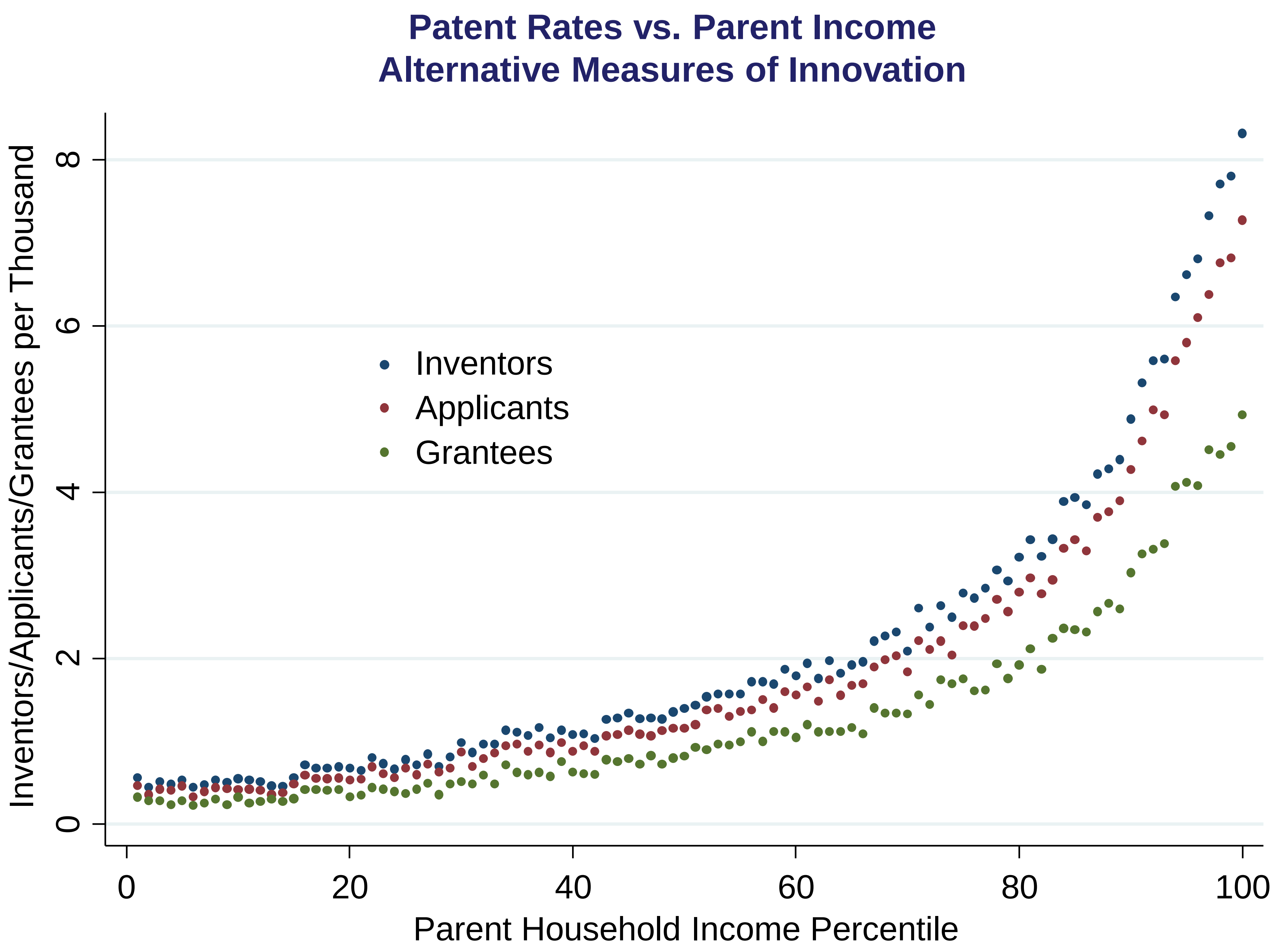
Conclusions

- Exposure to innovation is critical in determining who becomes an inventor
  - Many “lost Einsteins” among children from low-income families, minorities, and women because of a lack of exposure
  - If these groups invented at the same rate as white men from high-income families, innovation rate would quadruple

