When Protectionism Kills Talent

ABFER 12th Annual Conference

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May 19, 2025

The Rise of Economic Protectionism

- Governments design protectionist policies to
  - Revitalize domestic manufacturing and job growth
    - Smoot-Hawley Tariff Act during the Great Depression (1930s)
    - Mexico's Import Substitution Industrialization (ISI) Policies (1950s–80s)

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  - Reduce dependence on foreign supply chains
    - E.U. measures against Chinese steel (2000s)
  - Maintain technological leadership
    - Reagan tariffs on electronics & U.S.-Japan Semiconductor Agreement (1980s)
- Global resurgence in protectionist measures in recent years
  - Restrictions on goods flow
  - Restrictions on human capital flow

Recent Policy Shifts: Tariffs and Skilled Immigration

Key U.S. Policies (2018-present)

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Combined Effect

Simultaneous disruption to both supply chains and talent acquisition in a **critical industry**, which is heavily dependent on both

Why Semiconductors Provide an Ideal Research Setting

Relevant Industry Characteristics:

- Complex global supply chains (sensitive to tariff disruptions)
- High reliance on international talent (sensitive to immigration policies) Skill Map Skills

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- Educational pipeline traceable through degree programs

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Generalizable Insights

Findings apply to other high-tech industries with similar talent needs and global integration

Research Question

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How do protectionist policies impact the domestic talent ecosystem in the U.S. chip manufacturing industry?

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- *Expected Policy Outcome*: Encouraged domestic hiring and workforce development
- *Alternative Hypothesis*: Reduction in specialized talent and industry competitiveness
  - Increased input costs could reduce R&D budgets and specialized hiring
  - Restricted access to global talent pool may create shortages in specialized roles
  - Educational pipeline disruptions could reduce future talent availability

$\Rightarrow$ ***Combined effects may undermine the intended policy outcomes***

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Conceptual Framework

We develop a conceptual framework to guide our investigation of competing hypotheses.

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Key Model Components:

- A representative consumer who demands both chips and other products
- A chip manufacturer uses domestic and foreign labor to produce chip products

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Repercussion of protectionist policies:

- They provide investment subsidies that enhance a firm's TFP and increase MPL
- They impose tariffs on raw materials and intermediate inputs imported from abroad, raising domestic firms' variable costs and thereby reducing their profit margins
- They limit firms' access to labor, particularly foreign workers

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Testable Predictions:

Protectionist policies will have most adverse effects when

1. Industries have high reliance on foreign talent
2. Labor supply is inelastic for specialized roles
3. Foreign labor and domestic labor are complements

Key Findings

Main Employment Effects:

- 9% reduction in recruitment of scientists and engineers
  - 3% reduction in total scientist and engineer workforce size
  - Annual loss of 2,285 science and engineering positions (9,140 jobs, 2019-2022)
- Hiring reductions *despite increased job postings* for these positions

Educational Pipeline Effects:

- Fewer chip manufacturing degrees obtained in the U.S.

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Effect Heterogeneity:

- Disproportionate impact on entry-level and junior positions
- Strongest effects in firms with high pre-policy H-1B visa reliance
- Greater impact in firms more exposed to tariff-affected supply chains

Data Sources & Sample

Primary Data Source:

- Comprehensive dataset with detailed employee-job-employer relationships globally
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Key Variables:

- High-dimensional employment indicators (hiring, attrition, workforce size)
  - Job categories and specializations
  - Geographic location
  - Experience levels and career progression
- Education background, skills, career paths

Data Sources & Sample

Sample Coverage:

- U.S. semiconductor firms and their global operations
- Time period: 2014-2022 (capturing pre- and post-treatment periods)
- 76,150 scientists and engineers employed in U.S. chip industry
- Cross-country comparison for multinational operations

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Supplementary Data:

- U.S. Department of Education data on degree completions and immigration status
- H-1B visa petition data by firm
- Tariff exposure metrics for semiconductor-related products
- Job posting data

The Agenda

- **What are the effects of protectionist policies on science and engineer jobs within the semiconductor industry?**
  I. Evidence on new hirings, separations, and turnover
  II. Hiring trends: new graduates vs. seasoned professionals, junior-level vs. senior roles
  III. Domestic vs. international positions
  IV. Firms with high vs. low H-1B exposure
- **How do protectionist policies influence career choices of chip manufacturing students?**
  V. Assessment of changes in cohort sizes based on immigration status

The Effect of U.S. Protectionism on STEM Roles at U.S. Chip Manufacturing Firms

- We empirically estimate the effects of U.S. protectionism on science and engineering roles in U.S. chip manufacturing firms

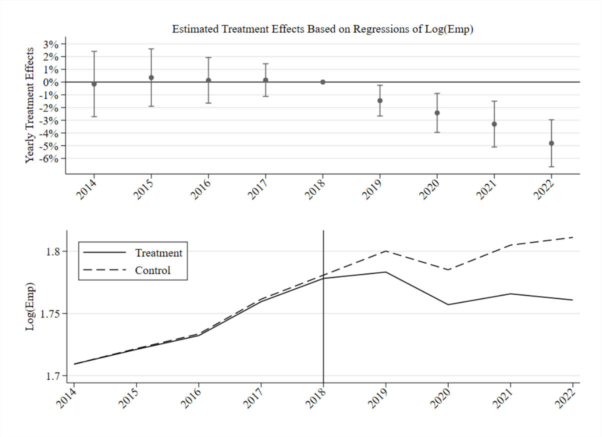
$$y_{i,j,t} = \beta \text{Treated}_j \times \text{Post}_t + \alpha_{i,t} + \delta_{i,j} + \epsilon_{i,j,t}, \tag{1}$$

