Scientific Education and Innovation: From Technical Diplomas to University STEM Degrees

Nicola Bianchi, Northwestern University and NBER
Michela Giorcelli, UCLA and NBER

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Scientific Education and Innovation

Innovation as a driver of aggregate production

- Capital and labor account for half of productivity growth (Copeland, 1937)
- Residual component in production function as technical change (Solow, 1957)
- Innovation correlated with firm productivity (Griliches, 1996; Peri, et al., 2015)

Policy makers has focused on education to spur innovation

- In developed countries not enough STEM graduates (Carnevale et al., 2011)
- "Need for 1 million more STEM professionals in US" (PCAST, 2012, p.i)
- $\rightarrow$ Increase number of students with STEM degrees

Open questions

- Does STEM education have a causal effect on innovation?
- Selection into STEM majors
- Role of labor market and occupation choices

This Paper: STEM Majors Reform – Italy, 1961

In 1961, industrial high-school students could enroll in STEM majors

- Before 1961: ONLY academic high-school students could go to college
- Academic high-schools: theoretical education in humanities and sciences
- Industrial high-schools: practical training in STEM disciplines

Data: 46,743 students who completed HS in Milan, 1958-1973

- Education: HS transcripts, university transcripts (Bianchi, 2017)
- Labor market: work histories from social security institute
- Innovation: Italian + European patents; US patents

Variation in the likelihood of receiving STEM degree

- Only for industrial students who finished HS after 1961
- Between-cohort: students who completed HS before vs after 1961
- Within-cohort: industrial vs academic students

Preview of the Results

STEM education impacted type of innovation produced

- Different patent fields for industrial and academic students before 1961
- Industrial students with STEM degrees patented in STEM fields after 1961
- Smaller change for industrial students without STEM degree after 1961

Industrial students with STEM degree more likely to patent after 1961

- Heterogeneous effects by students' ability
- Fewer patents from high-achieving students after 1961
- No effects on high-quality patents

Change into occupational sorting for high-achieving students

- Increased access to self-employed professions and public jobs
- Lower employment in manufacturing
- Lower-achieving students remained in manufacturing or moved to R&D

Contribution to the Literature

New evidence on the returns to university education *Wages*: Card (1999, 2001); Meghir and Rivkin (2011) for a review; *Health*: Lleras-Muney (2005); Silles (2009); Cutler and Lleras-Muney (2010); de Walque (2010); Webbink, Martin and Visscher (2010); Eide and Showalter (2011); *Social capital*: Dee (2004); Milligan et al. (2004); Wantchekon et al. (2015); *Crime*: Lochner (2004); Lochner and Moretti (2004); Buonanno and Leonida (2009); Cook et al. (2016); *Innovation*: Cantoni and Yuchtman (2014); Toivanen and Vaananen (2015); Andrews (2016)

Career outcomes of inventors Murphy, Shleifer, and Vishny (1991); Baumol (1990); Philippon (2010); Lockwood, Nathanson, and Weyl (2017); Shu (2016)

Characteristics of inventors Giuri et al. (2007); Jung and Ejermo (2014); Aghion et al. (2017); Bell et al. (2017); Akcigit, Grigsby and Nicholas (2017)

Overview

- Institutional Details
- Data
- Identification
- Main Results
  - Effects on the Type of Innovation
  - Effects on Innovation Propensity
  - Effects on Labor Market Outcomes
- Conclusions

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The Italian High-School System

***Licei* (Academic)**

- Humanities and science
- 31.5% of HS population (1960/61)
- 41.3% had father with at least HS diploma (SHIW)

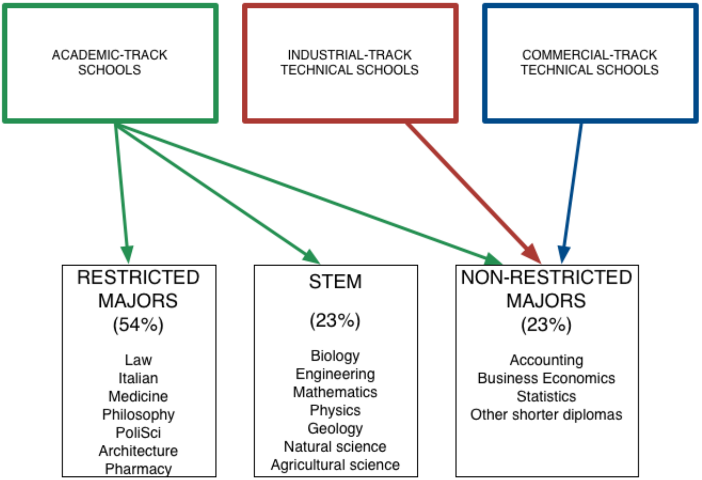
***Istituti industriali* (Industrial)**

- Applied STEM disciplines
- 26.2% of HS population (1960/61)
- 17.6% had father with at least HS diploma (SHIW)

Other details:

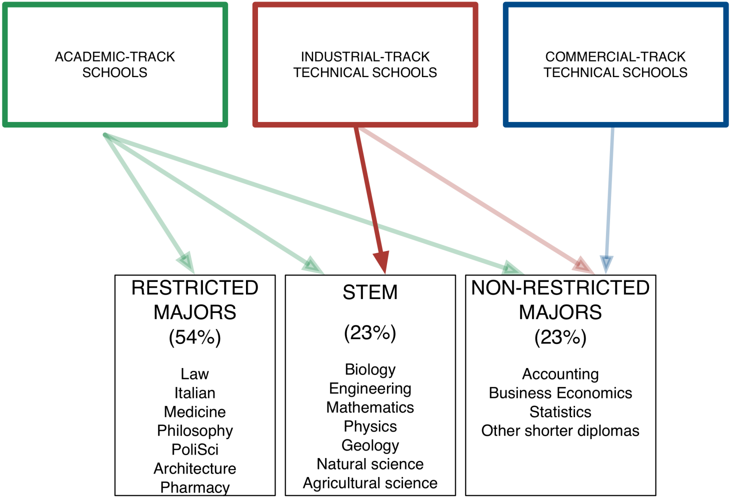
- Other technical (commercial, education, ..) and vocational schools.
- Most HS/universities public and charging low/no tuition fees.
- HS students: 18.6% of 14-18 population. (1960/61).
- University students: 4.1% of 19-24 population. (1960/61).

