Borrowing for Breakthroughs: Student Loans and Innovation*

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Abstract

We investigate the impact of higher education financing on innovation, focusing on how student loan policies shape the innovative potential of individuals. Leveraging a novel dataset linking administrative patent records to consumer credit data, we first document a variety of stylized facts about household finance and innovation, including event studies of credit scores around the time of patent filing and age-debt profiles of inventors relative to the general population. We then estimate the causal relationship between access to student loans and the likelihood of subsequent patenting. Our quasi-experimental design exploits changes in federal Stafford loan limits, finding that increased borrowing capacity leads to substantially higher rates of patenting among credit-constrained borrowers. Critically, effects are at least as large for highly-cited and top-quartile patents as for any patent, indicating that the innovation crowded out by financial barriers is not merely low-value—consistent with a "lost Einsteins" mechanism. Our preliminary estimates imply that roughly every $2.2 million in marginal first-year lending produces one additional inventor. The findings suggest that alleviating credit constraints through student loan policy generates significant social spillovers by enabling broader participation in innovation, and contribute to our understanding of education financing as a lever for sustaining long-run economic growth and reducing innovation disparities across socioeconomic groups.

JEL: I22, G51, J24, H52, O31

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"When it comes to technological innovation, we are rowing with one hand tied behind our back."
—Michelle K. Lee, former U.S. Under Secretary of Commerce for Intellectual Property, testimony before the House Judiciary Committee hearing "Lost Einsteins: Lack of Diversity in Patent Inventorship," March 2019

1 Introduction

Although economists have long viewed innovation as a key driver of economic growth, systemic barriers stifle the innovative potential of many talented Americans. The amount of innovation that leaks out of the pipeline is alarming: equalizing innovation rates across gender, race, and parent background could result in as much as four times as many inventors in the next generation (Bell et al., 2019a), which could increase long-run economic growth by 14% (Brouillette, 2025). Yet research has so far failed to shine light on particular programs or policies that can remedy these innovation gaps.

This paper contributes the first empirical investigation into whether higher education financing can be an effective policy lever to bring talented students back into the innovative ecosystem. Specifically, we focus our analysis on the role of student loan policy in shaping the innovation of subsequent generations. The linked dataset also allows us to document novel stylized facts about the household finance side of innovation.

Existing evidence and economic theory offer ambiguous predictions about how the generosity of student loan policy shapes innovation. On the one hand, student loan availability can increase access to higher education and allow students to focus more on education instead of working while in school (Black et al., 2023; Card and Solis, 2022). The positive "human capital" effect of student loans may increase students' future innovation. On the other hand, because innovation is often viewed as a risky career with potential payoffs accruing later in life (Bell et al., 2019a; Akcigit et al., 2017), the "debt overhang" channel may push students to pursue higher-paying and less risky careers (Field, 2009; Rothstein and Rouse, 2011; Krishnan and Wang, 2018).[1] This tendency of student loans to push students away from

[1]Contrary to the findings of this paper, prior literature has emphasized the effects of debt overhang in pushing students away from careers with social spillovers. For instance, Rosenblatt and Andrilla (2005) find that medical students are less likely to enter into primary care (with high public demand but low wages) if they hold student loans than medical students without student loans, though the effects are modest when

high-growth careers appears in several other studies (Minicozzi, 2005; de Gayardon et al., 2018; Gervais and Ziebarth, 2019; Daniels Jr. and Smythe, 2019; Black et al., 2023; Sauers, 2023).

To produce novel empirical evidence on how student loan policies shape innovation, we construct an unprecedented linked dataset. We combine four distinct data sources at the individual level: USPTO administrative patent records, consumer credit bureau records capturing complete financial histories, granular student loan origination and repayment data, and quarterly credit panel data spanning 2004 to 2021. The resulting dataset tracks nearly 250,000 US inventors—roughly a third of all inventors in the country—with complete credit histories covering the years before, during, and after their innovative activity. To our knowledge, no prior study has linked administrative patent records to individual-level credit bureau and student loan data at this scale. This linkage enables analyses that are simply impossible with any single source: we can observe how credit-market experiences early in life, including student loan borrowing, shape the probability of later becoming an inventor—and we can do so using identified variation in a federal policy rather than cross-sectional comparisons. While recent literature on higher-education financing has focused on labor market outcomes, our work is the first to exploit individual-level linked data to study effects on innovation, which is particularly valuable given its social spillovers.

We find that access to student loans substantially increases future innovation. Exploiting increases in federal Stafford loan borrowing limits in the late 2000s, and following the difference-in-differences instrumental variables design of Black et al. (2023), we compare students who were constrained by the pre-reform limit to their unconstrained peers across cohorts. Constrained students increased their borrowing when limits rose, and their patenting rose in turn: our IV estimates imply that an additional $1,000 of first-year borrowing raises future patenting by 0.45 inventors per 1,000 borrowers, a 74% increase relative to the sample mean. While large in percentage terms, this effect reflects a low base rate of

demographic characteristics are taken into account. This comports with the findings of Rothstein and Rouse (2011) relating to public-interest careers. Other studies have suggested that the psychology of debt matters a great deal in pushing students away from public interest careers: In an experiment at NYU's Law School studied by Field (2009), two career-contingent financial aid packages with equivalent monetary value were randomly assigned to students, and the negative psychological effects of student loans pervade into more than just initial job choice.

invention—in absolute terms, it amounts to roughly one additional inventor for every $2.2 million in marginal first-year lending. Critically, effects are at least as large for highly-cited and top-quartile patents as for any patent, indicating that the innovation crowded out by financial constraints is not merely low-value—consistent with the "lost Einsteins" hypothesis of Bell et al. (2019a).

Although little is known about direct impacts of student loans on innovation, the literature has established some evidence that student loans negatively impact entrepreneurship (Lammers, 2015; Checovich and Allison, 2017; Krishnan and Wang, 2018; Desai et al., 2020). While different from innovation, there is overlap in the skillsets and risk profiles, and starting a firm is often in practice a means of commercializing one's innovation. The entrepreneurship literature may lead one to expect a negative effect of student loan policy on innovation, although the outsized importance of access to higher education for innovation relative to for entrepreneurship may help to explain the apparently contradictory findings of this paper.

Our findings carry important implications for policy. While innovation is widely recognized as a cornerstone of economic growth, disparities in access to higher education continue to limit the innovative potential of many talented Americans. The evidence presented here—that relaxing credit constraints at the margin of student borrowing meaningfully increases future patent rates—suggests that education financing policy deserves a central place in discussions about how to broaden American participation in innovation, particularly among underrepresented groups.

The remainder of the paper is organized as follows. Section 2 provides background on U.S. student loan programs and the policy changes we exploit. Section 3 describes our novel linked dataset connecting patent and credit bureau records. In Section 4, we document new descriptive facts on the relationship between household finance and innovation. Section 5 outlines our empirical strategy, and Section 6 presents our main causal estimates of how increased student loan access affects patenting. Section 7 concludes with a discussion of policy implications and directions for future research.

2 Student Loans in the US

Over the last two decades, student loans have become an increasingly prominent form of debt for many individuals in the U.S. As shown in Figure A1, aggregate student loan debt balances in the U.S. rose from $240 billion in 2003 to $1.6 trillion in 2024 (nominal dollars). During this period, student loans became the third largest category of debt behind mortgages ($12.6 trillion) and auto loans ($1.6 trillion).[2] In terms of aid to access education, student loans are a significant form of aid to undergraduates. Almost 40% of full-time undergraduate students were awarded some form of federal student loan in 2020 (National Center for Education Statistics, 2023). The federal government primarily makes student loans available to borrowers.[3]

For decades, the bulk of federal student loan programs were provided under the Stafford Loan program. Stafford Loans are loans made available by the United States federal government to students attending accredited higher-education institutions. For undergraduates, borrowers may access loans up to a specific dollar amount based on their dependent status and their years of enrollment. Undergraduate students may be eligible for either subsidized or unsubsidized loans based on financial eligibility determined by the Free Application for Financial Student Aid (FAFSA). Subsidized loans do not accrue interest while students maintain an enrollment status of at least half-time. In addition, from 2008 to 2013, subsidized loans had a slightly lower interest rate.