  - $y_{i,j,t}$ refers to number of employees, new hires, separations, and turnover for firm i, job category j, and year t
  - **Treated**$_j$ is one for **Scientist** and **Engineering** roles, and zero for **Finance**, **Operations**, **Marketing**, **Sales** and **Admin** roles.
  - **Post**$_t$ is one after 2018, and zero otherwise.
  - $\alpha_{i,t}$ is firm-year FE, $\delta_{i,j}$ firm-job category FE
  - Errors are corrected for clustering of observations at the firm level

Main Findings (I): Employment, Hiring and Separations

	$\text{Log}(\text{Emp}_{i,j,t})$	$\text{Log}(\text{Hiring}_{i,j,t})$	$\text{Log}(\text{Separation}_{i,j,t})$	$\text{Log}(\text{Turnover}_{i,j,t})$
	(1)	(2)	(3)	(4)
$\text{Treated}_j \times \text{Post}_t$	-0.03***	-0.09***	-0.04***	-0.09***
	(-3.45)	(-8.93)	(-4.19)	(-7.73)
Firm $\times$ Job Category FE	Yes	Yes	Yes	Yes
Firm $\times$ Year FE	Yes	Yes	Yes	Yes
Observations	68,949	68,949	68,949	68,949
R-squared	0.975	0.874	0.863	0.889

Effect Dynamics: Science and Engineering Roles at U.S. Chip Manufacturers



Means

Main Findings (I - *Cont.*): Hiring Rates

	Hiring Rate$_{i,j,t}$	Separation Rate$_{i,j,t}$	Net Hiring Rate$_{i,j,t}$	Turnover Rate$_{i,j,t}$
	(1)	(2)	(3)	(4)
Treated$_j$ $\times$ Post$_t$	-0.03***	-0.01***	-0.02***	-0.04***
	(-4.70)	(-3.54)	(-3.16)	(-5.16)
Firm $\times$ Job Category FE	Yes	Yes	Yes	Yes
Firm $\times$ Year FE	Yes	Yes	Yes	Yes
Observations	68,949	68,949	68,949	68,949
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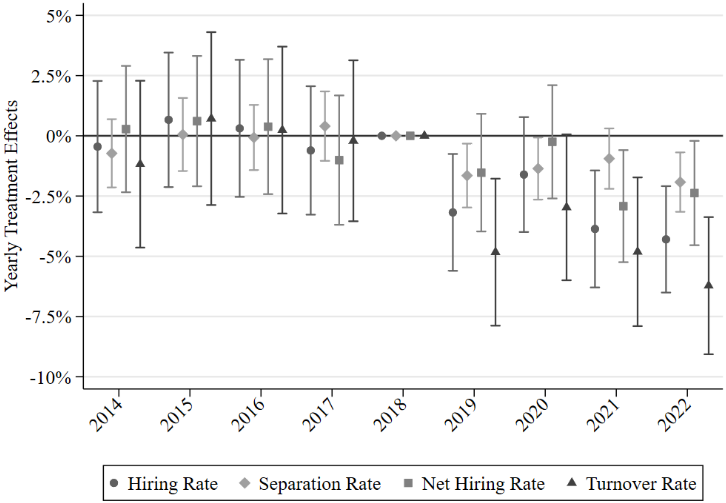
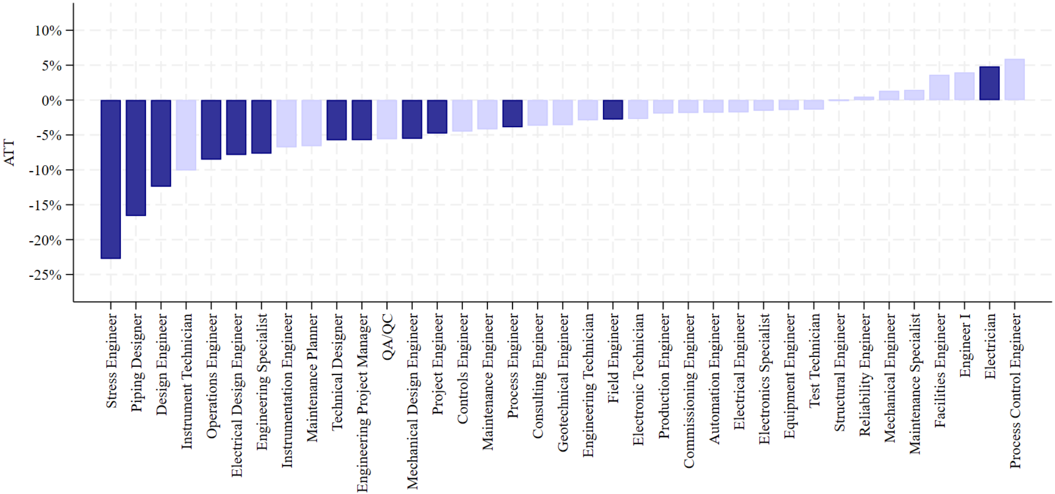
Effect Dynamics: Hiring, Separation, and Turnover Rates



Effect Heterogeneity: Engineering Job Categories



Main Findings (II): Junior *vs.* Senior Employees

	Log(FirstJobEmp$_{i,j,t}$)	Log(ExprEmp$_{i,j,t}$)	Log(JunPosEmp$_{i,j,t}$)	Log(MidSenPosEmp$_{i,j,t}$)
	(1)	(2)	(3)	(4)
Treated$_j$ × Post$_t$	-0.03***	-0.01	-0.02**	-0.01
	(-4.27)	(-1.55)	(-2.04)	(-0.81)
Firm × Job Category FE	Yes	Yes	Yes	Yes
Firm × Year FE	Yes	Yes	Yes	Yes
Observations	68,949	68,949	68,949	68,949
R-squared	0.975	0.874	0.863	0.889

The Effect of U.S. Protectionism in the U.S. Segments (III)

- We empirically estimate the effects of U.S. protectionism on *domestic* STEM employment in U.S. Chip Manufacturing Firms.