Access to the University Before 1961



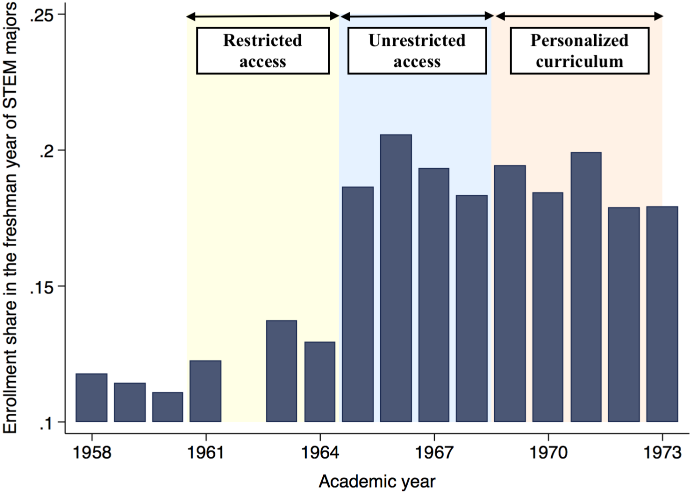
Notes. In parentheses, share of total university students (1960/61). Open-door admissions in university, conditional on HS diploma.

From 1961, Industrial Students Could Enroll in STEM



Notes. Reform approved on July 27, 1961 (Legge 685) by government formed on July 20, 1960.

Enrollment Increase in STEM Majors



Notes. Enrollment as share of high school graduates.

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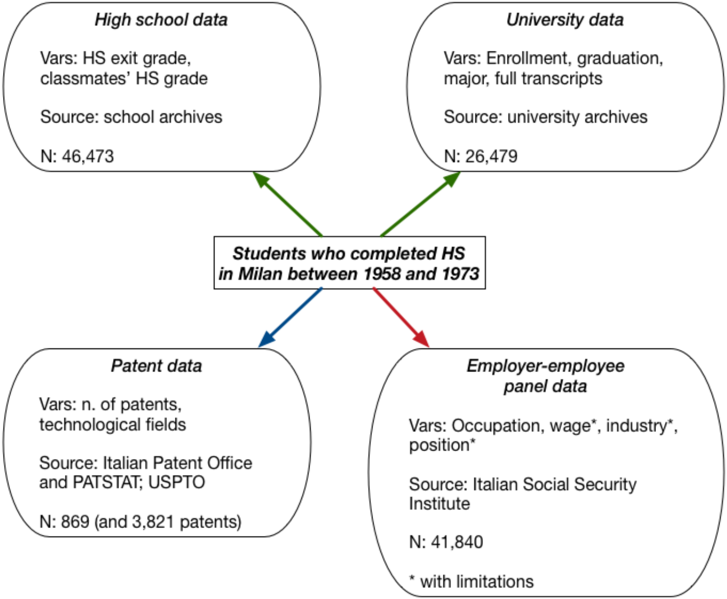
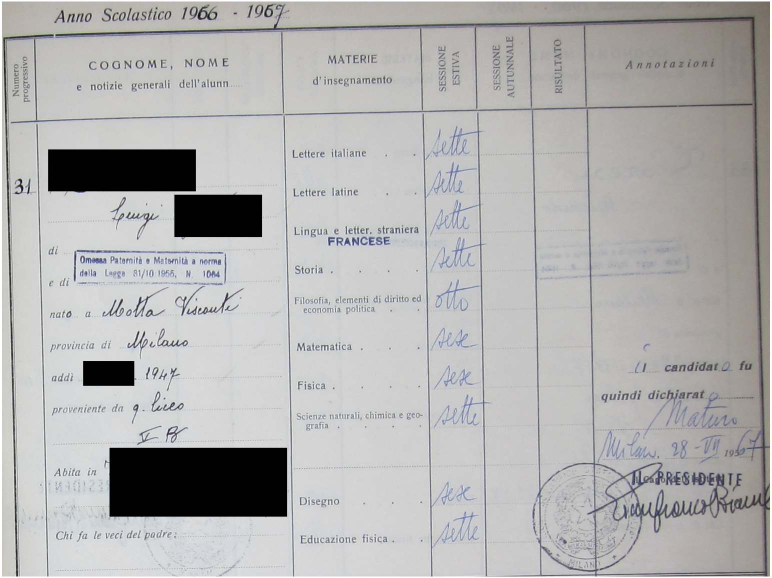
Data on Education, Innovation, Work Histories



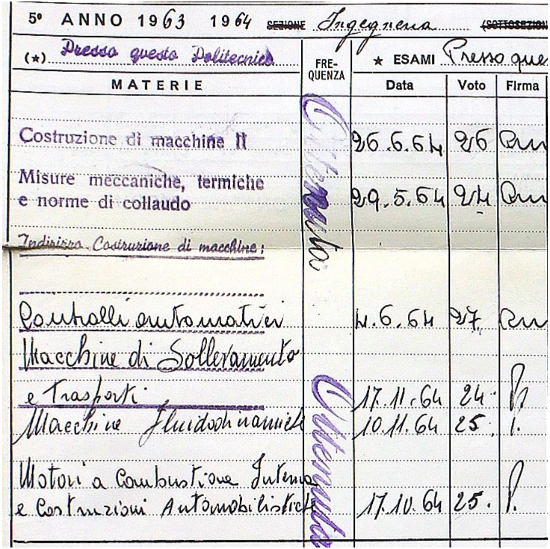
High-School Data: Final Exam *(Maturità)*



