WHO BECOMES AN INVENTOR IN AMERICA? THE IMPORTANCE OF EXPOSURE TO INNOVATION

Alexander M. Bel, Raj Chetty, Xavier Jaravel Neviana Petkova, John Van Reenen

Innovation is widely viewed as a central driver of economic growth (e.g., Romer 1990, Aghion and Howitt 1992). As a result, many countries use a variety of policies to spur innovation, ranging from tax incentives to technical education. How effective are these policies? One way to understand the effectiveness is to study who becomes an inventor. What do their experiences teach us about factors that affect rates of innovation?

In fact, relatively little is known about the characteristics of inventors because most data on innovation (e.g., patent records) do not record even basic demographic information, such as an inventor's age or gender. In our research paper, we present the first comprehensive portrait of recent U.S. inventors.

Following standard practice in prior work on innovation, we define an "inventor" as an individual who holds a patent, although we recognize limitations to this narrow definition.[1]

To build our database, we linked data from the universe of patent applications and grants in the U.S. between 1996 and 2014 with federal income tax returns. As a result we constructed a panel dataset covering 1.2 million inventors (patent applicants or recipients). Using this dataset, we tracked inventors' lives chronologically-from birth to adulthood-to identify factors that helped determine who becomes an inventor. We also examined what policies may be most and least effective in increasing innovation based on these findings.

IN THIS BRIEF

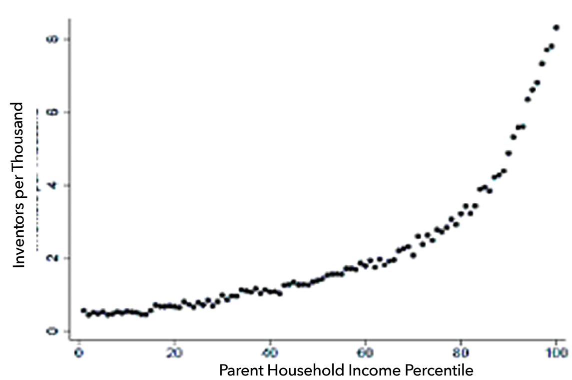
- We characterize the factors that determine who becomes an inventor in America by using de-identified data on 1.2 million patent-holders linked to federal tax records.
- Children's characteristics at birth – their socioeconomic class, race, and gender – are highly predictive of their propensity to become inventors. There are many "lost Einsteins"- individuals who might have significant inventions had they been exposed to innovation. Girls are more likely to become inventors if they grow up in an area with more female inventors.
- The financial returns to inventions are extremely skewed and highly correlated with their scientific impact, as measured by citations.
- If women, minorities, and children from low-income families were to invent at the same rate as white men from high-income families, there would be four times as many inventors in America as there are today.

EARLY SIGNS OF INNOVATION DISPARITIES

In the first part of our empirical analysis, we show that children's characteristics at birth-their socioeconomic class, race, and gender–are highly predictive of their propensity to become inventors. Children born to parents in the top 1% of the income distribution are ten times as likely to become inventors as those born to families with below-median income. [2] Whites are more than three times as likely to become inventors as blacks, and 82% of 40-year-old inventors today are men.

The gender gap in innovation is shrinking gradually over time, but at the current rate of convergence, it will take another 118 years to reach gender parity. Putting these data together, we estimate that if women, minorities, and children from lower-income families were to invent at the same rate as white men from high-income families, there would be four times as many inventors in America as there are today.

FIGURE 1: Patent Rates & Parent Income



Why do rates of innovation vary so sharply based on characteristics at birth? In economic models, any choice can be traced to three exogenous factors: endowments (e.g., differences in genetic ability across subgroups); preferences (e.g., a greater taste for pursuing science or a career with risky returns), and constraints (e.g., a lack

1The use of patents as a proxy for innovation has well-known limitations (e.g. Griliches 1990, OECD 2009). In particular, not all innovations are patented and not all patents are meaningful innovations. We address these measurement issues by showing that (a) our results hold if we focus on highly cited (i.e., high-impact) patents and (b) the mechanisms that lead to the differences in rates of patenting across subgroups that we document are unlikely to be affected by these concerns.