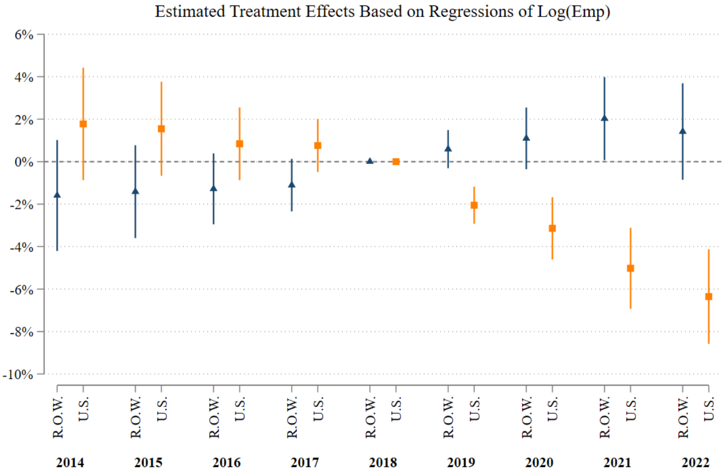
$$\begin{aligned} y_{i,c,j,t} = & \omega \text{Treated}_j \times \text{Post}_t \times \textbf{US}_c \\ & + \alpha_{i,t} + \pi_{c,t} + \rho_{j,t} + \delta_{i,c,j} + \epsilon_{i,c,j,t}, \end{aligned} \tag{2}$$

  - **US**$_c$ is one for U.S. and zero otherwise.
  - $\alpha_{i,t}$ is firm-year FE, $\pi_{c,t}$ is country-year FE, $\rho_{j,t}$ is job category-year FE, and $\delta_{i,c,j}$ firm-country-job category FE.

Main Findings (III): Effects of U.S. Protectionism in the U.S. Segments

Panel A: Analyses of Chip Manufacturing Workforce (N=231,696)				
	Log($Emp_{i,c,j,t}$)	Log($Hiring_{i,c,j,t}$)	Log($Separation_{i,c,j,t}$)	Log($Turnover_{i,c,j,t}$)
	(1)	(2)	(3)	(4)
$Treated_j \times Post_t \times US_c$	-0.05***	-0.07***	-0.04***	-0.06***
	(-4.74)	(-4.71)	(-3.12)	(-4.00)
Panel B: Analyses of Employment Growth (N=231,696)				
	Hiring $Rate_{i,j,t}$	Separation $Rate_{i,j,t}$	Net Hiring $Rate_{i,j,t}$	Turnover $Rate_{i,j,t}$
	(1)	(2)	(3)	(4)
$Treated_j \times Post_t \times US_c$	-0.01***	-0.01**	-0.01**	-0.02***
	(-3.60)	(-2.64)	(-2.40)	(-3.72)
Panel C: Analyses of Chip Manufacturing Workforce by Career Progression (N=231,696)				
	Log($FirstEmp_{i,c,j,t}$)	Log($ExprEmp_{i,c,j,t}$)	Log($JunEmp_{i,c,j,t}$)	Log($MidSenEmp_{i,c,j,t}$)
	(1)	(2)	(3)	(4)
$Treated_j \times Post_t \times US_c$	-0.01***	-0.06***	-0.05***	-0.03***
	(-2.90)	(-4.88)	(-4.28)	(-3.15)
Panel D: Fixed Effects				
	(1)	(2)	(3)	(4)
Firm × Country × Job Category FE	Yes	Yes	Yes	Yes
Firm × Year FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Job Category × Year FE	Yes	Yes	Yes	Yes

Effect Dynamics: U.S. vs. Non-U.S. Segments (III)



H-1B Exposure

- We empirically estimate the effects of U.S. protectionism on *domestic* and *H-1B oriented* STEM employment in U.S. Chip Manufacturing Firms.

$$
\begin{aligned}
y_{i,c,j,t} = {} & \phi \text{Treated}_j \times \text{Post}_t \times \mathbf{US}_c \times \mathbf{Sponsor}_i \\
& + \gamma \text{Treated}_j \times \text{Post}_t \times \text{US}_c \\
& + \eta \text{Treated}_j \times \text{Post}_t \times \text{Sponsor}_i \\
& + \theta \text{Post}_t \times \text{US}_c \times \text{Sponsor}_i \\
& + \alpha_{i,t} + \pi_{c,t} + \rho_{j,t} + \delta_{i,c,j} + \epsilon_{i,c,j,t},
\end{aligned} \tag{3}
$$

  - $\mathbf{US}_c$ is one for U.S. and zero otherwise.
  - $\mathbf{Sponsor}_i$ is equal to one for U.S. chip manufacturing firm i that sponsored H-1B petitions in fiscal year 2017 and zero otherwise.
  - $\alpha_{i,t}$ is firm-year FE, $\pi_{c,t}$ is country-year FE, $\rho_{j,t}$ is job category-year FE, and $\delta_{i,c,j}$ firm-country-job category FE.