The Stafford Loans borrowing limit experienced two significant increases in the last two decades. The Higher Education Reconciliation Act of 2005 raised borrowing limits from $2,625 to $3,500 and $3,500 to $4,500 for first-year and second-year students, respectively. These new limits went into effect for the 2007-2008 academic year, which began on July 1, 2007. The Ensuring Continued Access to Student Loans Act of 2008 increased borrowing limits for the 2008-2009 academic year. First-year borrowing limits increased from $3,500 to $5,500, second-year limits increased from $4,500 to $7,500, and finally third-, fourth- and fifth-year students' limits increased from $5,500 to $7,500. Table 1 summarizes these changes

[2]See Center for Microeconomic Data (2024) for additional details.

[3]Ma et al. (2024) estimates federal student loan lending comprises between 75% and 93% of all education borrowing each year with non-federal student loan amounts coming from states, post-secondary institutions and private markets.

for each academic cohort by enrollment year. The Stafford Loan program stopped offering loans for the 2010-11 academic year and was replaced by the Federal Direct Loan Program, which preserved the limits established by the Ensuring Continued Access to Student Loans Act of 2008.

Table 1: Loan limits by entry cohort and academic level

	Academic level (year in school)					
Entry cohort	1st	2nd	3rd	4th/5th	Total	Relative
2004-05 and earlier	$2,625	$3,500	$5,500	$5,500	$17,125	-
2005-06	$2,625	$3,500	$5,500	$7,500	$19,125	$2,000
2006-07	$2,625	$4,500	$7,500	$7,500	$22,125	$5,000
2007-08	$3,500	$6,500	$7,500	$7,500	$25,000	$7,875
2008-09 and later	$5,500	$6,500	$7,500	$7,500	$27,000	$9,875

Notes: This table shows the Stafford Loan borrowing limits for dependent undergraduate student loan borrowers by entry cohort and academic level. Column (6) shows the aggregate loan amount available to borrow for each entry cohort over the course of their four years of enrollment. Column (7) shows the cumulative amount in Column (6) relative to the 2004-05 entry cohort. The entry cohort "2004-05 and earlier" applies to cohorts from 2001-02 to 2004-05. Stafford Loan limits were different for cohorts before the 1995-96 academic year, but our sample begins with cohorts in 2001-02. Source: Federal Student Aid (2006, 2007, 2008)

3 Data

Our main source of data on student loans comes from the University of California Consumer Credit Panel (UC-CCP). The UC-CCP consists of quarterly loan-level credit records from an anonymized longitudinal panel of over 70 million individuals. As described in Section 2, borrowing limits vary by an individual's enrollment year and academic level. However, while the UC-CCP contains detailed information on individual loans, it does not contain education enrollment information of borrowers. In order to identify the first-year of enrollment of borrowers, we assume the first year of enrollment coincides with the first year of borrowing. More specifically, we define a borrower's academic year of enrollment if they first took out a loan during that academic year. For example, if a borrower's first education loan originated on September 24, 2004, then their enrollment year is defined as 2004-05 since that origination date falls within July 1st, 2004 and June 30th, 2005. One limitation of the UC-CCP is that the panel only begins in 2004. However, since the UC-CCP contains information on the

origination date and the origination amount, this allows us to construct a panel of student loan borrowing that extends back before 2004, covering our earliest entry cohorts.

The credit dataset consists of loan-level credit records from a consumer credit bureau totaling 60 million individuals each quarter from 2004 to 2021. The data include a complete sample of every individual with a credit record in California and a 2 percent random sample of individuals with a credit record in the U.S. For a complete picture of household borrowing, the dataset also includes the credit records of all household members and associated borrowers (e.g., co-signers or joint-account holders) of each individual sampled. Even after an individual leaves California, the credit panel continues to observe the credit records of the individual along with their household members and associated borrowers. In other words, an inventor does not necessarily need to live in California at time of invention to be in the 100 percent California sample if the inventor lived or studied in California in an earlier year. For instance, a student who studied in California in 2004 but has lived in Texas since would remain in the UC-CCP for each year since moving out of CA. While our paper has a national scope, we see the 100 percent coverage of California as a strength on top of the 2 percent national sample. In particular, California is the most useful state to over-sample because although it only accounts for 12 percent of the U.S. population, we find that it accounts for nearly one quarter of all U.S. patents, which is far higher than any other state.

A patent is an exclusive right granted by the government to an inventor for a product or process. Most but not all patents are assigned to firms by their inventors, and the term is generally 20 years from the filing date. The United States Patent and Trademark Office (USPTO) is the entity responsible for evaluating and approving patent applications in the U.S. In 2020, the USPTO received 646,244 applications and issued 388,900 patents.

An example of one such granted patent is shown in Figure A2, which helps convey the richness of the data available. Data on inventors and their patents are sourced directly from the USPTO. This dataset is built from administrative records first made public in response to the Obama administration's Open Government Initiative; we use the Patent Examination Research Dataset (PatEx) dataset produced by Graham et al. (2018), which contains two types of documents. First, it contains all patents granted since approximately 1980. Second, it contains most patent applications that were filed—regardless of whether

they were granted—since the passage of the American Inventors Protection Act (AIPA) heavily incentivized application publication beginning in late 2000. We define an individual as an inventor if they are listed as an inventor on a patent grant or application during the timeframe for which we observe individuals in the UC-CCP, which runs from 2004 to present. Following Bell et al. (2019a), we include all individuals listed as inventors, not just those assigned intellectual property rights. In particular, inventors employed by firms are listed as inventors while their firms are listed as assignees.

Our main approach to measuring patent value is the number of citations a patent has received from future patents. Because more recent patents have mechanically had less time with which to accumulate citations, we define a citation-based ranking relative to other patents granted in the same year. Though still not a perfect measure of quality, Bell et al. (2019a) have established that inventors of higher-cited patents earn more than inventors of patents with fewer citations, suggesting that citations may be a reasonable proxy of quality. Griliches (1990) points out that there is good empirical support to view patents as a proxy for innovation because a very robust relationship exists across firms between expenditures on R&D and patent output. Still, many important innovations are not patented (or patentable), and many patents do not correspond to real innovation. A natural direction for future work is to assess robustness to alternative, citation-based measures of patent quality. Prior work by Hall et al. (2005) linking patent records to Compustat has established that firms with more highly cited patents have higher stock market valuations, and citation-weighting may also help down-weight so-called "defensive" patents that add less value to society.

For every student loan borrower in the credit data, we observe detailed information on each of their loans. Variables include the loan origination date, original loan amount, remaining balance, and scheduled payment amount for every quarter that the loan provider reported information to the credit bureau. In addition, even loans that have been closed will remain in the credit bureau data for up to seven years. We also have limited information on the characteristics of the borrowers. For each borrower, the dataset includes birth year and month, household composition, ZIP Code, and Census Block.

There are two key limitations to the credit panel data. First, the data do not contain high-quality self-reports of individuals' race and ethnicity. We therefore rely on imputed

demographic variables available from the credit bureau, along with individual-level race and gender imputations derived from names in the patent records. Second, not all people have credit records: an analysis by Brevoort et al. (2016) suggests as many as 26 million adult Americans may be lacking credit reports, and this population of so-called "credit invisibles" is concentrated among the young or elderly, racial minorities, and low-income consumers. We expect the incidence of credit invisibles among both student loan holders and inventors to be low. Thus, the issue of absence of credit reports is unlikely to significantly impact our record linkage rate and analysis. Despite these caveats, we believe the lack of alternative data sources and the importance of the research question justify this approach, and we note throughout where our methodologies are designed to mitigate the impact of these limitations.

4 Descriptive Results

Given the novelty of our linked dataset, we highlight several stylized facts about credit histories and student loan usage among inventors.

Table 2 summarizes the data. Applying imputation methods for race and gender, we find that 88% of our linked inventor sample is White or Asian (relative to 60% of the general CA population) and 17.5% are women. These roughly align with already existing estimates of the demographic backgrounds of inventors (Bell et al., 2019a).