2This pattern is not unique to innovation: children from high-income families are also substantially more likely to enter other high-skilled professional occupations and, more generally, reach the upper-tail of the income distribution. We focus on innovation here because it is thought to have particularly large social spillovers and because focusing on innovation has methodological advantages in understanding the mechanisms underlying career choice, as we discuss below.

MIT INITIATIVE ON THE DIGITAL ECONOMY

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of liquidity or opportunities to build human capital). Since each of these explanations has very different policy implications, we structured most of our analysis around assessing the relative importance of these three mechanisms.

To evaluate whether differences in ability explain the gaps in innovation we used test scores in early childhood as a proxy for ability. We obtained test score data from third to eighth graders by linking school district records for 2.5 million New York City public school children to patent and tax records. It turns out that math test scores in third grade are highly predictive of patent rates, but they account for less than one-third of the gap in innovation between children from high- versus low-income families.[3] This is because children from lower income families are much less likely to become inventors even if they score at the top of their third-grade class.

> **The gender gap in innovation is shrinking gradually over time, but at the current rate of convergence, it will take another 118 years to reach gender parity.**

The gap in innovation explained by test scores grows in later grades, consistent with prior evidence that test score gaps widen as children progress through school (e.g., Fryer and Levitt 2004, Fryer 2011). Half of the gap in innovation by parent income can be explained by differences in math test scores in eighth grade. These results suggest that low-income children start out on relatively even footing with their higher-income peers in terms of innovation ability, but fall behind over time, perhaps because of differences in their environment. However, these findings do not provide conclusive evidence about the role of environment because test scores are an imperfect measure of ability. If a child's ability to innovate is poorly captured by standardized tests, particularly at early ages, ability could still account for a substantial share of gaps in innovation.[4]

THE ROLE OF NURTURE, NOT NATURE

In the second part of our empirical analysis, we studied the impacts of childhood environment directly. We showed that exposure to innovation during childhood through one's family or neighborhood has a significant causal effect on a child's propensity to become an inventor.[5]

We established this result – which we view as the central empirical result of the paper – in a series of steps. We first showed that children who grow up in communities with higher patent rates are significantly more likely to become inventors. We then showed that the pattern holds not just for whether a child innovates, but also in the specific technology category in which he or she innovates. For example, among people living in Boston, those who grew up in Silicon Valley are especially likely to hold patents in computers, while those who grew up in Minneapolis – which has many medical device manufacturers – are especially likely to patent in medical devices.

Similar patterns exist at the family level: Children whose parents or parents' colleagues hold patents in a technology category are more likely to patent in exactly that field themselves. These patterns of transmission hold across the 445 narrowly defined technology subclasses into which patents can be classified. For example, a child whose parents hold a patent in amplifiers is much more likely to patent in amplifiers than in antennas. Moreover, the patterns are gender-specific: women are much more likely to patent in a specific technology if female workers in their childhood were likely to patent in that class. Conversely, men's innovation rates are influenced by male, rather than female inventors in their area.

> **Exposure to innovation during childhood through one's family or neighborhood has a significant causal effect on a child's propensity to become an inventor.**

Intuitively, as long as genetics do not govern one's ability to invent an amplifier rather than an antenna in a gender-specific manner, the close alignment between the subfield in which children innovate and the type of innovation they were exposed to in their families or neighborhoods must be driven by causal exposure effects. Using our data sets, we can estimate that moving a child from a region that is at the 25th percentile of the distribution in terms of innovation (e.g., New Orleans) to the 75th percentile (e.g., Austin, TX) would increase his or her probability of becoming an inventor by at least 17% and as high as 50%.

These exposure effects are consistent with recent evidence

[3] Test scores in English have no predictive power conditional on test scores in math, suggesting that tests in early childhood are diagnostic of specific skills that matter for innovation.

[4] On the other hand, since children from different socioeconomic backgrounds are exposed to different environments even before they enter school, these calculations could overstate the portion of the gap in innovation that is due to differences in ability.