Main Findings (IV): H-1B Exposure

Panel A: H-1B and Hiring Decisions (N=231,696)			
	Log($\text{Hiring}_{i,c,j,t}$)	Hiring $\text{Rate}_{i,c,j,t}$	Net Hiring $\text{Rate}_{i,c,j,t}$
	(1)	(2)	(3)
$\text{Treated}_j \times \text{Post}_t \times \text{US}_c \times \text{Sponsor}_i$	-0.09***	-0.02***	-0.03***
	(-4.09)	(-2.80)	(-4.27)
$\text{Treated}_j \times \text{Post}_t \times \text{US}_c$	-0.04***	-0.01	-0.00
	(-3.87)	(-1.59)	(-0.39)
$\text{Treated}_j \times \text{Post}_t \times \text{Sponsor}_i$	0.02	0.01	0.01
	(1.00)	(0.81)	(0.81)
$\text{Post}_t \times \text{US}_c \times \text{Sponsor}_i$	-0.01	-0.00	0.00
	(-0.48)	(-0.53)	(0.03)
Panel B: Fixed Effects			
Firm × Country × Job Category FE	Yes	Yes	Yes
Firm × Year FE	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes
Job Category × Year FE	Yes	Yes	Yes
R-squared	0.781	0.329	0.212

Main Findings (V): US Chip Manufacturing Degree Completions

Panel A: Bachelor & Pre-Bachelor Degrees

	$\text{Log(Total Completions}_{d,t})$	$\text{Log(US Resident Completions}_{d,t})$	$\text{Log(Non-US Resident Completions}_{d,t})$
	(1)	(2)	(3)
$\text{Treated}_d \times \text{Post}_t$	-0.14***	-0.14***	-0.17***
	(-3.87)	(-3.53)	(-4.83)
Degree FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	10,980	10,980	10,980
R-squared	0.974	0.974	0.944

Panel B: Graduate Degrees

	$\text{Log(Total Completions}_{d,t})$	$\text{Log(US Resident Completions}_{d,t})$	$\text{Log(Non-US Resident Completions}_{d,t})$
	(1)	(2)	(3)
$\text{Treated}_d \times \text{Post}_t$	-0.14***	0.05*	-0.29***
	(-3.46)	(1.82)	(-4.19)
Degree FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	9,044	9,044	9,044
R-squared	0.965	0.965	0.940

Conclusion

Key Findings:

- Protectionist policies intended to strengthen domestic chip manufacturing industry had opposite effect
  - Relocation of key functions overseas reduces control over critical technology
  - Entry-level talent gap creates structural weakness in innovation pipeline
- CHIPS Act faces challenges: a 16-year gap to fill projected new jobs!

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Broader Lessons:

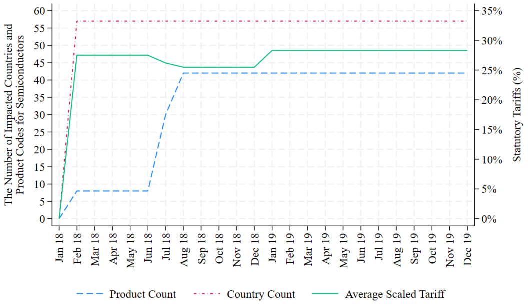
- Protectionist policies may backfire in industries with global talent dependencies
- Successful industrial policy must address talent development and immigration alongside manufacturing capacity

Appendix

U.S. Protectionism and Chip Manufacturing

- After decades of promoting open trade, the U.S. reembraced trade barriers in 2018.
  - Tariffs increased in 2018 from 2.6% of imported products to 16.6%, totaling $303B. (Fajgelbaum et al. 2020) Back

Semiconductor Import Tariffs



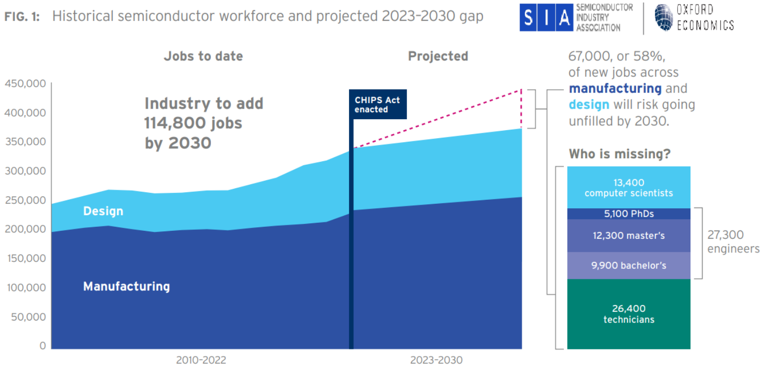
- "We are going to stamp everything we can 'Made in America,' *especially the computer chips*." (President Biden, 01/21/2022)

America's Chip Shortage: Manufacturing in Decline

A Sea of Ford Vehicles Waiting for Chips

- "We hardly make chips anymore." (Donald Trump, 09/12/2024)

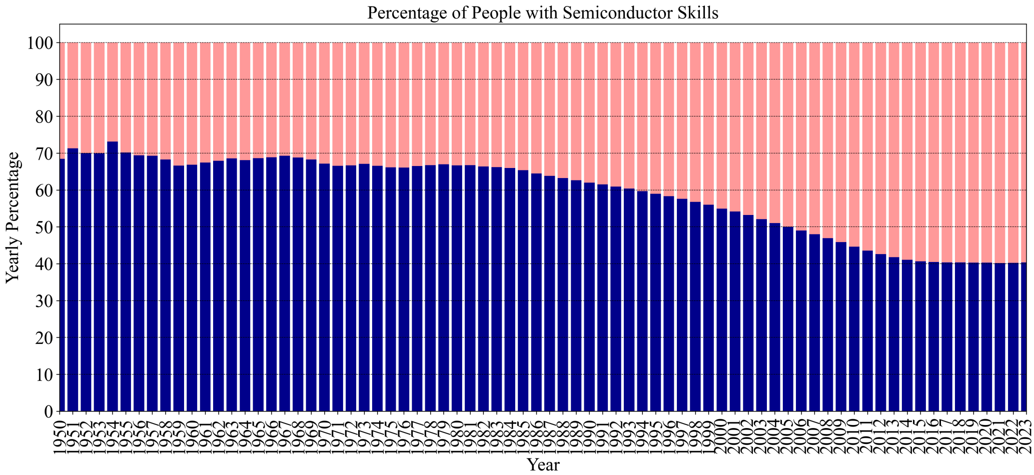
U.S. Protectionism and Chip Manufacturing



