Missing Women and Minorities: Implications for Innovation and Growth

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Outline

Motivation

- From Cook (2014), we know that unequal outcomes can emerge at each stage of innovation: education and training, invention, and commercialization of invention.
- Implications for income inequality between STEM and non-STEM fields greatest at the first two stages.
- In 2015, NSF reports that the median salary in the innovation economy was \$87,000 for men and \$62,000 for women, which was 71 percent of the median male salary.
- In the same year, African Americans earned 79 percent of the median salary for whites in the innovation economy.

Motivation

- The wealth implications are likely most stark at the stage of commercializing invention, e.g., Apple, Google, Uber founders, IPO participants.
- Among the Forbes list of richest people in the world, five of the top 10 derive their wealth primarily from the innovation economy.
- Apple's market capitalization is nearly $882 billion, which is greater than the size of the economy (GDP) of a number of the richest countries, including Argentina, Sweden, Switzerland, and Turkey.
- Roughly 5 percent of startups receiving VC funding have women as founders, and 1 percent of startups receiving VC funding have African American founders.

Motivation

- Chetty, et al. (2017) use patent and tax data to show the life cycle of inventors to show likelihood of exposure to innovation and divergence in outcomes related to inequality between those who are exposed and those who are not.
- We are reminded by Piketty and Saez, among others, why this matters. Income and wealth inequality leads to resentment and social conflict and undue influence of the most affluent on the political process.

Motivation

- Puzzle still remains. How are ideas converted into useful products and processes?
- Not all invention is patented. Not all patented inventions are commercialized. Who invents, who innovates, and why?
- How does this happen over the life cycle of an inventor?

Literature Review

- **Fields of Study** Hunt (2013), using the National Survey of College Graduates 2003, find only 7% of the gap in patenting rates is accounted for by women's lower probability of holding any science or engineering degree.
- **Industry** Wu, Welch and Huang (2015) find that patent commercialization is determined by inventors' attitude towards commercialization of research and collaboration with industry.
- **Firm Size** Bertrand and Hallock (2001) find women nearly tripled their participation in the top executive ranks and also strongly improved their relative compensation in larger corporations.

Research Questions

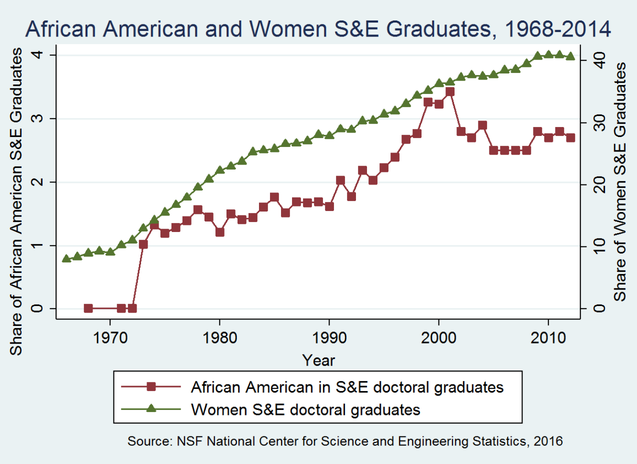
- We want to investigate the black box of converting ideas to products, processes, and, therefore, higher living standards.
- From Cook and Kongchareon (2010), we know that participation matters.
- Coed patent teams were more productive than single-sex patent teams.
- From Cook and Kongcharoen (2010), we also know that women patent one order of magnitude less than the average inventor with a U.S. patent, and African Americans patent one order of magnitude less than women.
- If who participates matters, who is participating in the patenting process? Does participation change by stage? What determines participation at each stage?

Broader Research Questions

- We know that women and African Americans are receiving a greater share of STEM degrees than in the past.

STEM Degrees Have Increased over Time

Figure 1: African American and Women S&E PhD Graduates



Research Questions We Will Address

- Are women and African Americans making it to and through each stage of invention like the broader patenting population?
- What can data on the careers of inventors tell us about the life cycle of inventors?
- How do individual inventors progress from ideas and patent applications to inventions to commercialized inventions?
- We cannot learn this solely from patent data or from inventor biographies and anecdotes, as in previous studies.
- We use NSF'S Survey of Doctoral Recipients over three waves to construct the (partial) life cycle of inventors.