Table 2: Descriptive Statistics

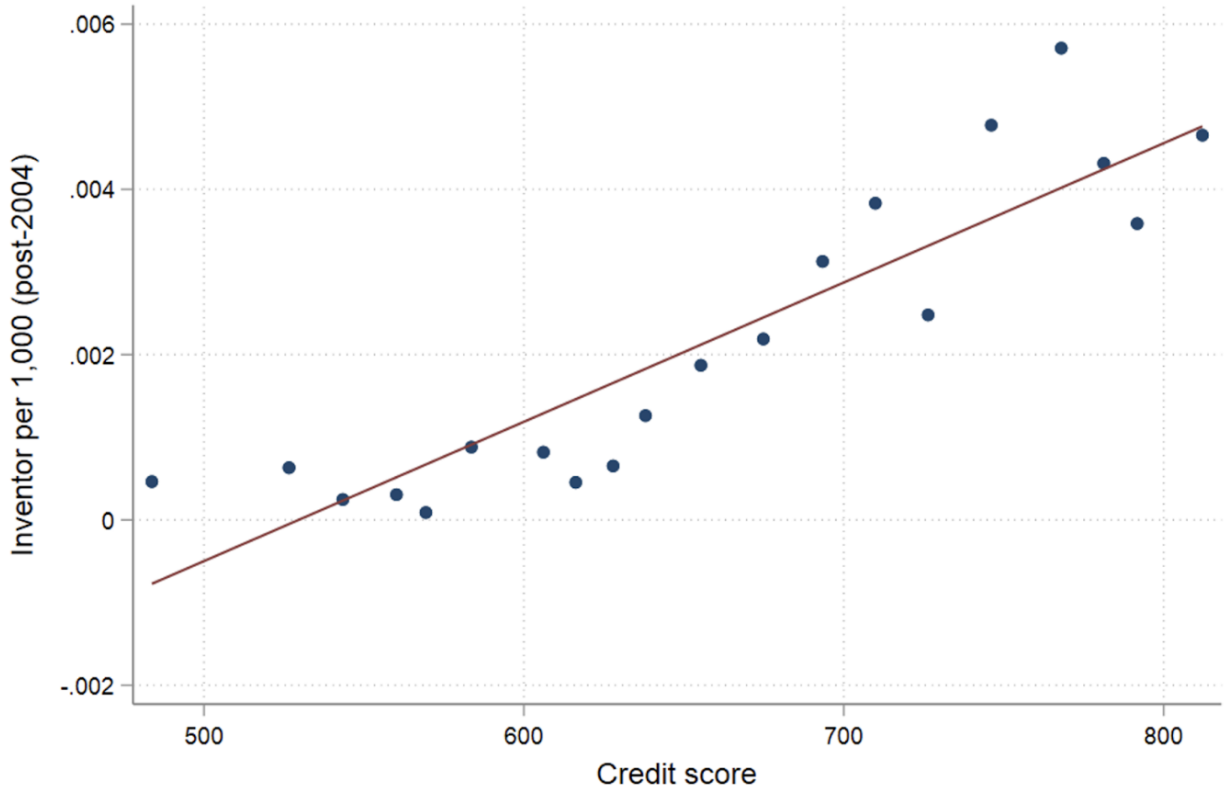
	Inventor	Non-inventor
BISG Race Probability		
White	0.611348	0.448608
Black	0.030516	0.069227
Latino	0.074786	0.320737
Asian Pacific Islander	0.257257	0.13684
Female	0.175	0.466
Credit score	761	677
Share with student loans	0.066	0.111
Amount of student loans ($)	2,544	3,707

Notes: Variables measured in most recent year available.

Figure 1 shows how the likelihood of filing a patent varies with credit scores at the start

of the sample. We find that inventors' credit histories are quite good: People with credit scores in the top 10% of the distribution are ten times as likely to invent as those with below-median credit scores.

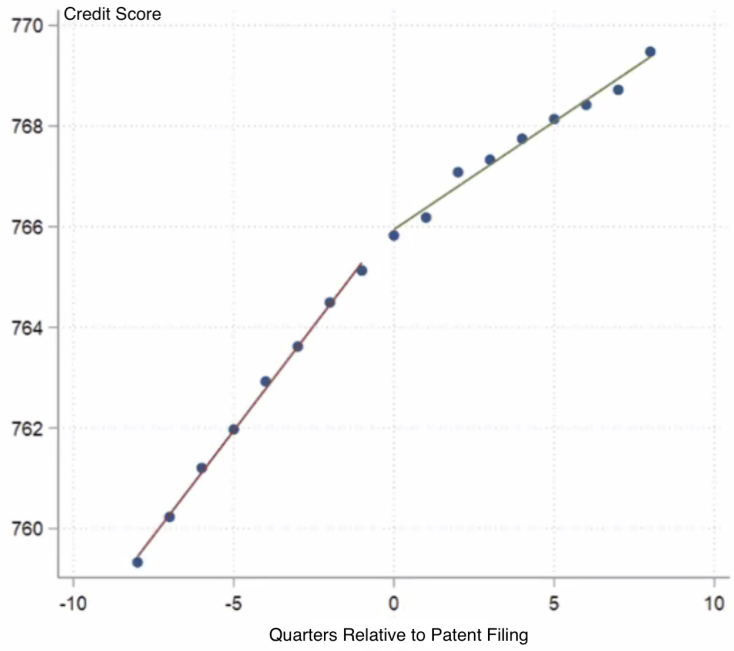
Figure 1: Innovation Rates by Credit Score



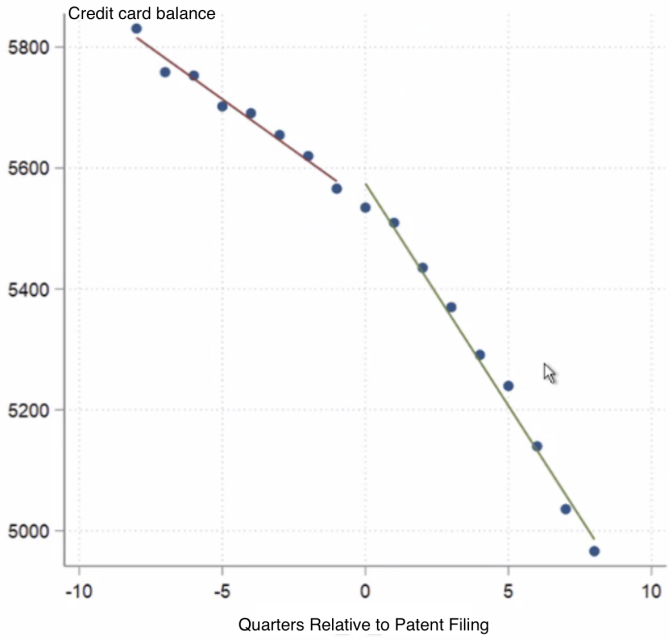
Notes: This figure plots innovation rates (per 1,000) by credit score in 2004.

We do not find obvious evidence of large private returns to innovation for the average invention. Panel A of the event studies in Figure 2 shows that around the time of innovation credit scores are increasing, but if anything increase somewhat more slowly after the time of innovation. Panel B shows a similar analysis for credit card usage, which we view as a rough proxy for consumption. If anything, credit card usage also exhibits a decline relative to trend following an innovation. These findings are consistent with other recent work that has sought to identify the private returns to innovation, which have suggested that the private rents accruing to individual inventors are likely on average small (Depalo and Di Addario, 2014; Bell et al., 2019b; Kline et al., 2019).

Figure 2: Event Studies Around Patenting



(a) Credit score



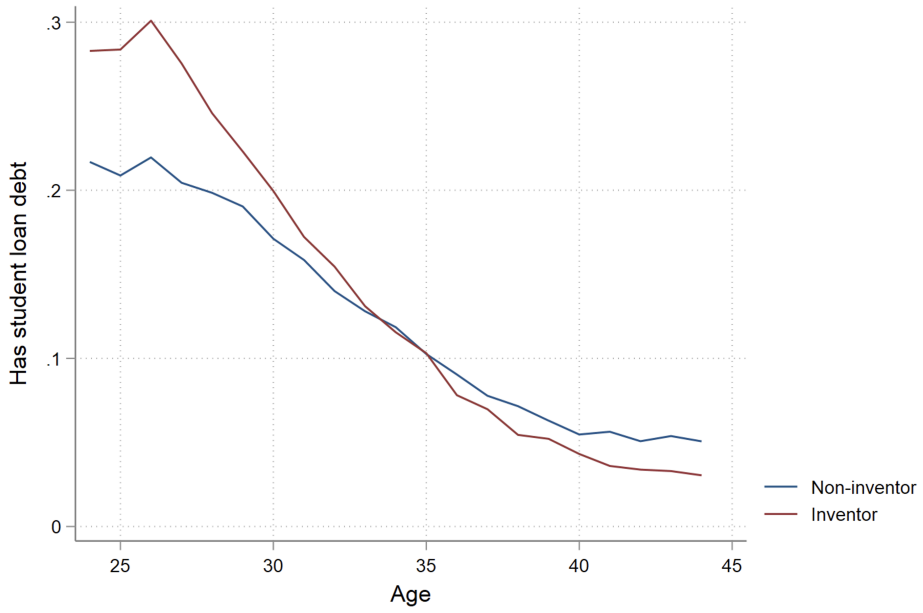
(b) Credit Card Balance Amount

Notes: Panel (a) shows credit scores around the time of innovation. Panel (b) shows a similar analysis for credit card usage. For individuals with more than one patent in the sample frame, we choose a random one as the event.