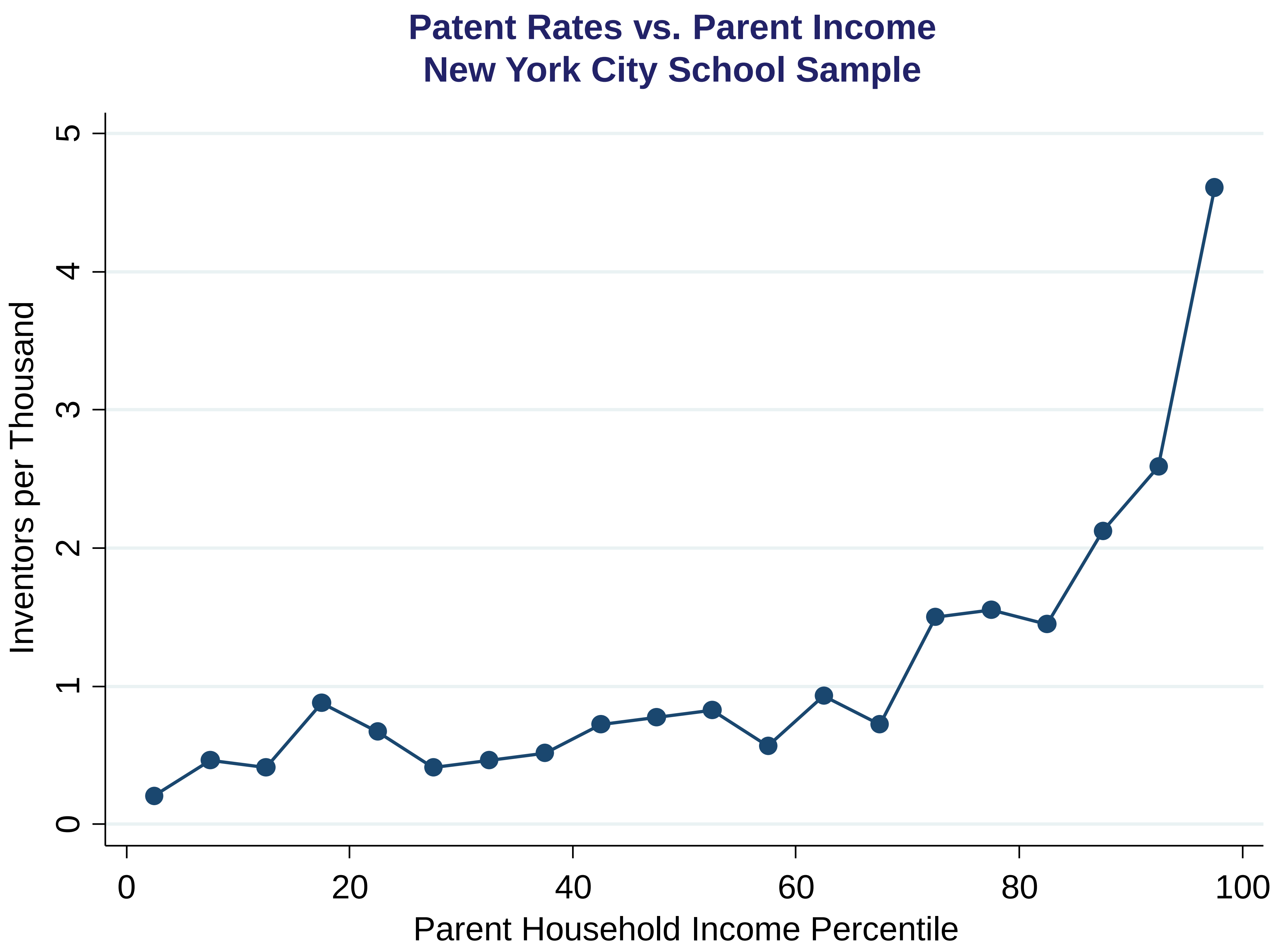
Conclusions

- Results do not provide specific guidance on policies to increase exposure
  - Could include mentorship programs, internships, changes in networks
- But they do provide guidance on how these programs should be *targeted*
  - Should be targeted toward women, minorities, and children from low-income families who excel in math/science at early ages
  - Should also be tailored by background: women more likely to be influenced by female inventors
- Key question: what programs are effective in increasing exposure?
  - We have posted online data tables with statistics on patent rates (www.equality-of-opportunity.org/data) to facilitate such analyses