Data

- We use the 2001, 2003 and 2008 waves of the SDR data and create a panel of respondents.
- There are 91,255 observations in the sample. We have collected:
- Data on gender, race, and ethnicity
- Data on patent activity – patent applications, patent grants, and commercialized patents
- Data on publications – articles and books; employment status; sector of employment; size of employer by number of employees; PhD field of study; whether the researcher receives government support, such as grants; membership in professional organizations [and tasks]
- Data on other demographic characteristics, such as gender, race and age

Figure 2: Summary Statistics

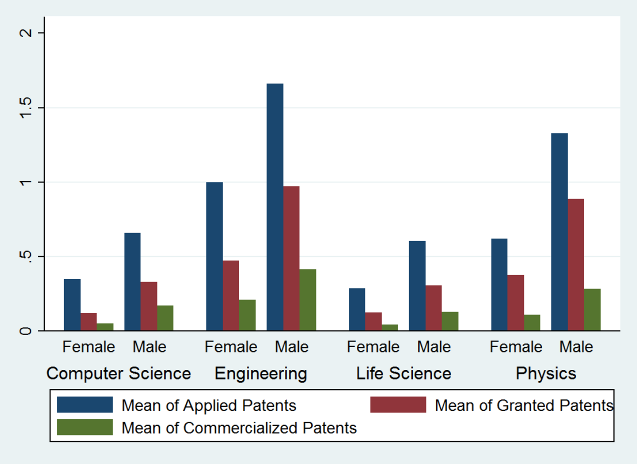
TABLE 1—SUMMARY STATISTICS

	Year 2001			Year 2003			Year 2008		
	Obs.	Female	Male	Obs.	Female	Male	Obs.	Female	Male
Panel A									
Black	1777	42.2	57.8	1660	44.3	55.7	1896	49.7	50.3
Asian	5242	32.9	67.1	4728	32.9	67.1	5414	34.7	65.3
Hispanic	1687	39.1	60.9	1676	43.0	57.9	1888	45.3	54.7
White	24397	28.7	71.3	23637	30.3	69.7	22798	33.6	66.4
Panel B									
Patents Applied	19655	12.2	87.8	20786	12.9	87.1	21048	12.2	87.8
Patents Granted	12365	9.5	90.5	11367	10.8	89.2	12010	10.4	89.6
Patents Commercialized	4727	8.6	91.4	4401	10.7	89.3	4696	9.9	90.1
Panel C									
Computer Science	2203	75.5	24.5	2005	74.7	25.3	2222	71.9	28.1
Engineering	5493	87.9	12.1	4868	87.3	12.7	4927	85.1	14.9
Life Sciences	9075	62.6	37.4	7559	65.6	34.4	7471	62.3	37.7
Physical Sciences	6277	81.2	18.8	5828	81.0	19.0	5415	78.0	22.0
Social Sciences	8313	57.6	44.2	8264	54.7	45.3	8404	54.7	45.3

Source: NSF SDR Survey Data 2001, 2003 and 2008

Stylized Facts

Figure 3: Patents Across Both Fields and Genders



Source: NSF SDR Survey Data 2001, 2003 and 2008

Conditional Probabilities

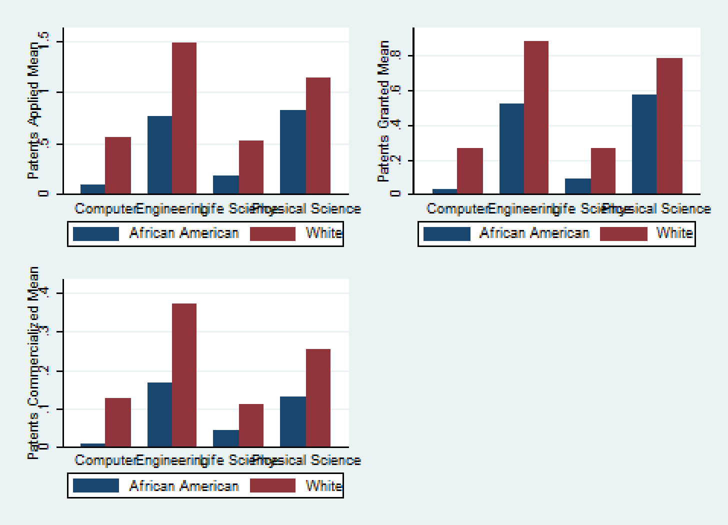
The conditional probability of applied patents for women in the fields of engineering and physics are 25.2% and 16.33%, respectively, in contrast to men in the same fields at 30.84% and 24%.