Anno Scolastico 1966 - 1967

Numero progressivo	COGNOME, NOME e notizie generali dell'alunn...	MATERIE d'insegnamento	SESSIONE ESTIVA	SESSIONE AUTUNNALE	RISULTATO	Annotazioni
31	[redacted]	Lettere italiane	Sette			
	Luigi [redacted]	Lettere latine	Sette			
	di Omessa Paternità e Maternità a norma della Legge 31/10/1955, N. 1064	Lingua e letter. straniera FRANCESE	Sette			
	e di	Storia	Sette			
	nato a Motta Visconti	Filosofia, elementi di diritto ed economia politica	otto			
	provincia di Milano	Matematica	sei			Il candidato fu
	addì [redacted] 1947	Fisica	sei			quindi dichiarato Maturo
	proveniente da g. liceo V B	Scienze naturali, chimica e geografia	sette			Milano, 28-VII-1967
	Abita in [redacted]					IL PRESIDENTE
		Disegno	sei			
	Chi fa le veci del padre:	Educazione fisica	sette			

University Data: Detailed Transcripts



Start/End of university career:

- Date
- Final outcome and score

Information on each course:

- Course title
- Exam date
- Result

Italian Social Security Data (INPS)

Work histories from Italian Social Security Institute (INPS)

- All: Occupation
- Private sector: Industry, position, wages

Defining occupations

- Pension funds tied to jobs
- Different types of public employees, entrepreneurs, medical doctors, engineers, lawyers, accountants, etc.
- 40 occupations

Matching procedure

- Fiscal code

Matching Students to Patent Owners

1. Match using name: 43,246 patents-students
2. When available, use fiscal code to verify match
   - 496 correct and 7,300 incorrect
3. Employers from work histories
   - 2,662 correct and 27,642 incorrect
4. Online searches
   - 663 correct and 217 incorrect
5. Total result: 3,821 correct matches, 35,159 (81%) entries verified

Inventors Are Positively Selected

	Inventors	Non-Inventors	Diff.
# patents	4.010	-	-
Technological fields	1.478	-	-
Male	0.962	0.721	0.229***
Industrial diploma	0.641	0.351	0.233***
HS exit score (σ)	0.256	-0.005	0.246***
STEM degree	0.392	0.125	0.265***
Manufacturing*	0.838	0.521	0.317***
Managers*	0.556	0.292	0.264***
N	869	45,604	

Notes. The sample is composed of 46,473 individuals who completed high school in Milan between 1958 and 1973.

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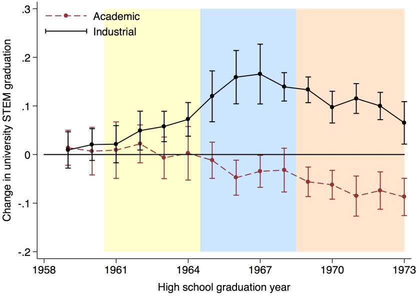
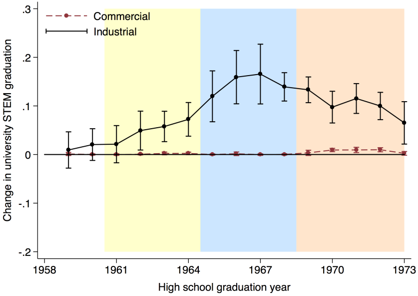
STEM Graduation: Increase Only for Industrial Students



A. Industrial vs Academic Students



B. Industrial vs Commercial Students

Notes. The graph shows the cross-cohort change in university STEM graduation. Standard errors are clustered by high school and cohort.

Empirical Specification: DID Estimation

Comparison between students with different HS diplomas:

$$\text{Invention}_{it} = \alpha + \beta \text{Industrial}_i + \gamma_t + \sum_t \delta_t [\text{Industrial}_i \times \text{Post}_t] + \zeta X_{it} + u_{it}$$

- Invention_{it}: indicator variable for
  - Individuals who developed at least one patent between 1968 and 2010
  - Number of developed patents
  - Number of technological fields in which an individual invented
- Industrial: indicators for industrial students
- Post: indicators for completing high school in '61-'64, '65-'68, '69-'73
- X: gender, province and high school fe, standardized HS score, average score of peers, home-schooled, and HS grad on time
- γ_t: cohort fixed effects
- Standard errors clustered at high school-cohort level

No Pre-Reform Trends in Innovative Activity

	Inventor	Inventor	Patents	Patents
	(1)	(2)	(3)	(4)
Industrial x Pre-Reform Trend	-0.003		-0.004	
	(0.004)		(0.004)	
Industrial x 1959		0.003		-0.070
		(0.008)		(0.071)
Industrial x 1960		-0.005		-0.079
		(0.008)		(0.080)
N	4,430	4,430	4,430	4,430

Notes. The dependent variables are a dummy for individuals who developed at least one patent (col. 1-2) and the number of developed patents (col. 3-4). *Industrial* is 1 industrial HS students. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Pre-Trends by HS

Matching Industrial and Academic Students

Goals of matching:

1. Measure effects on industrial students who completed STEM degree
2. Ensure that control group is consistent over time

Matching of:

- Pre-reform industrial and post-reform industrial with STEM degree
- Pre-reform academic and post-reform academic with STEM degree

Nearest–neighbor propensity score matching

- Only males to address increasing female education over cohorts
- Separately by quartiles of HS ability
- Controls for: high school, high school GPA, average GPA of high school classmates, home-schooled

▸ Matched Industrial Students ▸ Matched Academic Students

No Pre-Trend in Innovative Activity on Matched Sample

	Inventor (1)	Inventor (2)	Patents (3)	Patents (4)
Industrial x Pre-Reform Trend	-0.005		-0.013	
	(0.033)		(0.215)	
Industrial x 1959		0.003		0.286
		(0.053)		(0.499)
Industrial x 1960		-0.010		-0.040
		(0.065)		(0.411)
N	683	683	683	683