Appendix Figures



Patent Rates vs. Parent Income
Alternative Measures of Innovation
Inventors/Applicants/Grantees per Thousand
0
2
4
6
8
Inventors
Applicants
Grantees
0
20
40
60
80
100
Parent Household Income Percentile


Patent Rates vs. Parent Income
New York City School Sample
Inventors per Thousand
0
1
2
3
4
5
0
20
40
60
80
100
Parent Household Income Percentile

Other Upper-Tail Outcomes

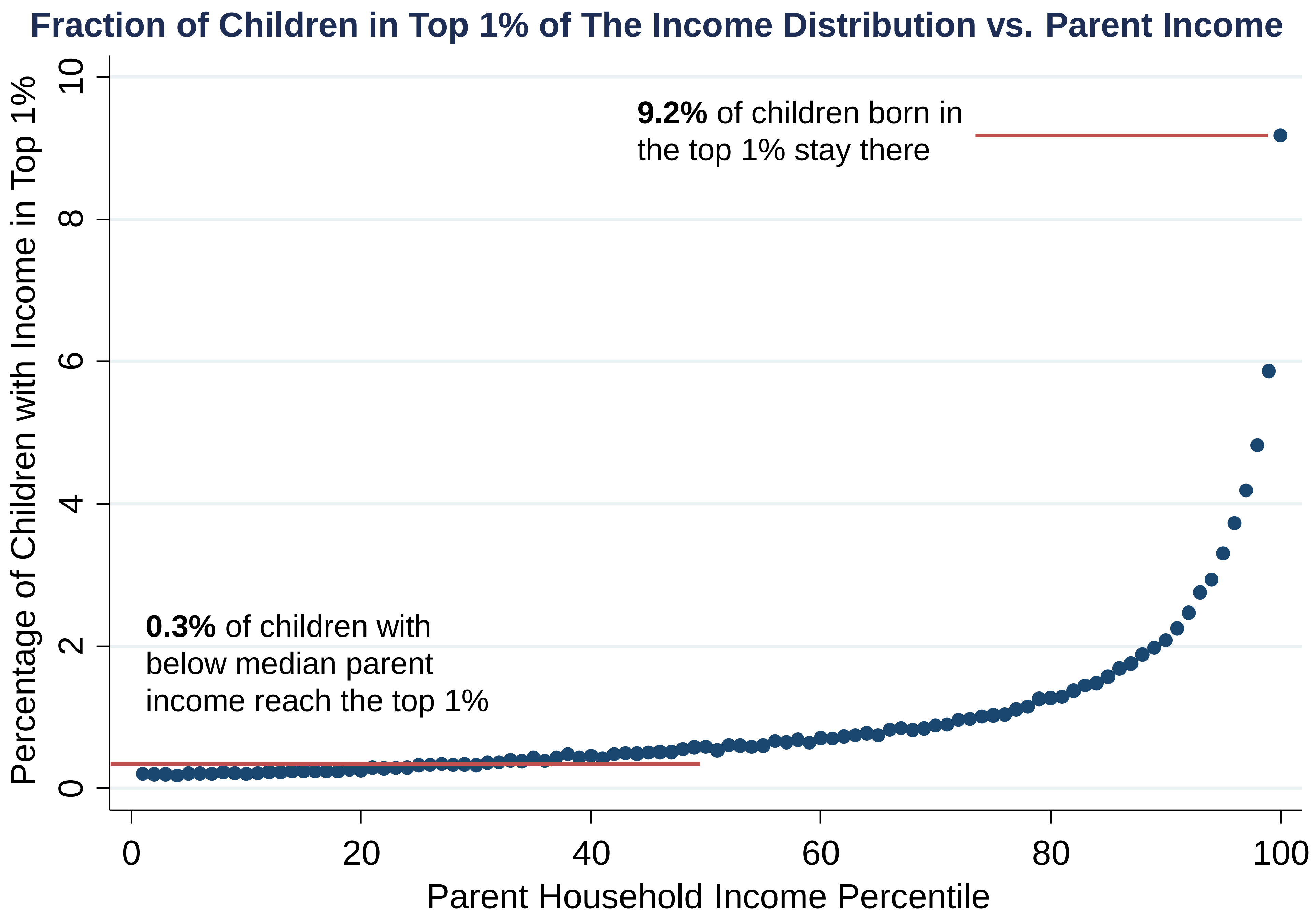
- Probability of patenting is an increasing, convex function of parent income percentile