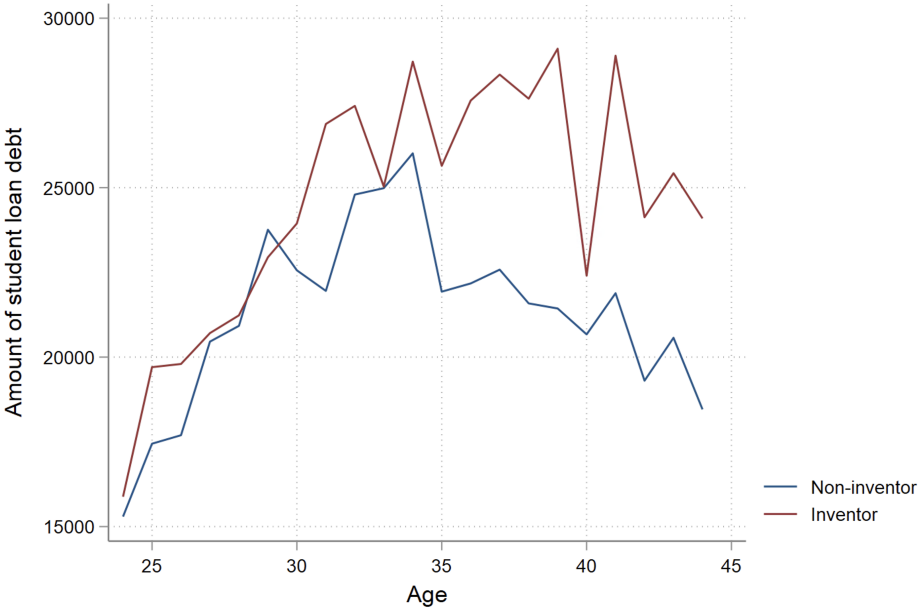
Figure 3 investigates how student loan amounts accrue to inventors over the lifecycle. During their early 20s, inventors accumulate substantially more student loan debt than most

people, but also pay off the debt more quickly; by age 40, inventors are actually substantially less likely to hold any student loan debt than their peers.

Figure 3: Student Debt Over the Lifecycle



(a) Share of Observations with Any Student Loans



(b) Amount of Student Loan Debt

Notes: Panel (a) plots the share of individuals in the credit panel that have student loans by age, separately by whether the individual has filed a patent or not. Panel (b) plots the amount of loans, among those that have any loans. Age and student loans are both measured in 2004, and inventor status is aggregated over all years since 2004.

5 Empirical Framework

Following Black et al. (2023), we identify the causal effect of student loan borrowing by comparing borrowers constrained versus not by the Stafford Loan limit before and after the expansion to borrowing limits.[4] This empirical strategy relies on the identifying assumption that the difference between constrained and unconstrained students would be similar across cohorts if limits did not expand. We use the following event-study specification to examine the similarity of cohorts before and after the policy change, where we interpret the post-policy period as the causal effect of increasing student loan limits on borrowers.

$$y_{ic} = \beta_0 + \beta_1 Constrained_i + \sum_{j \neq 2005} \beta_c Constrained_i \times \mathbf{1}\{j = c\} + \delta_c + \varepsilon_{ic} \tag{1}$$

where y_{ic} refers to the dependent variable of interest for individual i in cohort c. Our sample consists of cohorts from academic year 2001-02 ($c = 2002$) through 2012-13 ($c = 2013$).

The coefficients of interest for the event graph specification in Equation 1 are on the interaction terms, $\beta_c Constrained_i \times \mathbf{1}\{j = c\}$. Finally, we include cohort fixed effects denoted δ_c.

Our main regression specification takes the following form:

$$y_{ic} = \alpha + \beta_1 Constrained_i + \beta_2 Constrained_i \times \mathbf{1}\{c > 2005\} + \delta_c + \varepsilon_{ic} \tag{2}$$

where δ_c corresponds to cohort fixed effects for $c \in [2002, 2013]$. For cohorts before 2006, borrowers are considered constrained if they borrowed exactly the Stafford borrowing limit. For cohorts 2006 and onward, they are considered constrained if they borrowed between the original Stafford loan limit and the Stafford borrowing limit for their relevant cohort.[5] See Table 1 for additional details on Stafford borrowing limits.

In order to make the magnitude of the causal effect of student loan debt comparable to existing studies, we follow the approach outlined in Black et al. (2023) where we instrument

[4] This design has subsequently been applied in other work, including by Sauers (2023).

[5] The variable $Constrained_i$ is an indicator that equals 1 for borrowers in cohorts through academic year 2006-07 ($c \leq 2007$) who borrowed exactly $\$2,625$; for borrowers in the 2007-08 cohort ($c = 2008$) who borrowed between $\$2,625$ and $\$3,500$; and for borrowers in cohorts from academic year 2008-09 onward ($c \geq 2009$) who borrowed between $\$2,625$ and $\$5,500$.

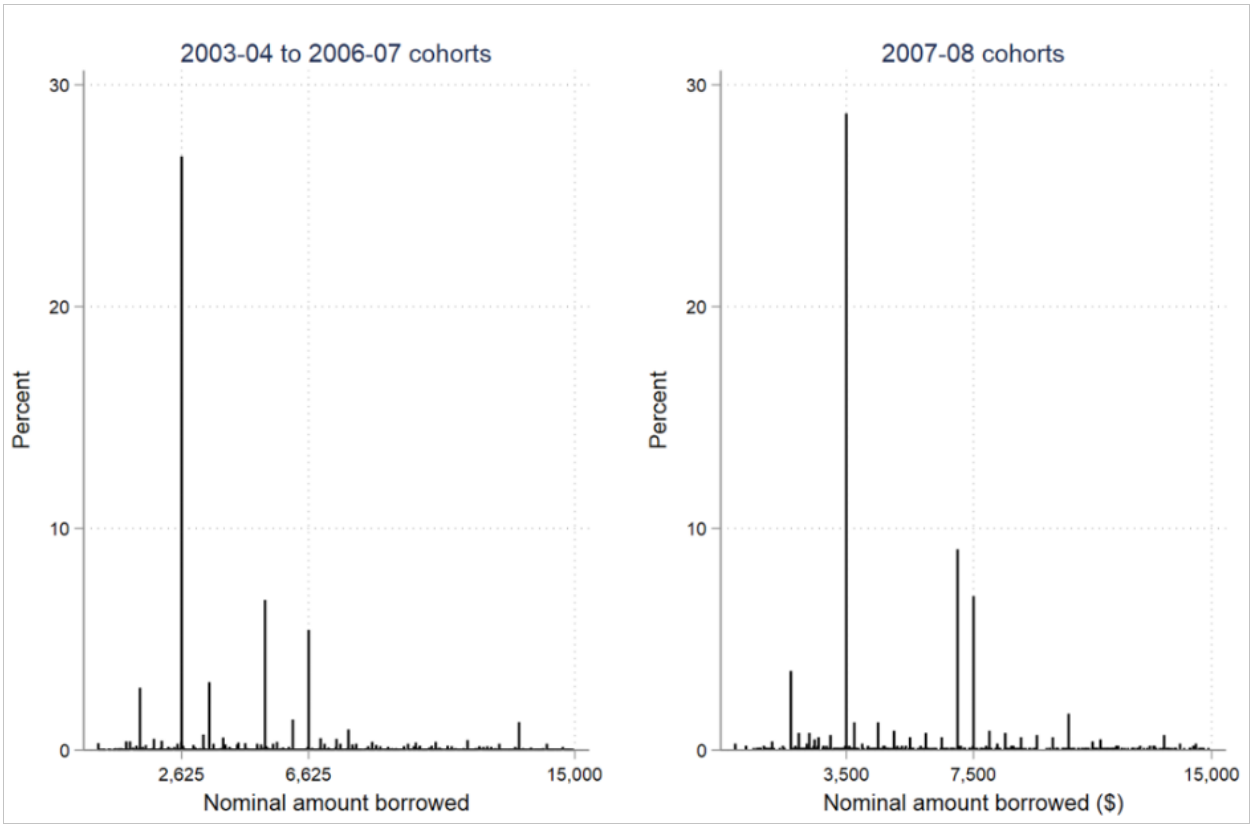
student loan borrowing with the interaction of being constrained and an indicator for affected cohorts. More specifically, we estimate the following system using two-stage least squares:

$$\begin{aligned} y_{ic} &= \beta_0 + \beta_1 Constrained_i + \beta_2 Loans_{ic} + \delta_c + \varepsilon_{ic} \\ Loans_{ic} &= \gamma_0 + \gamma_1 Constrained_i + \gamma_2 Constrained_i \times \mathbf{1}\{c > 2005\} + \delta_c + \eta_{ic} \end{aligned} \tag{3}$$

6 Causal Estimates

As described in Section 2, the statutory borrowing limit rose for students in the academic cohorts of 2007-08 (denoted as 2008). Figure 4 shows the distribution of loans for earlier cohorts versus the 2007-08 cohort. For both sets of cohorts, we observe bunching at the dependent individual Stafford loan limit, which we exploit for this paper. For the earlier cohorts, the bunching point occurred at \$2,625, whereas the mass shifted to \$3,500 after the loan limit was raised.