Notes. The dependent variables are a dummy for individuals who developed at least one patent (col. 1-2) and the number of developed patents (col. 3-4). *Industrial* is 1 industrial HS students. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Pre-Trends by HS

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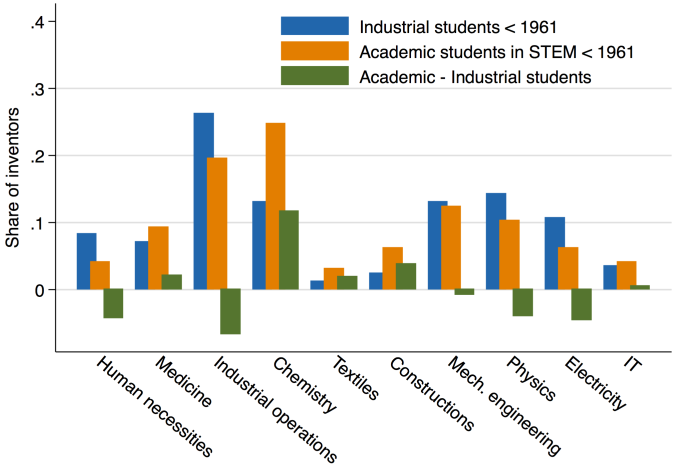
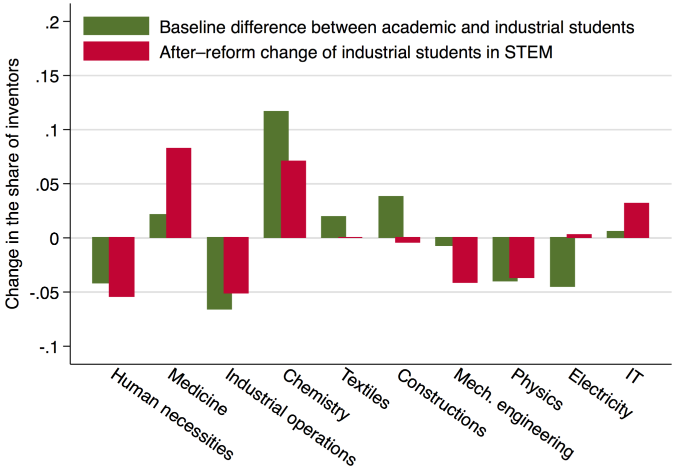
Different Patent Fields Before 1961



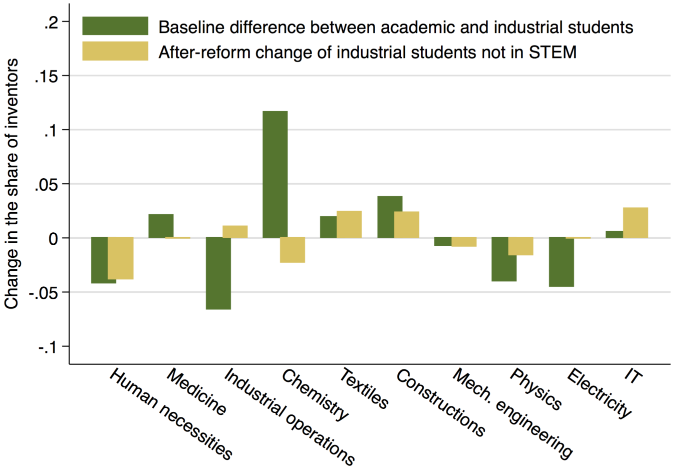
Notes. The graph shows the pre-reform distribution of inventors across technological fields for industrial and academic students.

Industrial Students with STEM Degree to STEM Fields



Notes. The graph shows the pre-post reform change in the distribution of inventors across technological fields.

Smaller Changes for Students without STEM Degree



Notes. The graph shows the pre-post reform change in the distribution of inventors across technological fields.

Between 26 and 68% More Patents in STEM Fields

	STEM Fields					
	Industrial vs academic			Matched Industrial vs academic		
	(1)	(2)	(3)	(4)	(5)	(6)
Industrial	0.141	0.223	0.020	0.089	0.167	0.058
x Post 1961	(0.093)	(0.236)	(0.129)	(0.148)	(0.413)	(0.286)
Industrial	0.261***	0.187	0.287**	0.677***	0.313	0.742***
x Post 1965	(0.087)	(0.245)	(0.124)	(0.156)	(0.381)	(0.202)
Industrial	0.281***	0.323	0.193*	0.507***	0.681*	0.461***
x Post 1969	(0.093)	(0.241)	(0.114)	(0.167)	(0.366)	(0.202)
N	818	241	577	310	118	192
Sample	All	Top	Other	All	Top	Other

Notes. *STEM fields* are medicine, chemistry, textiles, constructions, and IT. *Industrial* is 1 industrial HS students. Standard errors clustered by high school and cohort in parentheses.*** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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Theoretical Framework

Given education, choice about sector of employment and innovation

- STEM sector

$$\begin{cases} w_H + i \times g\,(\text{ability, STEM degree }) + \varepsilon_S & \text{if STEM degree} \\ w_L + i \times g\,(\text{ability, HS diploma }) + \varepsilon_S & \text{if HS diploma} \end{cases}$$

- Non-STEM sector

$$\begin{cases} w_N - c\,(\text{ability}) + \varepsilon_N & \text{if STEM degree} \\ 0 & \text{if HS diploma} \end{cases}$$

with $i = 1$ for inventors, $g \uparrow$ in ability, $c \downarrow$ in ability, $\varepsilon \sim EV$.

What happens to Prob(innovation), when HS diploma $\rightarrow$ STEM degree?