- The CHIPS and FABS Acts will create 115K jobs by 2030, but 67K of these could remain unfilled. (Source: SIA)
- "We need to hire more people. It is talent. It is people. I think that is where the biggest challenge will be." (Peter Wennink, ASML Holding CEO, Aug 2022)

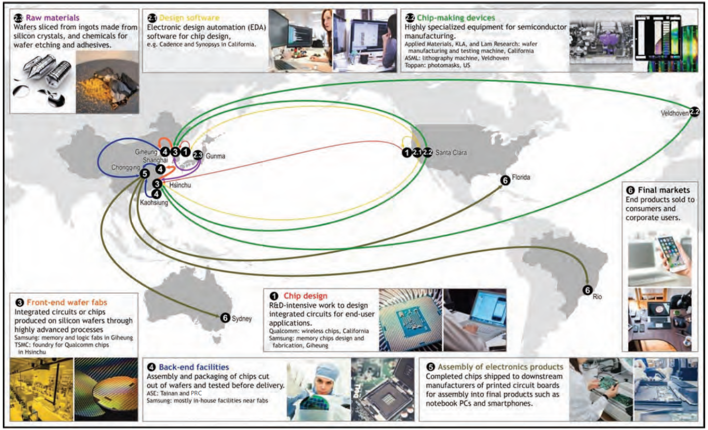
Chip Manufacturing Workforce

- Evidence From Nearly 1 Billion Employees and 70+ Years of Employment History:
    - U.S. is falling behind the rest of the world in terms of 150+ fundamental chip manufacturing skills.



Semiconductor Production Networks

Semiconductor Production Networks (Yeung 2022)



Value Added in the Semiconductor Value Chain by Activity

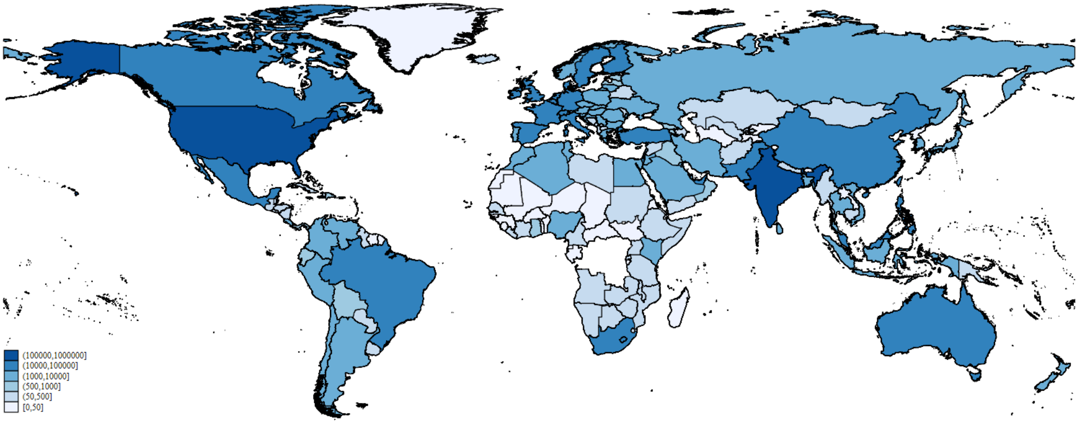
70% of graduate scientists and engineers in this sector come from overseas and they contribute to 90% of chip value in the U.S. (Source: SIA).

Value Added in the Semiconductor Value Chain by Activity

	US	Europe	PRC	S. Korea	Japan	Taiwan	IL/SG
Electronic **Design** Automation (EDA) & Core IP	72%	20%	3%	-	-	-	-
Design (Logic), Mostly fabless	67%	8%	6%	4%	4%	9%	3%
Design (Memory)	28%	-	-	58%	8%	4%	-
Design (Digital-Analog Optimization), fab-lite	37%	18%	9%	6%	21%	4%	6%
Design Subtotal	**49%**	**8%**	**5%**	**20%**	**9%**	**6%**	**3%**
Equipment	42%	21%	-	3%	27%	-	5%
Materials	10%	6%	19%	17%	14%	23%	12%
Wafer fabrication	11%	9%	21%	17%	16%	19%	7%
Assembly, Packaging & Testing (APT)	5%	4%	38%	9%	6%	19%	19%
Overall	**35%**	10%	11%	16%	13%	10%	5%

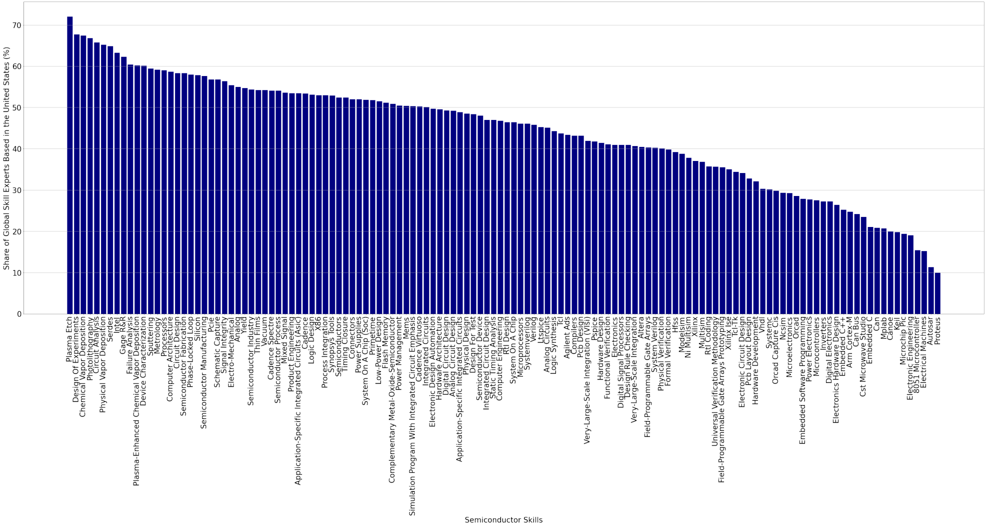
Source: 2023 Global Value Chain Development Report, WTO