The conditional probability of granted patents for women in the fields of engineering and physics are 16.53% and 11.66%, respectively, in contrast to men in engineering and physics fields at 22.57% and 18.4%.

The conditional probability of commercialized patents for women in the fields of engineering and physics are 8.36% and 5.57%, respectively, in contrast to men in engineering and physics fields at 13.29% and 9.91%.

Stylized Facts

Figure 4: Patents Across Both Fields and Races



Conditional Probabilities

The probabilities of applying for a patent conditional on being African American and in the fields of engineering and physics are 20.9% and 20.6%, respectively, in contrast to whites in engineering and physics fields at 31.5% and 23%.

The probability of a patent grant conditional on being African American and in the fields of engineering and physics is 13.3% and 15.7%, respectively, in contrast to whites in engineering and physics fields at 22.8% and 17.5%

The probability of commercializing a patent for African Americans in the fields of engineering and physics is 7.4% and 6.1%, respectively, in contrast to whites in engineering and physics fields at 13% and 9.4%

Stylized Facts: Job Activities and Tasks

Figure 5: Job Tasks Across Genders

		Year 2001		Year 2003		Year 2008			
	Obs.	Female	Male	Obs.	Female	Male	Obs.	Female	Male
Computer Skill	3588	21.21	78.79	2410	19.50	80.50	2051	19.80	80.20
Management$sales$	10235	70.55.9	29.45	10617	67.66	32.34	11077	63.80	36.20
Management	10235	70.55.9	29.45	10617	67.66	32.34	11077	63.80	36.20
Applied Research	15835	27.93	72.07	14597	29.27	70.71	15324	33.11	66.89
Teach	8907	33.97	66.04	8319	35.39	64.61	8192	39.34	60.66
Basic Research	11221	29.33	70.67	11094	30.48	69.52	11149	34.08	66.92

Source: NSF SDR Survey Data 2001, 2003 and 2008

We fit the following regression model to the data. Because of the large number of zeros, as is characteristic in empirical patent work, we use a zero-inflated negative binomial model in estimation.

$$\text{Patent}_{i,t} = \alpha_0 + \beta_1 Female_{i,t} + \beta_2 Race_{i,t} + \beta_3 Field_{i,t} + \beta_4 Female_{i,t} Size_{i,t} + \beta_5 Female_{i,t} Sector_{i,t} + \beta_6 Field_{i,t} + \beta_7 Article_{i,t} + \sigma Other_{i,t}$$

where $Patent_i$ is a count variable of patents; $Race_i$ is a dummy variable with the value one if inventor i is African American $Field_{i,t}$ is the Ph.D. field i; $Sector_{i,t}$ are dummy variables indicating academia, government or industry, $Size_{i,t}$ is the firm size and $Article_i$ is the number of publications in the last five years. $Other_{i,t}$ are controls included for employment status and age.

Results

Table 1: ZINB Estimates of Females

	(Applied)	(Granted)	(Commercialized)
Female	-22.5%*	-26.5%**	-23.1%
	(-1.723)	(-1.991)	(-1.262)
Female*Government	-46.7%**	-46.5%**	-55.3%*
	(-2.370)	(-2.046)	(-1.929)
Female*Industry	23.8%	37.5%	47.8%
	(1.447)	(1.457)	(1.271)
Observation *N*	79,992	79,992	79,992

Notes: ZINB Estimates of Percentage change in expected count. t-statistics are in parentheses.

Results

Table 2: ZINB Estimates of African Americans

	(Applied)	(Granted)	(Commercialized)
African-American	-8.8%	17.3%	-36.8%
	(-0.366)	(0.536)	(-1.334)
African-American*Government	-64.6%*	-74.1%**	-76.6%
	(-1.832)	(-2.137)	(-1.560)
African-American*Industry	2.6%	-25.5%	6.8%
	(0.058)	(-0.650)	(0.132)
Observation N	79,992	79,992	79,992

Notes: ZINB Estimates of Percentage change in expected count. t-statistics are in parentheses.