- Ambiguous effect on the probability of inventing
- Ambiguous selection outside STEM sector
- Empirical question that depends on features of local labor markets

Pr(Innovate): Heterogeneous Effects by Ability

	Probability of Patenting					
	Industrial vs academic			Matched Industrial vs academic		
	(1)	(2)	(3)	(4)	(5)	(6)
Industrial	-0.000	-0.000	-0.001	0.041	0.004	0.067*
x Post 1961	(0.007)	(0.017)	(0.006)	(0.038)	(0.050)	(0.039)
Industrial	0.004	-0.032**	0.012**	0.023	-0.068**	0.080***
x Post 1965	(0.006)	(0.014)	(0.006)	(0.025)	(0.033)	(0.030)
Industrial	-0.011**	-0.040***	-0.003	-0.000	-0.063**	0.053*
x Post 1969	(0.0052)	(0.012)	(0.005)	(0.022)	(0.030)	(0.027)
N	35,479	7,662	27,812	4,718	1,807	2,911
Sample	All	Top	Other	All	Top	Other

Notes. *Probability of Patenting* is 1 for students who patented at least once from 1968 to 2010. *Industrial* is 1 industrial HS students. Standard errors are clustered by high school and cohort. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

No Effects on High-Quality Patents

	Probability of Patenting					
	Industrial vs academic			Matched Industrial vs academic		
	(1)	(2)	(3)	(4)	(5)	(6)
Industrial	-0.003	-0.008	-0.002	0.061**	0.062	0.048*
x Post 1961	(0.005)	(0.02)	(0.004)	(0.029)	(0.043)	(0.028)
Industrial	-0.001	-0.004	-0.001	0.035**	0.003	0.053**
x Post 1965	(0.0064)	(0.009)	(0.004)	(0.018)	(0.030)	(0.021)
Industrial	-0.007**	-0.014***	-0.006	0.014	-0.017	0.037*
x Post 1969	(0.003)	(0.008)	(0.004)	(0.015)	(0.025)	(0.020)
N	35,479	7,662	27,812	4,718	1,807	2,911
Sample	All	Top	Other	All	Top	Other

Notes. *Probability of Patenting* is 1 for students who developed at least one patent issued by the US Patent Office. *Industrial* is 1 industrial HS students. Standard errors are clustered by high school and cohort. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Controlling for Entry into Industrial HS

- Changes in innovative activity for academic students only ▸ Results
- Restringing the sample to students who completed HS before 1966 ▸ Results
- Using weights to keep students characteristics constant over time ▸ Results
- Alternative matching process ▸ Results
- Controlling for students family characteristics ▸ Results

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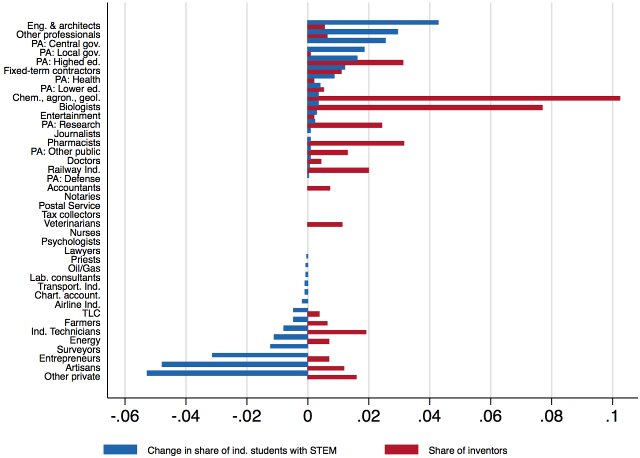
Strong Correlation between Occupations and Innovation

	Industrial vs academic			Matched Industrial vs academic		
	Prob.	#Pat.	STEM	Prob.	#Pat.	STEM
	(1)	(2)	(3)	(4)	(5)	(6)
Self-employed	-0.001**	-0.002***	-0.001*	-0.004***	-0.007***	-0.003***
	(0.000)	(0.001)	(0.000)	(0.001)	(0.002)	(0.001)
Public	-0.001***	-0.002***	-0.001***	-0.006***	-0.017***	-0.004***
Employees	(0.000)	(0.000)	(0.000)	(0.001)	(0.002)	(0.001)
Entrepreneurs	-0.001***	-0.002***	-0.001***	-0.006***	-0.009***	-0.004***
	(0.002)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
N	1,017,854	1,017,854	1,017,854	151,963	151,963	151,963

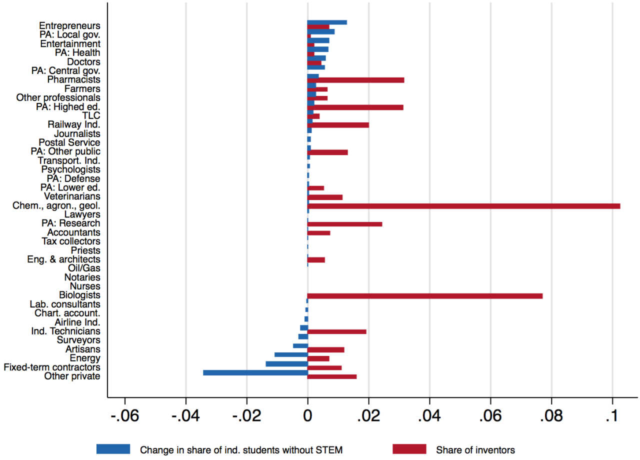
Notes. *Prob.* equals to 1 for patenting at least once in year t (col. 1 and 4); *#Pat.* is the number of patent applications issued in year t (col. 2 and 5); *STEM* equals to 1 for patenting at least once in a STEM field (medicine, chemistry, textiles, constructions, and IT; col. 3 and 6). Standard errors clustered by student in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Occupational Changes for STEM Industrial Students



Notes. The graph shows the before–after reform change in the share of industrial students with a STEM degree in each occupation. The red line is the share of inventors in each occupation.

Different Changes for non-STEM Industrial Students



Notes. The graph shows the before–after reform change in the share of industrial students without a STEM degree in each occupation. The red line is the share of inventors in each occupation.