Active Workforce with Semiconductor Skills



Back

Chip Manufacturing Skills (Active Workforce)



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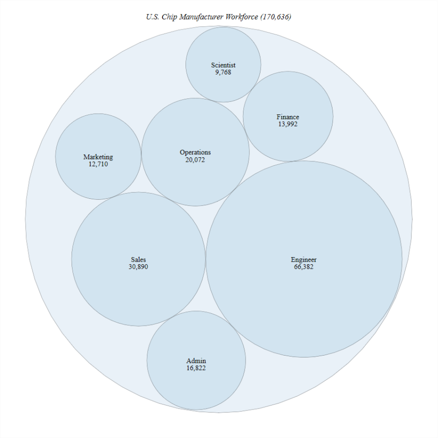
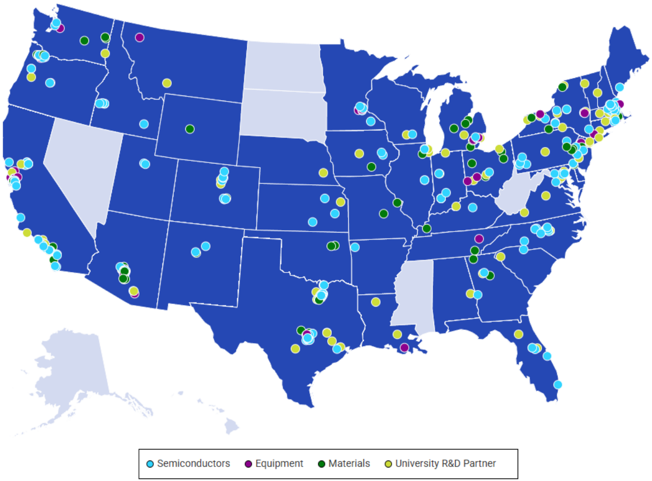
U.S. Chip Manufacturers Before the Protectionist Era



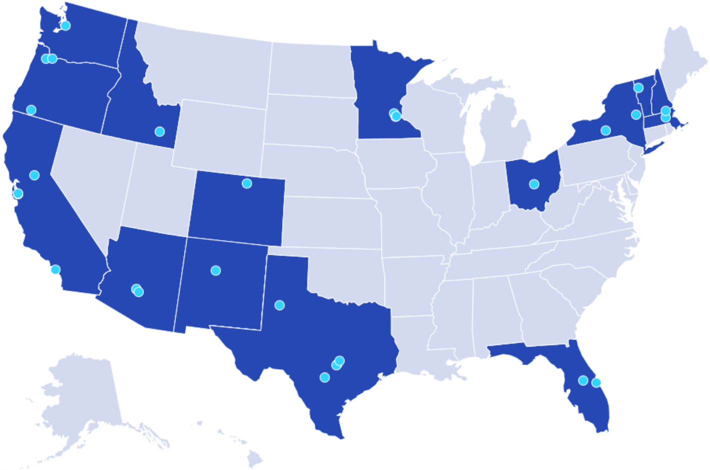
U.S. Equipment and Materials Facilities



Note: Semiconductors refers to Integrated Device Manufacturers (IDM), Outsourced Semiconductor Assembly and Test (OSAM) etc.

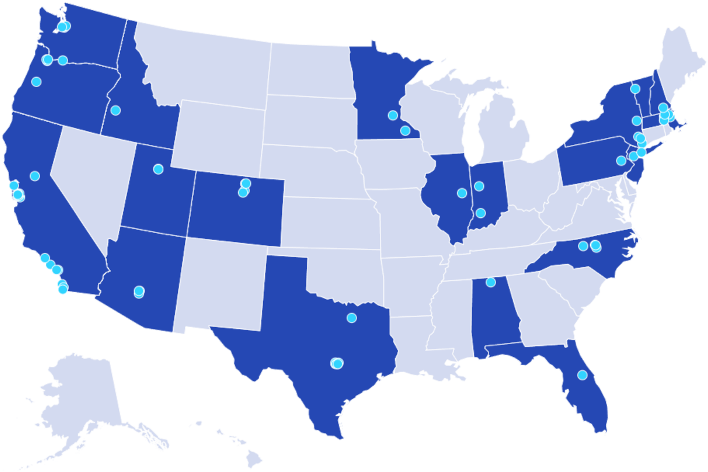
Back

U.S. Foundries (Chip Designers)



Source: SIA Back

U.S. Fabless Facilities (Chip Production)



Source: SIA Back

Data

- Our Revelio data contains near 1B employees around the world scraped as of March 2023.
  - For each employee, we observe current as well as past jobs, skills, location, education background, job category, seniority, various personal characteristics like estimated age and gender as well as employer characteristics.
- We produce three main data frames:
  - **Active Semiconductor Workforce:** 150+ chip skills.
  - **U.S. Chip Manufacturer Firms:** NAICS codes. Job category clusters. Firm-country-job category-year panel.
  - **Yearly Cohorts of Students Proficient in Chip Manufacturing Skills:** Data on classmates of people with chip skills. Country-job category-degree-year panel.
- Complementary datasets: **job postings** (LinkUp), **graduates by concentration** (U.S. Department of Education), **H-1B petitions** (USCIS), **firm and employee counts** (U.S. Census).