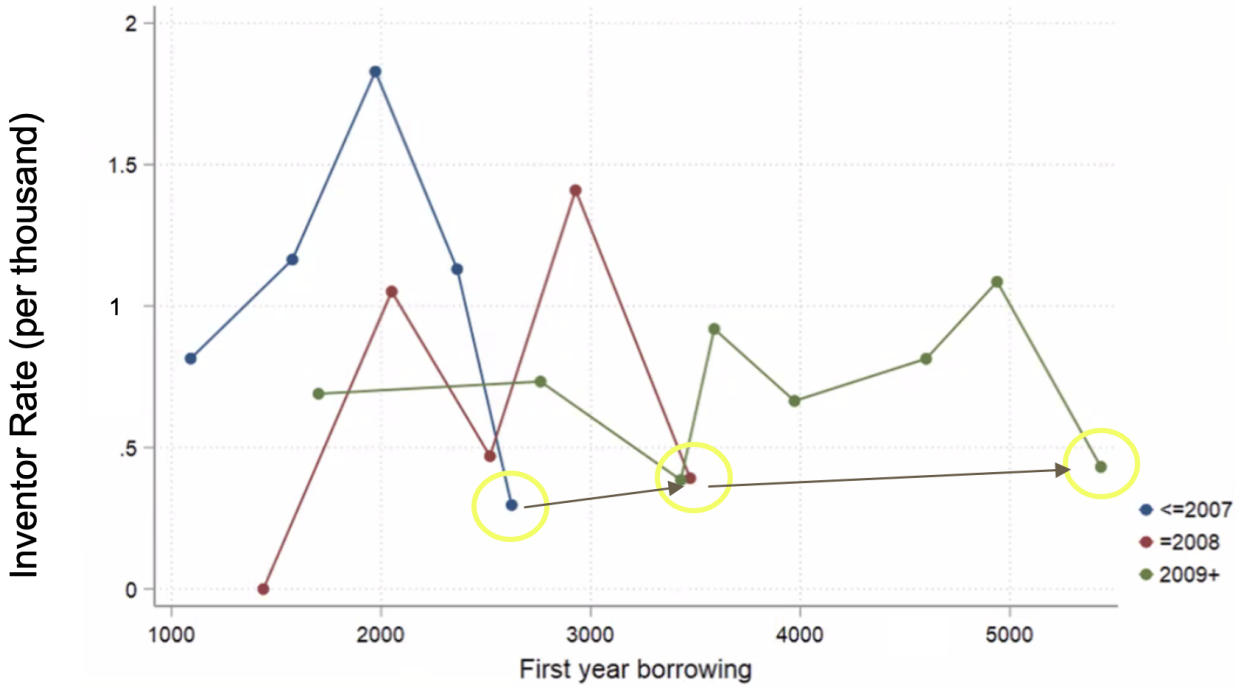
Figure 4: Bunching Response to Policy Change



Notes: This figure shows student loan borrowing during first year of college (i.e., the year in which person is observed to have student loans). Source: Authors' calculations based on the UC-CCP. For the earlier cohorts, the individual dependent Stafford loan limit was $2,625 and the non-dependent limit was $6,625. For the 2007-08 cohort, the dependent limit was changed to $3,500 and the non-dependent limit was changed to $7,500.

To provide graphical intuition of how innovation rates varied for these cohorts, Figure 5 plots innovation rates by student loan amounts, separately by cohort. As constraints became higher in subsequent cohorts, innovation rates among the constrained students increased. While this analysis abstracts from important confounders like overall cohort effects, it provides visual intuition for how the lifting of the constraints can be used to identify the positive effects of access to higher education financing on future innovation.

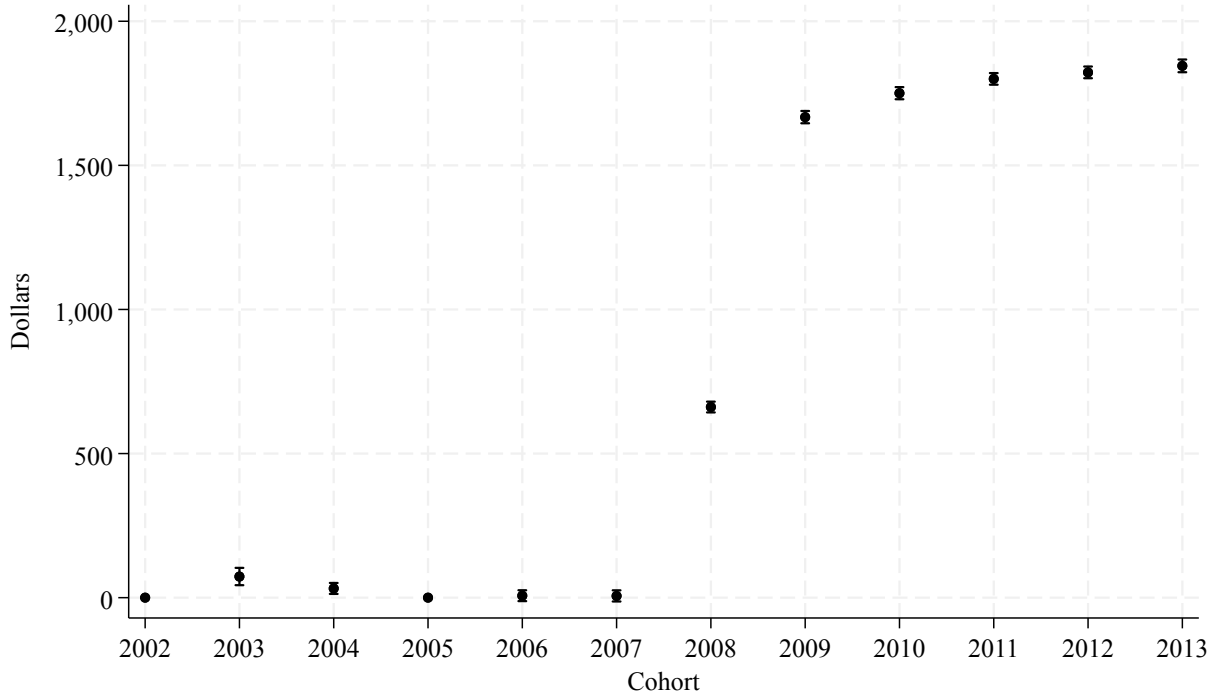
Figure 5: Innovation Rates by First Year Borrowing, by Policy Regime



Notes: This figure shows innovation rates per thousand individuals based on the amount the individual borrowed in their first year of college. For cohorts prior to 2007, the borrowing limit was $2,625, which was raised for the 2008 cohort to $3,500 and for subsequent cohorts to $5,500.

Figure 6 shows how much constrained borrowers actually borrowed additionally relative to unconstrained borrowers in their respective cohorts. Prior to the policy change, the difference within cohorts in borrowing between constrained and unconstrained borrowers remained fairly similar to the academic cohorts of 2004-05 (denoted as 2005). There is no confidence interval for 2005 because that cohort is normalized as the base year. The estimated effect increases by roughly $680 for the 2007-08 cohort, who experienced an increase of $875 in their borrowing limit, and increases by more than $1,700 over the later cohorts, who experienced an increase of $2,500 in their borrowing limit relative to the 2004-05 cohort. The increase in actual amounts borrowed is less than the increase in the limit because not all students borrow at the new limit.