- Same is true of other upper tail outcomes, e.g. probability of having income in top 1% of distribution

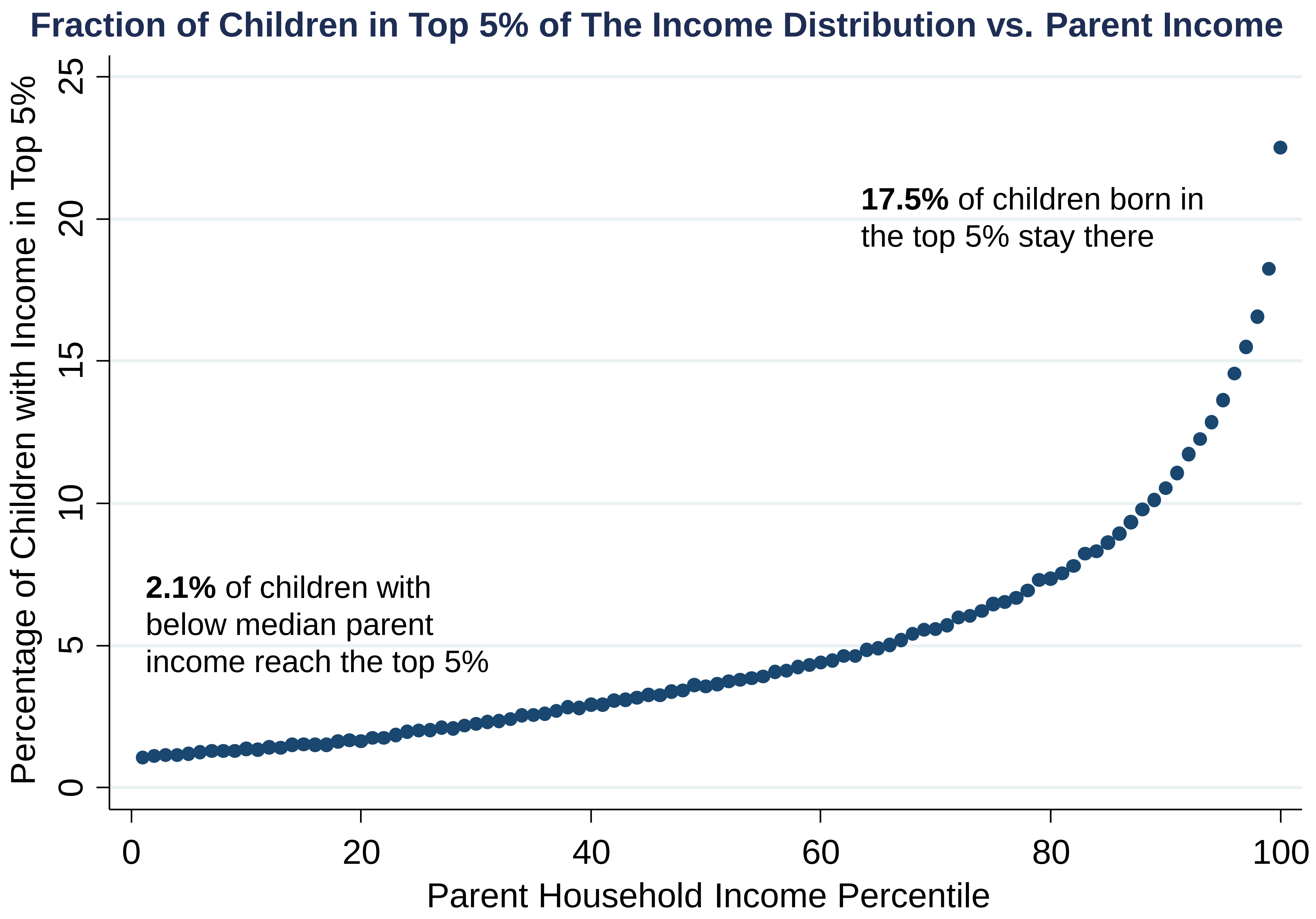
- Why focus on patenting instead of simply having high income?