More Self-Employed High-Achieving Industrial Students

	Engineers		Self-Employed	
	(1)	(2)	(3)	(4)
Industrial x Post 1961	0.044***	0.002	0.064***	-0.002
	(0.016)	(0.011)	(0.020)	(0.017)
Industrial x Post 1965	0.022*	-0.005	0.035**	-0.009
	(0.012)	(0.008)	(0.015)	(0.012)
Industrial x Post 1969	0.005	-0.022**	0.024	-0.023*
	(0.013)	(0.010)	(0.015)	(0.013)
N	59,122	93,272	59,122	93,272
Matched sample	Top	Other	Top	Other

Notes. *Industrial* is 1 industrial HS students. Standard errors are clustered by individual. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Fewer Researcher High-Achieving Industrial Students

	Top Occupations		Researchers	
	(5)	(6)	(7)	(8)
Industrial x Post 1961	0.005	0.053*	-0.012	0.050
	(0.026)	(0.032)	(0.026)	(0.031)
Industrial x Post 1965	0.005	-0.002	0.000	-0.002
	(0.023)	(0.012)	(0.023)	(0.012)
Industrial x Post 1969	-0.045***	0.006	-0.041***	0.003
	(0.015)	(0.009)	(0.016)	(0.008)
N	59,122	93,272	59,122	93,272
Matched sample	Top	Other	Top	Other

Notes. *Top Occupations* is a dummy for the top 10 percent occupations in terms of share of inventors: self-employed biologists, self-employed chemists, pharmacists, and public employees of institutions of higher education. *Industrial* is 1 industrial HS students. Standard errors are clustered by individual. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Why Occupational Shift for High-Achieving Students?

Barriers to entry

- Self-employed engineers: STEM degree + national exam
- Public servants chosen through screening, also based on academic grades
- $\rightarrow$ More attractive for high-achieving industrial students

High-variance of returns in self-employment

- Private sector earnings no lower than minimum wage
- More volatility in self-employment
- $\rightarrow$ Less attractive for lower-achieving industrial students

Weak signal provided by poor academic achievements

- HS and college final grades evaluated in business relations
- Especially important in self-employment
- $\rightarrow$ More attractive for high-achieving industrial students

High-Achieving Industrial Students Left Manufacturing

	Manufacturing		R&D		Top Pay	
	(1)	(2)	(3)	(4)	(5)	(6)
Industrial x Post 1961	-0.337***	-0.039	-0.001	0.077*	0.062	0.023
	(0.094)	(0.103)	(0.019)	(0.042)	(0.055)	(0.056)
Industrial x Post 1965	-0.143*	0.001	0.013	0.053**	0.083*	0.028
	(0.077)	(0.075)	(0.016)	(0.021)	(0.049)	(0.041)
Industrial x Post 1969	-0.156**	0.030	0.007	0.038**	0.086*	0.021
	(0.070)	(0.072)	(0.012)	(0.018)	(0.044)	(0.040)
N	25,528	25,528	25,528	42,274	42,274	42,274
Matched sample	Top	Other	Top	Other	Top	Other

Notes. *Top Pay* is a dummy for the five industries with the highest average salaries for workers with STEM degrees (energy, food/hospitality, transportation/communications, finance/banking, and international organizations). *Industrial* is 1 industrial HS students. Standard errors are clustered by individual. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Low-Achieving Industrial Students in Manufact. or R&D

	Manufacturing		R&D		Top Pay	
	(1)	(2)	(3)	(4)	(5)	(6)
Industrial x Post 1961	-0.337***	-0.039	-0.001	0.077*	0.062	0.023
	(0.094)	(0.103)	(0.019)	(0.042)	(0.055)	(0.056)
Industrial x Post 1965	-0.143*	0.001	0.013	0.053**	0.083*	0.028
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Industrial x Post 1969	-0.156**	0.030	0.007	0.038**	0.086*	0.021
	(0.070)	(0.072)	(0.012)	(0.018)	(0.044)	(0.040)
N	25,528	25,528	25,528	42,274	42,274	42,274
Matched sample	Top	Other	Top	Other	Top	Other

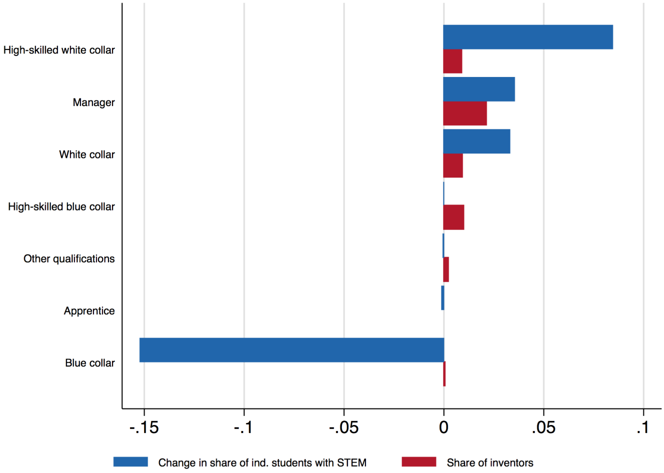
Notes. *Top Pay* is a dummy for the five industries with the highest average salaries for workers with STEM degrees (energy, food/hospitality, transportation/communications, finance/banking, and international organizations). *Industrial* is 1 industrial HS students. Standard errors are clustered by individual. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Higher Propensity to Innovate in Higher-Ranked Positions

	Prob.		#Pat.		STEM	
	(1)	(2)	(3)	(4)	(5)	(6)
Managers	0.004***	0.004***	0.008***	0.007***	0.002***	0.002
	(0.001)	(0.001)	(0.003)	(0.003)	(0.000)	(0.001)
University		0.008***		0.015***		0.007**
Degree		(0.004)		(0.006)		(0.003)
N	120,273	120,273	120,273	120,273	120,273	120,273
Matched Sample	All	All	Top	Top	Other	Other