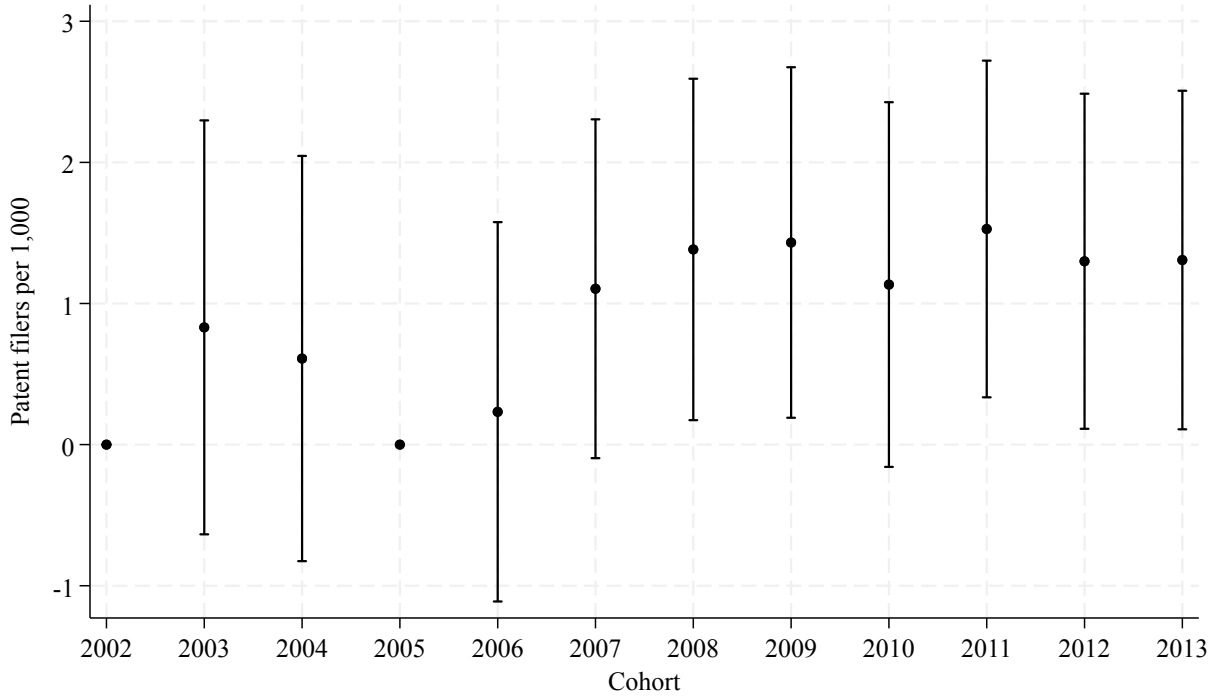
Figure 6: First-Stage Effect of Loan Limits on Borrowing



Notes: Estimated coefficients from the event-study regression specification described in Equation 1 where the dependent variable is first-year borrowing.

Figure 7 shows a significant increase in patenting among constrained borrowers after the policy change, indicating a clear positive link between loan access and innovation. Constrained borrowers relative to unconstrained borrowers in their respective cohorts after the policy change were more likely to file patents. Prior to the policy change, the difference within cohorts in borrowing between constrained and unconstrained borrowers remained fairly similar to the academic cohorts of 2004-05 (denoted as 2005). The estimated effect increases by roughly 1 patent filer per 1,000 individuals in the 2007-08 cohort and onward.

Figure 7: Reduced-Form Effect of Loan Limits on Innovation



Notes: Estimated coefficients from the event-study regression specification described in Equation 1 where the dependent variable is patent filers per 1,000 individuals.

Table 3 presents OLS and IV estimates that are helpful for interpreting magnitudes. Columns 1-3 present the naïve OLS specifications, with a varying set of controls. In column 1, without any instrumental variation, we find no significant relationship between amount of loans and future patenting rates. While not significant, here student loan debt is associated with slightly lower future patent rates: $1,000 of first-year borrowing is associated with .044 fewer inventors per thousand (6.7% of the mean innovation rate). Column 2 adds a control for whether the student was constrained (coefficient not displayed), and Column 3 additionally adds cohort fixed effects. While it is clear that innovation rates are lower among constrained students than unconstrained students, there remains no significant relationship between first-year borrowing and future innovation rates.

Table 3: Regression Specifications

Outcome: inventors per 1,000 Mean of outcome: 0.613				
	OLS (1)	OLS (2)	OLS (3)	IV (4)
First Year Borrowing ($1,000s)	-0.0440 (0.0341)	0.0339 (0.0398)	0.0267 (0.0515)	0.454** (0.152)
Cohort Fixed effects	No	No	Yes	Yes

Notes: Regression specification from Equation 3. The outcome is patent filers per 1,000 individuals. Columns 2, 3, and 4 include controls for whether the student is constrained.
Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Our IV results are presented in Column 4 of Table 3. As in the prior columns, this specification regresses innovation rates on first-year borrowing, but in this specification first-year borrowing is instrumented by time variation in student loan limits. The IV coefficient implies that $1,000 of student debt leads to .454 more inventors per 1,000 students (with a lower bound of .16). Given the base rate of innovation in the sample, the IV estimate suggests $1,000 more loans leads to approximately a 74% increase in innovation rates (lower bound of 26%). Stated differently, roughly every $2.2 million of marginal first-year lending produces one additional inventor.[6] These results suggest that the social spillovers from lifting credit constraints at the margin may be quite large.

6.1 Are the Marginal Innovations Important?

A natural concern with our findings is that the patents induced by expanded loan access may be of low quality—incremental filings that do not represent genuine technological advances. If credit-constrained students disproportionately lack the scientific training or institutional resources to produce high-impact work, then lifting their borrowing limits might simply lower the average quality of the patent pool without generating meaningful social returns. On this

[6]One additional inventor requires $1{,}000/0.454 \approx 2{,}200$ constrained students to each borrow an additional $1,000, or approximately $2.2 million in additional loan volume. This figure is preliminary: it scales by first-year borrowing, our endogenous variable, while the policy changes also raised limits in subsequent years of enrollment. Ongoing data work incorporating cumulative undergraduate borrowing will raise the dollars-per-inventor figure, plausibly by a factor of two to three based on the cumulative borrowing responses reported by Black et al. (2023).

view, the welfare case for expanded student loan access would be considerably weaker than the aggregate patent counts suggest.

Table 4 directly tests this concern. We re-estimate Equation 3 using progressively more demanding patent quality thresholds: any patent, any patent with at least one subsequent citation, patents in the top quartile of the within-year citation distribution, and patents in the top 5%. If the induced innovations were primarily low-value filings, we would expect the percentage impact to shrink as the quality threshold rises.

Table 4: Testing the Lost Einsteins Hypothesis for Financial Constraints

	Outcome: Patent Filers per 1,000			
	Any Patent (1)	Cited Patent (2)	Top Quartile (3)	Top 5% (4)
First Year Borrowing ($1,000s)	0.454**	0.330**	0.176*	0.0313
	(0.152)	(0.115)	(0.0697)	(0.0262)
1[Constrained]	−1.169***	−0.734**	−0.315*	−0.0365
	(0.318)	(0.242)	(0.146)	(0.0625)
Cohort Fixed Effects	Yes	Yes	Yes	Yes
Mean of outcome	0.612	0.390	0.193	0.0349
% impact of $1,000 more loans	74%**	85%**	91%*	90%
95% CI for % impact	(26%, 123%)	(27%, 142%)	(20%, 162%)	(−57%, 237%)

Notes: Each column re-estimates the IV specification from Equation 3 using a progressively more selective patent quality threshold as the outcome. Column (1) replicates the main result (any patent filer). Column (2) restricts to patents with at least one subsequent citation. Column (3) restricts to patents in the top quartile of the within-year citation distribution. Column (4) restricts to patents in the top 5%. The % impact row reports the IV coefficient scaled by $1,000 and divided by the mean, expressed as a percentage. Cohort fixed effects included throughout.
Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The results run counter to this concern. The estimated percentage impact of $1,000 in additional loans is at least as large at higher quality thresholds: 74% for any patent, 85% for cited patents, and 91% for top-quartile patents. Confidence intervals overlap throughout, so these differences in point estimates should not be over-interpreted; the pattern is consistent with marginal innovations being drawn from a quality distribution comparable to that of inframarginal patents, and inconsistent with the low-quality substitution story. The estimate at the top 5% threshold is imprecise and statistically indistinguishable from both zero and the pooled effect; the data are too thin at that extreme tail to be informative.