  1. Innovation has larger positive externalities than other activities that generate large private returns

  2. Focusing on innovation yields more precise predictions that help us identify mechanisms



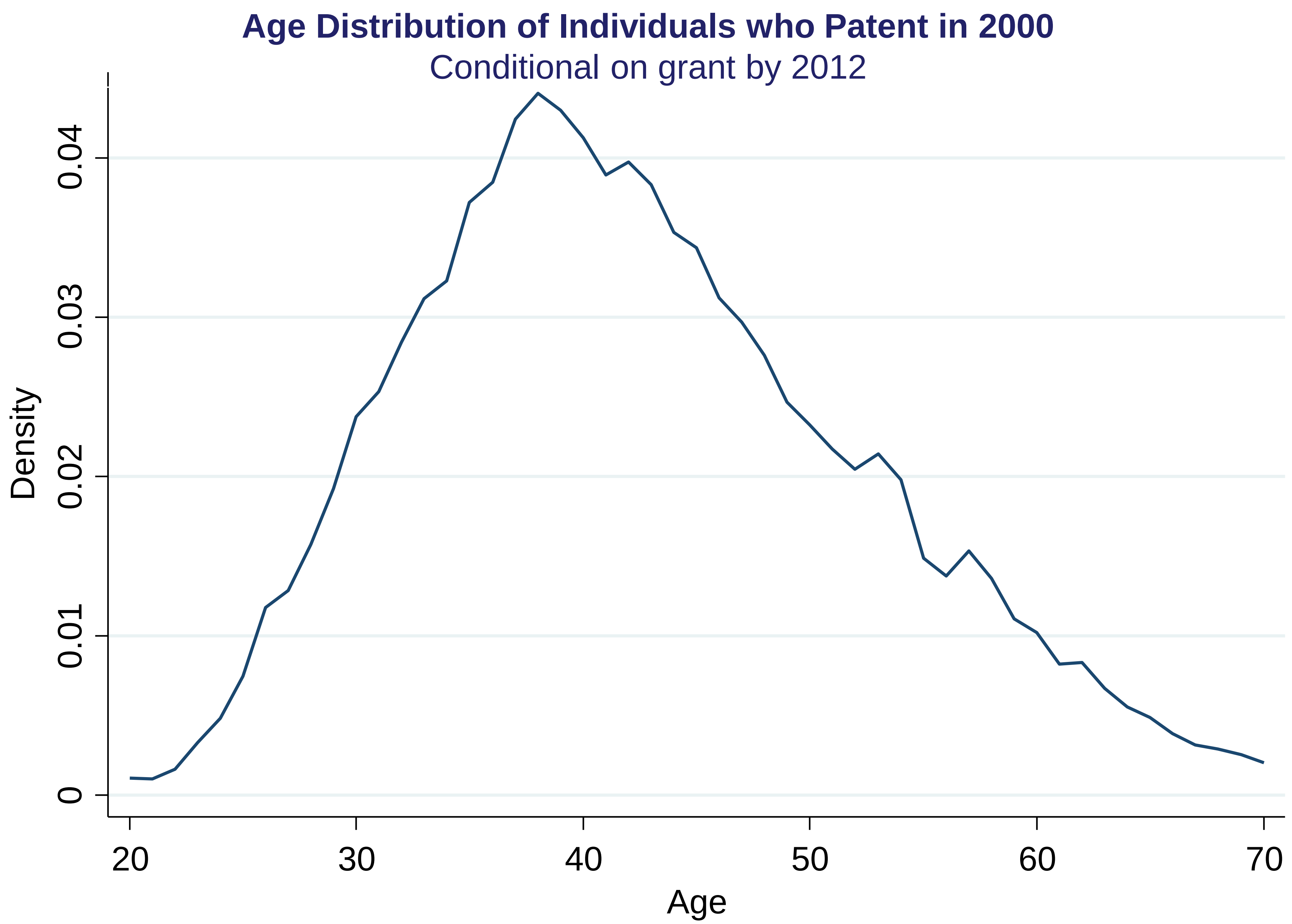
Fraction of Children in Top 1% of The Income Distribution vs. Parent Income
Percentage of Children with Income in Top 1%
0
2
4
6
8
10
0
20
40
60
80
100
Parent Household Income Percentile
9.2% of children born in the top 1% stay there
0.3% of children with below median parent income reach the top 1%