Related Literature

Our paper is closely related to several strands of literature.

- **Trade Frictions:**
  - Fajgelbaum et al. (2020); Amiti, Redding, and Weinstein (2019); Javorcik et al. (2022); Goldberg and Pavcnik (2016), Flaaen and Pierce (2019)
- **H-1B Visa, Hiring Restrictions:**
  - Doran, Gelber, and Isen (2022); Bernstein et al. (2025); D'Acunto et al. (2023); Chen, Hshieh, and Zhang (2021); Dimmock, Huang, and Weisbenner (2022); Glennon (2024a); Glennon (2024b); Kerr and Lincoln (2010); Morales (2023)
- **China Shock:**
  - **Firm Outcomes:** Hombert and Matray (2018); Bernard et al. (2012); Bernard, Jensen, and Schott (2006); Frésard and Valta (2016); Xu (2012); Cen et al. (2024)
  - **Labor/Politics:** Autor et al. (2014); Pierce and Schott (2016); Autor, Dorn, and Hanson (2013), Acemoglu et al. (2016); Caliendo, Dvorkin, and Parro (2019); Autor, Dorn, and Hanson (2021); Stanig and Colantone (2018); Cen, Fos, and Jiang (2023)

Active Workforce with Semiconductor Skills

		Panel A: Talent Count by Job Category								Panel B: Economic Characteristics			
Rank	Country	Total Emp.	Admin	Engineer	Finance	Marketing	Operations	Sales	Scientist	Tenure	RN	Salary	Seniority
1	United States	680,602	26,373	480,193	8,531	11,578	31,790	72,622	49,515	2,819.03	5.47	100,384.72	2.95
2	India	165,352	9,880	122,978	2,476	2,728	7,216	11,946	8,128	1,986.43	4.11	12,750.81	2.79
3	United Kingdom	88,527	3,728	57,927	1,033	2,121	5,687	10,888	7,143	2,543.08	5.7	58,110.89	3.02
4	Canada	63,376	2,784	44,752	758	1,223	2,770	6,229	4,860	2,407.60	5.58	61,114.26	2.70
5	Germany	43,597	1,272	28,759	261	682	1,725	4,665	6,233	2,037.52	5.7	79,377.39	2.97
6	France	38,024	1,476	25,422	349	916	1,572	3,600	4,689	2,089.61	6.08	52,630.56	2.92
7	Italy	30,545	1,236	20,301	237	697	1,557	3,660	2,857	2,832.06	5.15	55,721.32	2.81
8	Australia	30,199	1,456	20,703	407	603	1,523	3,264	2,243	2,286.17	5.88	80,238.36	2.79
9	China	28,664	1,930	16,330	306	586	1,817	5,320	2,375	3,330.75	3.66	28,236.07	3.19
10	Netherlands	28,320	1,180	18,415	225	755	1,501	2,913	3,331	2,513.68	6.31	64,067.80	2.89
11	Brazil	25,968	1,999	17,787	466	497	1,415	2,396	1,408	2,711.02	5.48	14,588.81	2.51
12	Israel	21,956	572	16,511	103	275	889	1,516	2,090	2,395.99	4.99	73,976.56	3.16
13	Spain	20,989	1,166	14,450	176	493	724	1,708	2,272	2,413.65	5.62	50,341.81	2.72
14	Singapore	18,648	607	12,547	291	244	1,238	2,215	1,506	2,395.93	4.86	46,346.70	3.2
15	Pakistan	18,232	1,820	12,539	198	380	925	1,290	1,080	2,453.57	4.13	13,330.76	2.64
16	Mexico	18,137	843	13,291	175	260	1,237	1,464	867	2,643.00	5.01	29,523.58	2.79
17	Sweden	17,869	561	12,241	83	269	837	1,691	2,187	2,164.33	6.55	66,023.95	2.91
18	Turkey	16,575	885	11,537	125	290	589	1,626	1,523	2,034.55	5.02	20,327.08	2.69
19	Taiwan	16,312	565	10,919	142	221	960	2,320	1,185	3,233.21	3.86	76,870.21	3.25
20	Malaysia	13,874	706	10,613	168	141	730	948	568	2,654.82	4.13	21,392.26	2.85
	Other Countries	285,143	16,541	195,247	2,763	5,505	13,647	26,783	24,657	2,524.85	5.07	48,186.61	2.78

Top 25 Employers of Active Chip Manufacturing Workforce

			Seniority						
Rank	Employer	Total Emp.	1	2	3	4	5	6	7
1	Intel Corp.	29,178	1,268	15,397	3,658	3,787	4,344	697	27
2	Government of the USA	13,361	4,893	5,590	891	1,001	914	41	31
3	Apple, Inc.	11,956	449	7,589	1,259	1,177	1,382	96	4
4	Amazon.com, Inc.	10,976	327	4,115	1,677	2,325	2,188	338	6
5	QUALCOMM, Inc.	10,427	78	2,233	2,330	3,461	1,783	539	3
6	Siemens AG	9,063	540	3,977	1,618	1,551	1,203	153	21
7	Alphabet, Inc.	7,877	119	5,561	716	701	686	91	3
8	Raytheon Technologies Corp.	7,455	674	2,784	1,000	1,390	1,497	108	2
9	Advanced Micro Devices, Inc.	7,148	79	2,420	1,234	1,887	1,130	392	6
10	Microsoft Corp.	6,849	150	4,274	582	640	948	243	12
11	NXP Semiconductors NV	6,546	296	2,319	1,068	1,246	1,362	248	7
12	Robert Bosch Stiftung GmbH	6,457	523	3,819	740	658	587	124	6
13	Infineon Technologies AG	6,196	373	2,534	817	891	1,377	183	21
14	Texas Instruments Incorporated	6,059	279	2,372	698	1,186	1,293	225	6
15	Samsung Electronics Co., Ltd.	5,996	395	2,615	580	666	1,520	213	7
16	Schneider Electric SE	5,560	572	2,532	727	810	771	138	10
17	Honeywell International, Inc.	5,434	593	3,064	489	609	586	85	8
18	STMicroelectronics NV	5,363	257	2,283	966	1,090	678	85	4
19	IBM Corp.	5,220	126	1,748	798	1,429	978	118	23
20	Analog Devices, Inc.	5,083	351	2,139	743	902	802	142	4
21	Broadcom, Inc.	5,076	159	1,537	647	802	1,799	127	5
22	NVIDIA Corp.	5,057	41	2,188	927	747	946	206	2
23	ABB Ltd.	4,960	378	2,313	693	809	703	57	7
24	Micron Technology, Inc.	4,883	236	1,260	595	1,056	1,427	302	7
25	Applied Materials, Inc.	4,693	163	1,343	680	936	1,236	316	19
	Other Employers	1,371,038	189,604	538,598	158,650	200,048	215,743	39,044	29,351