This pattern aligns naturally with the "lost Einsteins" hypothesis of Bell et al. (2019a), who document that many high-potential inventors never patent due to socioeconomic barriers encountered early in life. Our findings suggest that financial constraints on higher education are one such barrier, and that the innovation crowded out is not concentrated among low-value work. One economic mechanism consistent with these findings is that the human capital investments enabled by student loans—additional years of schooling, graduate training, exposure to research environments—are themselves complementary to producing high-quality innovation. Students who are most credit-constrained may have the greatest unmet demand for this type of training, so that easing their constraints enables not just more innovation but better innovation.

Appendix Tables A1–A3 examine whether the effects are concentrated in particular demographic groups or technology fields. Positive point estimates appear across all racial groups examined (White, Black, Hispanic, and Asian inventors) and across all six major technology categories, with the only statistically significant category-level estimate in Mechanical patents (106%). The absence of any demographic or technological pocket in which effects are clearly negative is itself informative: it provides no basis for concluding that the mechanism is peculiar to a narrow slice of the inventor population. Taken together, the heterogeneity results support the generality of the mechanism—expanded loan access appears to unlock innovation potential across a broad cross-section of students and fields, rather than benefiting a specific subgroup.

It bears emphasis that this IV estimate should be interpreted as a Local Average Treatment Effect (LATE): it captures the impact of additional loan access specifically for students who were genuinely constrained by the pre-reform borrowing limit—those who had borrowed up to the statutory cap and would have borrowed more had the limit been higher. This population is not representative of all student borrowers; by definition, they are students whose demand for financing exceeded what policy allowed. The implied effects for the broader population of borrowers—many of whom would not have changed their behavior under the higher limit—would be considerably smaller. Our results are therefore best understood as evidence that lifting binding credit constraints can generate large returns for the marginal student, rather than as a prediction of aggregate innovation gains from uniform increases in

loan access.

7 Conclusion

This paper contributes a novel large-scale linkage of administrative patent records with comprehensive consumer credit records, and uses it to measure the causal effect of access to higher education financing on subsequent innovation.

A priori, theory offered ambiguous predictions. While debt overhang might push students away from innovative careers—which tend to offer risky payoffs that are not fully captured by the individual—our results suggest that the human capital channel dominates. The evidence is more consistent with a story in which increased access to higher education financing opens pathways to further schooling, with downstream benefits for innovation. One reason students' interest in innovation may be less deterred by debt than prior literature would predict is the optimistic beliefs documented among students in science and technology careers (Ganguli et al., 2022).

A key question is whether the innovations crowded out by financial constraints are genuinely important or merely marginal. Using citation-based measures of patent quality, we find that the percentage impact of expanded loan access is at least as large for highly-cited and top-quartile patents as for any patent—indicating that the innovation suppressed by credit constraints is not disproportionately low-value, consistent with the "lost Einsteins" hypothesis of Bell et al. (2019a). Heterogeneity analysis by gender, race, and technology category yields imprecisely estimated but suggestive patterns, with the largest point estimates among men and Asian inventors; differences across subgroups are not statistically significant.

These magnitudes speak directly to the broader portfolio of innovation policy. Our preliminary estimates imply that roughly $2.2 million of marginal first-year student lending produces one additional inventor; because the policy changes also expanded borrowing capacity in subsequent years of enrollment, ongoing data work incorporating cumulative borrowing will raise this figure. Two features distinguish this margin from conventional innovation policies. First, because student loans are repaid, the fiscal cost of this lending is not its face value but only its subsidy component—in-school interest subsidies, defaults, and any

eventual forgiveness. Second, the LATE interpretation implies that this is the price at the current margin: it applies to the finite population of borrowing-constrained students rather than to an arbitrarily scalable program. With these caveats, the cost per inventor implied by our estimates provides a benchmark for policymakers weighing the composition of public investment in innovation. For comparison, Azoulay et al. (2019) estimate that a $10 million boost in NIH grant funding leads to a net increase of 2.7 private-sector patents. Under the conservative assumptions that the government treats loan face value as a pure expense and values only patent output, indifference between the marginal dollar of research funding and the marginal dollar of student lending would require roughly 0.6 granted patents per marginal inventor.[7] Because every marginal inventor in our data files at least one patent application, and roughly half to two-thirds of applications are ultimately granted (Carley et al., 2015), even the most conservative assumption—a single lifetime application per marginal inventor—places the two policies near parity under first-year scaling. Cumulative scaling of the lending figure would shift the comparison toward research funding, while subsequent patenting by marginal inventors and loan repayment shift it toward education financing; we expect the two policies to remain within the same order of magnitude.

Of course, patents are an incomplete metric for either policy. Research funding generates scientific knowledge, training, and local economic activity beyond patenting, just as education financing shapes earnings, occupational choice, and much else beyond invention. A full accounting of either policy is beyond the scope of this paper. Our contribution is to quantify a previously unmeasured input into that accounting: the innovation return to marginal education lending, which proves comparable to that of direct research funding.

Several directions present themselves for future research. One productive area is to investigate mechanisms more directly: while the data do not allow us to observe educational attainment, future work could examine whether expanded loan access raises degree completion, graduate enrollment, or participation in the kind of undergraduate research experiences shown to cultivate inventive human capital (Ganguli and Murciano-Goroff, 2025; Shu, 2012). Examining geographic heterogeneity would further illuminate whether effects are

[7] At 2.7 patents per $10 million, NIH funding yields 0.27 patents per $1 million. Marginal lending yields one inventor per $2.2 million, or 0.455 inventors per $1 million. Indifference requires $0.27/0.455 \approx 0.6$ patents per marginal inventor.

concentrated in high-innovation regions. Finally, a growing literature has shown that who invents shapes what gets invented (Koning et al., 2021; Einiö et al., 2023; Burrage et al., 2022); examining whether the inventors brought into the pipeline by expanded loan access tend to innovate in distinct technological domains could shed light on the broader societal consequences of these policies.

The core finding of this paper is that marginal increases in access to education financing can meaningfully expand participation in American innovation. Easing the credit constraints that bind the most financially limited students—precisely those for whom expanded access to higher education may be most transformative—appears to generate social spillovers that extend well beyond the individual students who benefit directly. This evidence suggests that ongoing policy efforts to reduce barriers to student borrowing, such as expanding Pell grants or streamlining FAFSA, may carry positive externalities for long-run innovation and economic growth.

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8 Appendix

8.1 Supplementary Figures

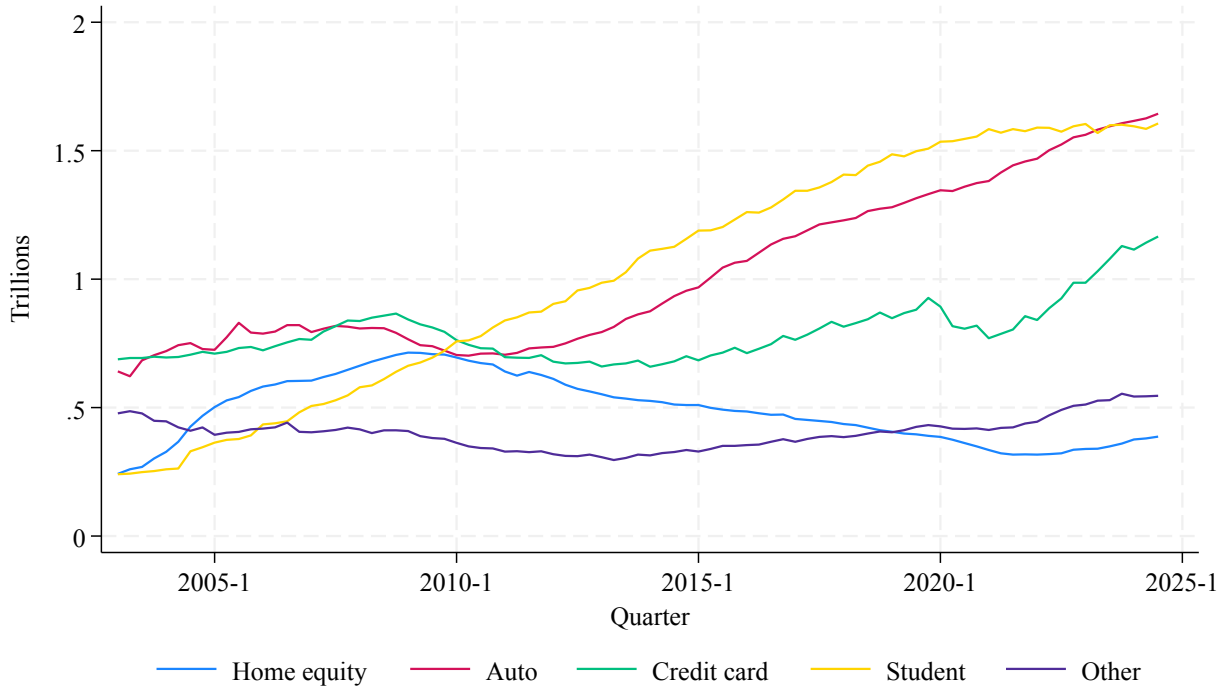


Figure A1: Top forms of debt by quarter (excluding mortgages)