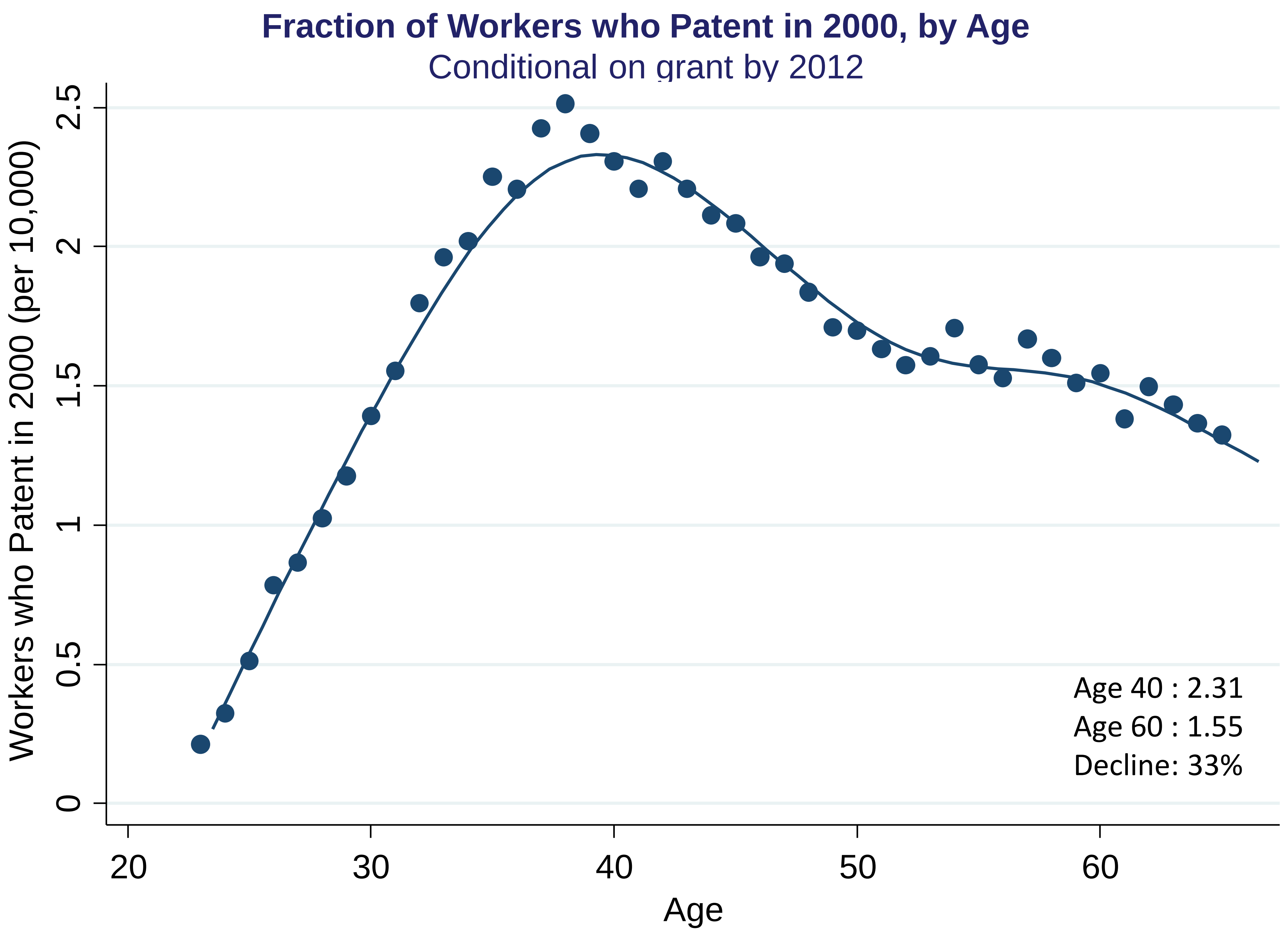
Fraction of Children in Top 5% of The Income Distribution vs. Parent Income
Percentage of Children with Income in Top 5%
0
5
10
15
20
25
0
20
40
60
80
100
Parent Household Income Percentile
17.5% of children born in the top 5% stay there
2.1% of children with below median parent income reach the top 5%