Results

Table 3: ZINB Estimates of Females*Firm Sizes

	(Applied)	(Granted)	(Commercialized)
Female*500-999per	113.2%	174.9%**	145.5%*
	(2.509)	(2.163)	(1.947)
Female*1000-4999per	91.6%**	37.2%	155.3%
	(1.850)	(0.702)	(1.583)
Female*5000-24999per	56.0%	47.3%	14.1%
	(.532)	(1.105)	(0.284)
Female*25000+50000per	81.0%**	109.0%**	202.1%**
	(.219)	(2.236)	(2.399)
Female*50000per+	72.7%**	99.5%**	196.0%**
	(2.047)	(2.148)	(2.530)

Notes: ZINB Estimates of Percentage change in expected count. t-statistics are in parentheses.

Results

Table 4: ZINB Estimates of Fields of Doctoral Studies

	(Applied)	(Granted)	(Commercialized)
Computer Science	0.536**	0.589**	0.181
	(-0.245)	(-0.291)	(-0.46)
Engineering	0.850***	0.899***	0.537
	(-0.214)	(-0.242)	(-0.438)
Life Sciences	1.116***	1.403***	0.499
	(-0.213)	(-0.249)	(-0.434)
Social Sciences	-0.0544	-1.202***	-0.946**
	(-0.654)	(-0.346)	(-0.47)
Physical Sciences	1.099***	1.354**	0.678
	(-0.218)	(-0.251)	(-437)

Notes: ZINB Estimates of Raw Coefficients. Standard errors are in parentheses.

Results

Table 5: ZINB Estimates of Other Controls

	(Applied)	(Granted)	(Commercialized)
Article	-0.188***	-0.308***	-0.097***
	(-0.056)	(-0.070)	(-0.016)
Log Salary	0.305***	0.324***	0.415***
	(-0.041)	(-0.048)	(-0.047)
Hours of Work	0.01***	0.008***	0.015***
	(-0.002)	(-0.002)	(-0.003)
Age	-0.006*	0.016***	0.009**
	(-0.003)	(-0.003)	(-0.004)
Marital	0.142	0.288***	0.455***
	(-0.099)	(-0.093)	(-0.12)

Notes: ZINB Estimates of Raw Coefficients.Standard errors are in parentheses.

Pink and Black: Women and African American Inventors Now

- Hunt, Garant, and Munroe (2012) found that GDP per capita could be 2.7% higher with greater inclusion of women in S&E bachelor's degrees.
- Cook and Kongcharoen (2010) was the first to include under-represented minorities (African Americans) in systematic analysis of patent outcomes.
- Chetty, et al. (2016) use patent and tax data to show the life cycle of inventors to show likelihood of exposure to innovation and outcomes related to inequality.
- In Cook and Yang (2017), we use the NSF Survey of Doctorates to understand the gender gap and race gap in patenting and commercialization.
- We find that GDP could be 0.88% to 4.6% higher with the inclusion of more women and African American PhD's.

Greater Diversity Can Lead to More Innovation and Growth

- Hunt, Garant, and Munroe (2012) found that GDP per capita could be 2.7% higher with greater inclusion of women in S&E bachelor's degrees.
- To explain the economic magnitude better, from Hunts paper, we got the link between patents and patent per capita. We can make a crude calculation of the benefit of the additional PhD recipients using the results of Hunt (2012).
- According to U.S. Census 2013 data, PhD graduates are 1.68% of the US population. The number of men holding a PhD is approximately 1,678,000, compared to 817,000 women. The share of male is twice as female. According to U.S. Census 2009 data, PhD graduates are 1.2% of the US population.

Greater Diversity Can Lead to More Innovation and Growth

- Porter and Stern (2002), who that the elasticity of a country's GDP with respect to its patent stock is 0.113, controlling for capital and labor.
- Therefore, these data imply that a one percentage point rise in the share of African american phd graduates in the population increases patents per capita by 11.26%, and GDP per capita by 1.27%. If we use the commercialized patent, the increase in patents per capita is 5.62%, and GDP capita by 0.64%.

Future Research

- We will use individual-level data, e.g., from the UMETRICS data to investigate the channels through which patenting and commercialization occur among females and African Americans and whether there are differences with the larger population engaged in similar activities.
- UMETRICS data allows us to cluster our baseline regression based on the research projects. It will extend our previous study by connecting the individual characteristics with the project characteristics.
- We plan to use the project-level UMETRICS data to examine these disadvantaged groups, including assessing whether they have less access to RD or are underpaid during the initial research process.

Thank You

- Thank you for your attention! I look forward to your questions.
- I'm tweeting about my research and my experience working with the talented economists here at the Minneapolis Fed at **@drlisadcook**.