Each line depicts the nominal dollar value of debt over time by each quarter for each major category of debt aside from mortgages from 2003, Quarter 1 to 2024, Quarter 3. Mortgage debt has been excluded. Source: Center for Microeconomic Data (2024)

United States Patent [19]

Johnson

[11] **Patent Number: 4,591,071**

[45] **Date of Patent: May 27, 1986**

[54] **SQUIRT GUN**

[76] Inventor: **Lonnie G. Johnson,** 1463 E. Barkley Dr., Mobile, Ala. 36606

[21] Appl. No.: **541,898**

[22] Filed: **Oct. 14, 1983**

[51] **Int. Cl.**[4] **B67D 5/32**

[52] **U.S. Cl.** ..... **222/39;** 222/79; 222/401; 340/384 E; 340/406; 116/137 R

[58] **Field of Search** ..... 340/384 E, 406; 116/137 R, 139; 222/39, 79, 323, 324, 401

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4,239,129	12/1980	Esposito	222/79

Primary Examiner—H. Grant Skaggs
Attorney, Agent, or Firm—John A. Beehner

[57] **ABSTRACT**

A toy squirt gun which shoots a continuous high velocity stream of water. The squirt gun is configured as a structure facilitating partial filling with water leaving a void for compressed air. The squirt gun includes a nozzle for ejecting water at high velocity, a pressurization pump for compressing air into the gun to pressurize water contained therein, and a trigger actuated flow control valve for shooting the gun by controlling flow of pressurized water through the nozzle. A battery-powered oscillator circuit and a water flow powered sound generator produce futuristic space ray gun sound effects when the gun is shooting.

9 Claims, 7 Drawing Figures

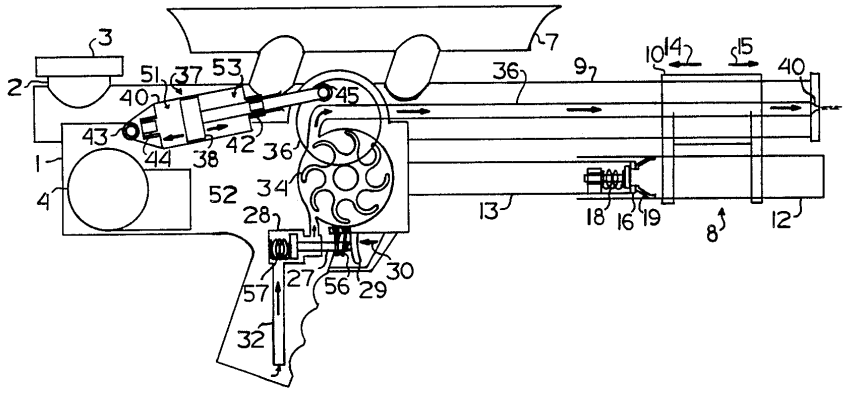


Figure A2: Example of a granted patent

8.2 Heterogeneity

Table A1: Heterogeneity by Gender

	Outcome: Patent Filers per 1,000		
	Main	Male	Female
	(1)	(2)	(3)
First Year Borrowing ($1,000s)	0.454**	0.819*	−0.0483
	(0.152)	(0.331)	(0.127)
1[Constrained]	−1.169***	−2.309***	0.198
	(0.318)	(0.726)	(0.265)
Cohort Fixed Effects	Yes	Yes	Yes
Mean of outcome	0.612	0.786	0.232
% impact of $1,000 loans	74%**	104%*	−21%
95% CI	(26%, 123%)	(22%, 187%)	(−128%, 86%)

Notes: Re-estimates the IV specification from Equation 3 on subsamples defined by imputed inventor gender. Column (1) reproduces the main pooled estimate for reference. Gender is imputed using name-based methods. The difference between male and female estimates is not statistically significant. Cohort fixed effects included throughout.
Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A2: Heterogeneity by Race

	Outcome: Patent Filers per 1,000				
	Main	White	Black	Hispanic	Asian
	(1)	(2)	(3)	(4)	(5)
First Year Borrowing ($1,000s)	0.454**	0.650**	0.387	0.176	0.740
	(0.152)	(0.240)	(0.475)	(0.182)	(0.628)
1[Constrained]	−1.169***	−1.547***	−1.365	−0.424	−1.957
	(0.318)	(0.469)	(0.899)	(0.414)	(1.438)
Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes
Mean of outcome	0.612	0.844	0.559	0.369	0.653
% impact of $1,000 loans	74%**	77%**	69%	48%	113%
95% CI	(26%, 123%)	(21%, 133%)	(−97%, 236%)	(−49%, 144%)	(−75%, 302%)

Notes: Re-estimates the IV specification from Equation 3 on subsamples defined by imputed inventor race. Column (1) reproduces the main pooled estimate for reference. Race is imputed using name-based and geography-based methods. Differences across racial groups are not statistically significant. Cohort fixed effects included throughout. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A3: Heterogeneity by Technology Category

	Outcome: Patent Filers per 1,000					
	Chemical (1)	Comp. & Comm. (2)	Drugs & Medical (3)	Elec. & Electronic (4)	Mechanical (5)	Design/Plant (6)
First Year Borrowing ($1,000s)	0.0570	0.0483	0.0586	0.0359	0.0810*	0.0330
	(0.0493)	(0.0665)	(0.0658)	(0.0587)	(0.0348)	(0.0268)
1[Constrained]	−0.170	−0.170	−0.267*	−0.0793	−0.106	−0.0370
	(0.0991)	(0.124)	(0.130)	(0.128)	(0.0822)	(0.0637)
Cohort Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Mean of outcome	0.0476	0.117	0.0602	0.0824	0.0761	0.0380
% impact of $1,000 loans	120%	41%	97%	44%	106%*	87%
95% CI	(−83%, 323%)	(−70%, 153%)	(−117%, 312%)	(−96%, 183%)	(17%, 196%)	(−51%, 225%)

Notes: Re-estimates the IV specification from Equation 3 using patent filings in each technology category as the outcome. Technology categories follow the NBER patent classification. The only statistically significant effect is in Mechanical patents; differences across categories are not statistically significant. Cohort fixed effects included throughout. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

8.3 Match Appendix

In order to match our patent data to the UC-CCP, we undergo an anonymized "hashed merge" process. The patent data were systematically linked to the CCP records by employing a standardized name-matching process similar to that of Bell et al. (2019a). Initially, all names were converted to lowercase and assigned a match priority of 1. Any subsequent modifications to a name resulted in the creation of a new observation, with the match priority incremented by one. Excessive spaces within names were identified and removed. Furthermore, all non-Latin alphabet characters and punctuation marks were eliminated. Extraneous information, such as "(Deceased)", "(Owner)", "(Esq)", "(Real Party in Interest)", "(patentee/owner)", and "(3rd Party Rq.)", was also removed. Honorifics were stripped from names, specifically if "PhD", "JD", "MBA", or "PE" appeared at the end of a name. In cases where nicknames were indicated by parentheses or "aka", the nickname was initially used to replace the given first name; subsequently, these nicknames were removed. Suffixes, which occasionally appeared at the end of first, middle, or last name fields, were extracted if they included "JR", "SR", "1st" through "5th", or numerals I-V, and were stored separately from the name. The sequence of these edits, while not necessarily aligned with the "match priority" variable if each round did not yield an edit, was as follows: names were converted to lowercase, spaces were removed, punctuation was eliminated, extraneous information was discarded, honorifics were stripped, nicknames were processed, and suffixes were extracted and stored separately. For city and state data, all entries were converted to lowercase. Additionally, it was ensured that the entries were within the United States or that the inventor region code corresponded to one of the 51 states plus the District of Columbia.