[5] We use the term "exposure to innovation" to mean having contact with someone in the innovation sector, e.g. through one's family or neighbors. We do not distinguish between the mechanisms through which such exposure matters, which could range from specific human capital accumulation to changes in aspirations.

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documenting neighborhood exposure effects on earnings, college attendance, and other outcomes (Chetty et al. 2016, Chetty and Hendren 2017). They point to mechanisms such as transmission of specific human capital, mentoring, or networks (e.g., through internships) that lead children to pursue certain career paths. As noted, children from low-income families, minorities, and women are less likely to have such exposure which helps explain why they have significantly lower rates of innovation overall. Considering gender alone, our estimates imply that if girls were as exposed to female inventors as boys are to male inventors in their childhood communities, the gender gap in innovation would be half its current size.

THE PATH TO INNOVATION PARITY

In the third part of our analysis, we examined inventors' careers after entering the labor market, with the aim of understanding how financial incentives affect individuals' decisions to become inventors. We found that the financial returns to innovation are highly skewed and highly correlated with their scientific impact – two key facts which (using a standard model of career choice) imply that small changes in financial incentives will not significantly affect aggregate innovation. In particular, the top 1% of inventors obtains more than 22% of total inventors' income, implying that the distribution of income among patent-holders is as skewed as the distribution of income in the population as a whole. Individuals with highly cited patents have much higher incomes, showing that the private benefits of innovation are correlated with their scientific impacts.[6]

How can we break the bad habits of innovation? We characterized the implications of our empirical findings for policies to increase innovation using a simple model of career choice in which three factors determine whether an individual pursues innovation: Financial incentives (Roy 1951); barriers to entry (Hsieh et al. 2016), and exposure to innovation, which is the new element we introduced given our empirical results. We modeled exposure as a binary variable: individuals not exposed to innovation never pursue it, while those who receive exposure decide whether to pursue innovation by maximizing expected lifetime utility.

Using this model, we offered three types of policies to increase innovation: Increasing exposure (e.g., through internships); reducing barriers to entry (e.g., by providing subsidies for certain subgroups), and increasing private financial returns (e.g., by cutting top income tax rates on inventors).

[6] We follow prior work (e.g., Jaffe et al. 1993) in using patent citations as a proxy for a patent's scientific impact. Although citations are an imperfect proxy for impact, they are well correlated with other measures of value, such as firm's profits and market valuations (Scherer et al. 2000, Hall et al. 2005, Abrams et al. 2013, Kogan et al. 2017).

Our research presented new evidence on the factors that determine who becomes an inventor by tracking the lives of recent American inventors from birth to adulthood. Most previous work on innovation has focused on factors such as financial incentives, barriers to entry, and STEM education.

As we described, our results point to a different channel-exposure to innovation during childhood-as a critical determining factor. It can help explain why high-ability children in low-income families, minorities, and women are significantly less likely to become inventors. Importantly, such lack of exposure screens out not just marginal inventors, but the "lost Einsteins"–those who might produce important innovations, if their ideas were realized. Policies that increase exposure, therefore, have the capacity to greatly increase quality-weighted aggregate innovation.

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In contrast, changes in financial incentives (e.g., via tax cuts) are less likely to spur additional star inventors to enter the field because the private financial returns to high-impact innovations are already quite large. Policies to increase exposure to innovation could range from mentoring by current inventors to internship programs at local companies.

Our analysis does not provide guidance on which specific programs are most effective, but it does offer guidance on how they should be targeted. In particular, targeting exposure programs to women, minorities, and children from low-income families who excel in math and science at early ages (e.g., as measured by performance on standardized tests) is likely to maximize their impact on innovation. Furthermore, tailoring programs to participants' backgrounds may increase their impact; for example, our findings suggest that women are more influenced by female inventors rather than male inventors.

More broadly, our findings suggest that policies designed to increase intergenerational mobility may also be beneficial for increasing economic growth. Drawing more low-income and minority children into science and innovation could increase their incomes-thereby reducing the persistence of inequality across generations-while stimulating growth by harnessing currently under-utilized talent.

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REPORT

The full working paper can be found here: http://www.nber.org/papers/w24062

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