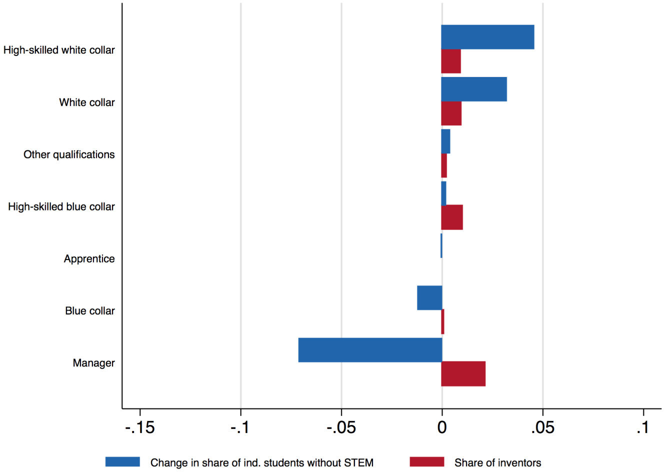
Notes. *Prob.* equals to 1 for patenting at least once in year t (col. 1-2); *#Pat.* is the number of patent applications issued in year t (col. 3-4); *STEM* equals to 1 for patenting at least once in a STEM field (medicine, chemistry, textiles, constructions, and IT; col. 5-6). Standard errors clustered by student in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

More Managerial Jobs for STEM Industrial Students



Notes. Distribution of industrial students who received a STEM degree after 1961 changed, relative to the pre- reform distribution. Share of inventors measures the percentage of inventors in each qualification (1968-2010).

Smaller Changes for non-STEM Industrial Students



Notes. Distribution of industrial students who did not receive a STEM degree after 1961 changed, relative to the pre-reform distribution. Share of inventors measures the percentage of inventors in each qualification (1968-2010).

More Top Positions for Lower-Achieving Students

	Top Positions		Managers	
	(1)	(2)	(3)	(4)
Industrial x Post 1961	0.070	0.266***	0.0354	0.281***
	(0.064)	(0.055)	(0.007)	(0.060)
Industrial x Post 1965	0.174***	0.318***	0.164***	0.284***
	(0.055)	(0.041)	(0.059)	(0.044)
Industrial x Post 1969	0.187***	0.273***	0.126***	0.250***
	(0.052)	(0.004)	(0.056)	(0.042)
N	45,258	45,258	75,347	75,347
Matched sample	Top	Other	Top	Other

Notes. *Top positions* is a dummy for the two highest positions of manager and higher-level white collar ("quadro" in Italian), and *Manager* is a dummy for workers in a managerial position. Standard errors are clustered by individual. *** p<0.01, ** p<0.05, * p<0.1.

Overview

- Institutional Details
- Data
- Identification
- Main Results
  - Effects on the Type of Innovation
  - Effects on Innovation Propensity
  - Effects on Labor Market Outcomes
- Conclusions

Conclusions

Effects of receiving university STEM degrees on innovation

- STEM education impacted type of innovation produced
- Industrial students with STEM degree more likely to patent after 1961
- Change into occupational sorting for high-achieving students

Complex relationship between education and innovation

- Mediated by local labor market
- 74% STEM graduates not employed in STEM jobs (Census Bureau, 2014)
- Non-STEM job sorting may indirectly affect innovation

External validity

- Willingness to increase STEM graduates in developing countries
- Changing in direction of innovation
- STEM graduates away from innovative jobs

Back-Up Slides

Pre-Trend by Class-Quartile of HS Score

	Inventor (1)	Inventor (2)	Patents (3)	Patents (4)
Industrial x Pre-Reform Trend	-0.011		-0.059	
	(0.067)		(0.091)	
Industrial x 1959		-0.001		-0.059
		(0.118)		(0.187)
Industrial x 1960		-0.022		-0.118
		(0.135)		(0.182)
N	756	756	756	756

Notes. The unit of observation is a pre-reform cohort of high school graduation (between 1958 and 1960)–high school class (small groups of 20–30 students)–quartile of precollegiate achievement combination. Industrial is 1 industrial HS students. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Back

Pre-Trend by HS-Quartile of HS Score

	Inventor (1)	Inventor (2)	Patents (3)	Patents (4)
Industrial x Pre-Reform Trend	-0.005		-0.046	
	(0.534)		(0.155)	
Industrial x 1959		-0.003		-0.055
		(1.095)		(0.315)
Industrial x 1960		-0.008		-0.091
		(1.076)		(0.311)
N	119	119	119	119

Notes. The unit of observation is a pre-reform cohort of high school graduation (between 1958 and 1960)—high school—quartile of precollegiate achievement combination. Industrial is 1 industrial HS students. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Back

Balancing Tests on Matched Industrial Students

	Top Students			Other Students		
	58-60	61-73	Diff.	58-60	61-73	Diff.
	(1)	(2)	(3)	(4)	(5)	(6)
HS Score	1.683	1.747	-0.064	-0.170	-0.223	0.053
			(0.093)			(0.089)
HS Peers' Mean Score	0.186	0.134	0.052	-0.039	0.014	-0.053
			(0.045)			(0.037)
Home-Schooled	0.000	0.003	-0.003	0.070	0.028	0.043
			(0.002)			(0.078)
HS grad at 19	0.988	0.995	-0.007	0.972	0.983	-0.012
			(0.012)			(0.012)

Notes. Standard errors clustered by high school and cohort in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Back

Balancing Tests on Matched Academic Students

	Top Students			Other Students		
	58-60	61-73	Diff.	58-60	61-73	Diff.
	(1)	(2)	(3)	(4)	(5)	(6)
HS Score	1.664	1.647	0.017	-0.306	-0.295	-0.012
			(0.050)			(0.028)
HS Peers' Mean Score	0.056	0.068	-0.012	0.009	-0.011	0.020
			(0.028)			(0.020)
Home-Schooled	0.018	0.017	0.0016	0.023	0.019	0.003
			(0.012)			(0.009)
HS grad at 19	0.991	0.992	-0.001	0.958	0.963	-0.005
			(0.007)			(0.018)