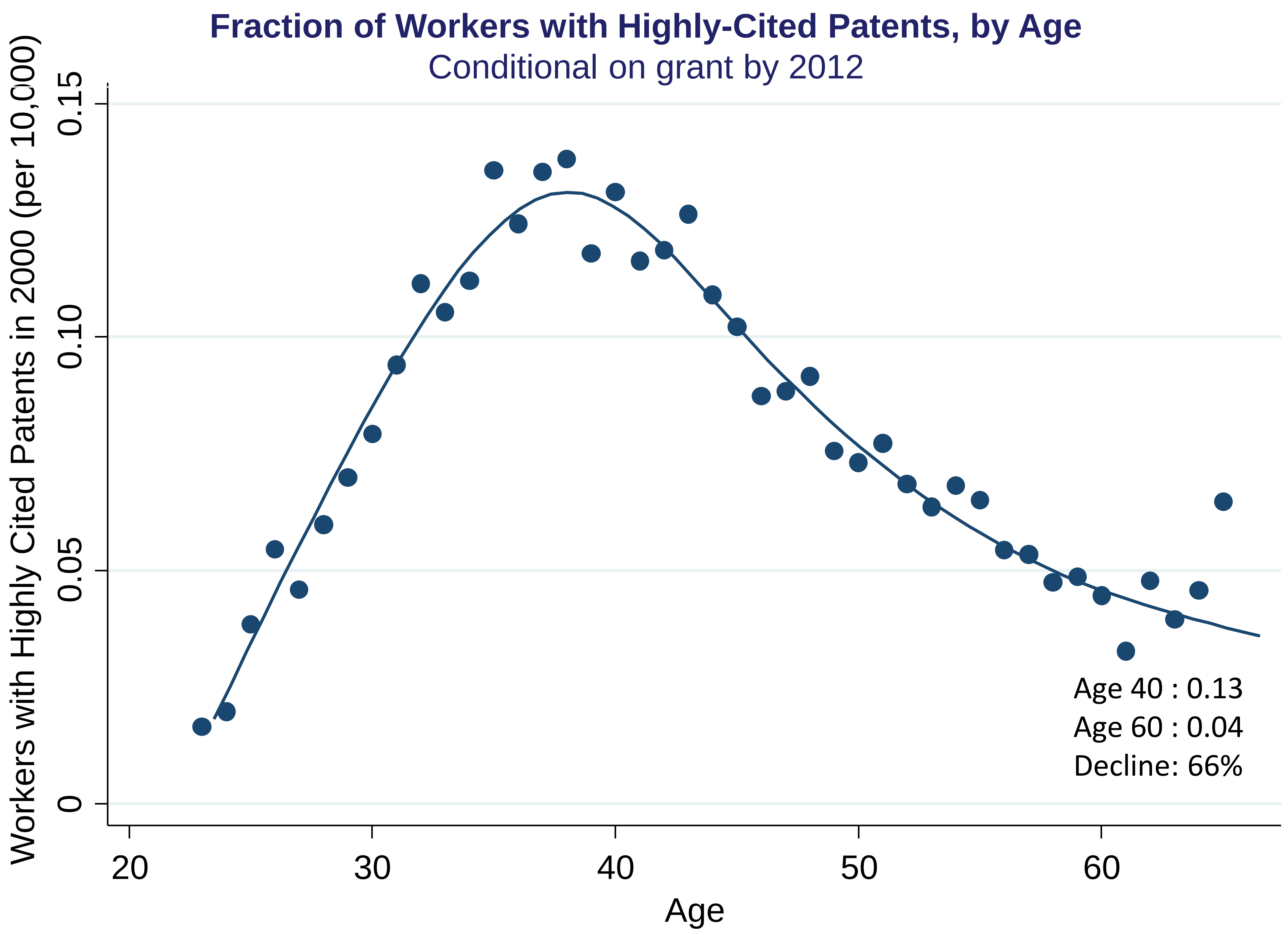
Age Distribution of Inventors

- At what stage of career do innovations occur?
  [e.g., Galenson and Weinberg 2001, Jones 2010]
  - When are the highest-impact discoveries made?



Age Distribution of Individuals who Patent in 2000
Conditional on grant by 2012
Density
0
0.01
0.02
0.03
0.04
20
30
40
50
60
70
Age


Fraction of Workers who Patent in 2000, by Age
Conditional on grant by 2012
Workers who Patent in 2000 (per 10,000)
0
0.5
1
1.5
2
2.5
20
30
40
50
60
Age
Age 40 : 2.31
Age 60 : 1.55
Decline: 33%



Fraction of Workers with Highly-Cited Patents, by Age
Conditional on grant by 2012
Workers with Highly Cited Patents in 2000 (per 10,000)
0
0.05
0.10
0.15
20
30
40
50
60
Age
Age 40 : 0.13
Age 60 : 0.04
Decline: 66%