Notes. Standard errors clustered by high school and cohort in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Back

Matched Sample: Pre-Trend by Class-Quartile of HS Score

	Inventor (1)	Inventor (2)	Patents (3)	Patents (4)
Industrial x Pre-Reform Trend	-0.000		-0.212	
	(0.069)		(0.167)	
Industrial x 1959		0.116		-0.051
		(0.158)		(0.498)
Industrial x 1960		-0.017		-0.470*
		(0.117)		(0.267)
N	316	316	316	316

Notes. The unit of observation is a pre-reform cohort of high school graduation (between 1958 and 1960)–high school class (small groups of 20–30 students)–quartile of precollegiate achievement combination. *Industrial* is 1 industrial HS students. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Back

Matched Sample: Pre-Trend by HS-Quartile of HS Score

	Inventor	Inventor	Patents	Patents
	(1)	(2)	(3)	(4)
Industrial x Pre-Reform Trend	-0.106		-0.234	
	(0.217)		(0.255)	
Industrial x 1959		0.130		0.054
		(0.486)		(0.529)
Industrial x 1960		-0.210		-0.465
		(0.414)		(0.470)
N	90	90	90	90

Notes. The unit of observation is a pre-reform cohort of high school graduation (between 1958 and 1960)—high school—quartile of precollegiate achievement combination. *Industrial* is 1 industrial HS students. *** p<0.01, ** p<0.05, * p<0.1.

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No Change in Innovative Activity for Academic Students

	Inventor		Patent Count		Number Fields	
	(1)	(2)	(3)	(4)	(5)	(6)
Top x Post 1961	0.001	0.002	0.058	0.031	-0.002	-0.012
	(0.010)	(0.015)	(0.052)	(0.051)	(0.016)	(0.021)
Top x Post 1965	0.004	0.005	0.087*	0.059	0.010	-0.000
	(0.009)	(0.014)	(0.051)	(0.049)	(0.014)	(0.019)
Top x Post 1969	-0.002	-0.002	-0.002	-0.029	-0.002	-0.012
	(0.009)	(0.014)	(0.037)	(0.035)	(0.013)	(0.019)
Top x Pre-Trend		0.001		-0.027		-0.010
		(0.009)		(0.047)		(0.014)
N	18,929	18,929	18,929	18,929	18,929	18,929

Notes. *Inventor* is 1 if student developed at least one patent, *Patent count* is number of patents developed, and *Number fields* is number of technological fields per inventor. *Top* is 1 for top quartile students in HS grade distribution. Standard errors clustered by high school and cohort in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Back

Similar Results on Students Who Completed HS by 1966

	Probability of Patenting			
	Industrial vs academic		Matched Industrial vs academic	
	(1)	(2)	(3)	(4)
Industrial x Post 1961	-0.009	-0.004	-0.045	0.081*
	(0.015)	(0.005)	(0.049)	(0.043)
Industrial x Post 1965	-0.048*	0.013**	-0.047	0.147***
	(0.025)	(0.007)	(0.075)	(0.047)
N	2,889	10,449	813	1,153
Sample	Top	Other	Top	Other

Notes. *Probability of Patenting* is 1 for students who patented at least once from 1968 to 2010. *Industrial* is 1 industrial HS students. Standard errors are clustered by high school and cohort. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Back

Similar Results Using Pre-1961 Characteristics as Weights

	Probability of Patenting	
	Industrial vs academic	
	(1)	(2)
Industrial x Post 1961	-0.006	-0.002
	(0.018)	(0.006)
Industrial x Post 1965	-0.039***	0.013**
	(0.014)	(0.006)
Industrial x Post 1969	-0.043***	-0.001
	(0.011)	(0.005)
N	7,598	27,530
Sample	Top	Other

Notes. *Probability of Patenting* is 1 for students who patented at least once from 1968 to 2010. *Industrial* is 1 industrial HS students. Observations are weighted to keep the average student characteristics constant at the pre-reform levels (DiNardo et al., 1996). Standard errors are clustered by high school and cohort. *** p<0.01, ** p<0.05, * p<0.1. Back

Similar Results with Alternative Matching Process

	Probability of Patenting	
	Matched Industrial vs academic	
	(1)	(2)
Industrial x Post 1961	-0.097	0.041
	(0.090)	(0.038)
Industrial x Post 1965	-0.145*	0.074**
	(0.086)	(0.030)
Industrial x Post 1969	-0.166**	0.034
	(0.083)	(0.030)
N	1,066	2,439
Sample	Top	Other

Notes. *Probability of Patenting* is 1 for students who patented at least once from 1968 to 2010. *Industrial* is 1 industrial HS students. The matching process uses only STEM graduates belonging to the cohorts between 1961 and 1965. Standard errors are clustered by high school and cohort. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Back

No Change in Students' Family Characteristics

	Paternal Characteristics		Maternal Characteristics	
	Change	N	Change	N
High-School or Higher	-0.047	1,362	-0.009	1,368
	(0.032)		(0.023)	
Manager	0.006	1,066	0.000	1,072
	(0.026)		(0.000)	
Blue-collar worker	-0.012	1,066	-0.038	1,072
	(0.034)		(0.028)	
Teacher	0.001	1,066	-0.005	1,072
	(0.013)		(0.022)	
Public Employee	0.019	966	0.137	277
	(0.047)		(0.095)	
Industrial Sector	-0.050	966	-0.107	277
	(0.039)		(0.086)	

Notes. 2008, 2010, 2012, and 2014 Survey of Household Income and Wealth, for academic and industrial HS students born 1939–1954. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Back