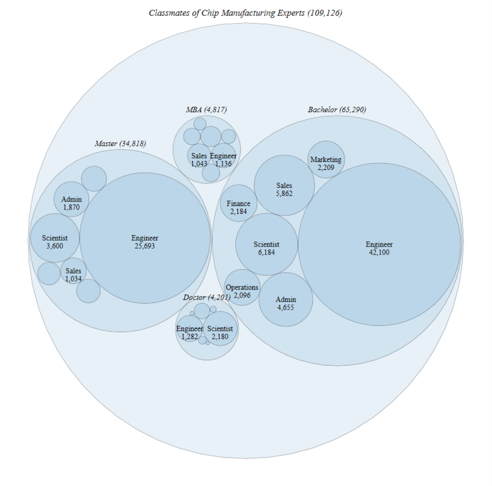
Industry Composition of Active Chip Manufacturing Workforce

Rank	Industry	NAICS	Total Emp.	Tenure	RN	Salary	Seniority
Panel A: Chip Manufacturing Industries							
1	Semiconductor and Related Device Manufacturing	334413	72,512	3,035.24	4.9	113,197.25	3.24
2	Semiconductor Machinery Manufacturing	333242	7,943	3,159.26	4.99	109,462.64	3.34
3	Instrument Mfg. for Electricity & Electrical Signal Testing	334515	6,514	3,719.29	4.73	101,481.78	2.97
4	Printed Circuit Assembly (Electronic Assembly) Manufacturing	334418	1,526	4,054.05	4.32	98,851.70	3.16
Panel B: Other Industries							
Rank	Industry	NAICS	Total Emp.	Tenure	RN	Salary	Seniority
1	Software Publishers	511210	35,572	1,811.93	6.42	122,691.03	3.22
2	Colleges, Universities, and Professional Schools	611310	27,661	2,905.84	5.3	78,354.48	2.46
3	Radio/TV Broadcasting & Wireless Communications Equipment Mfg.	334220	14,591	2,227.03	5.55	125,834.12	2.8
4	Internet Publishing and Broadcasting and Web Search Portals	519130	13,512	1,270.00	6.67	136,641.06	2.74
5	Search & Navigation System Instrument Mfg.	334511	12,868	2,978.82	5.28	96,177.27	2.72
6	Other Computer Related Services	541519	10,877	2,421.91	5.89	109,739.59	3.34
7	Engineering Services	541330	10,593	2,565.56	5.4	94,665.02	2.67
8	Surgical and Medical Instrument Manufacturing	339112	9,991	2,822.09	5.69	102,990.94	3.17
9	Other Electronic Component Manufacturing	334419	9,230	3,534.28	4.82	98,744.39	3.03
10	Automobile Manufacturing	336111	8,664	2,253.57	5.92	93,032.16	2.74

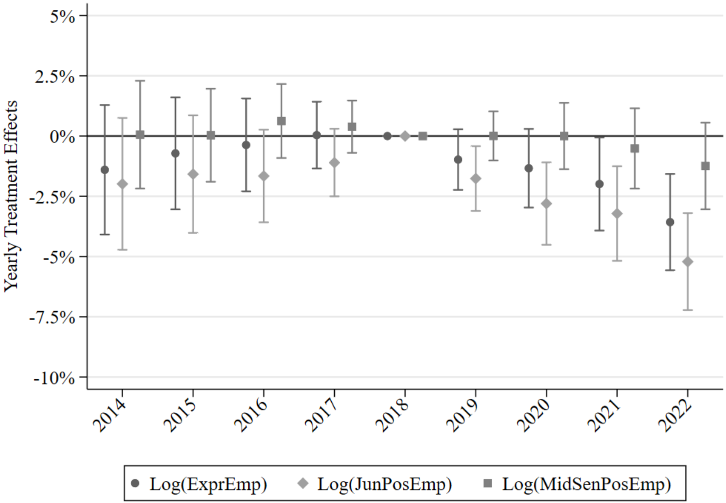
Summary Statistics

Panel A: U.S. Chip Manufacturer Workforce						
	N	Mean	Median	SD	P5	P95
Log(Emp$_{i,j,t}$)	68,949	1.76	1.39	1.47	0.00	4.86
Log(Hiring$_{i,j,t}$)	68,949	0.62	0.00	0.96	0.00	2.89
Log(Separation$_{i,j,t}$)	68,949	0.59	0.00	0.92	0.00	2.77
Log(Turnover$_{i,j,t}$)	68,949	0.88	0.69	1.16	0.00	3.50
Hiring Rate.$_{i,j,t}$	56,497	0.16	0.00	0.38	0.00	0.83
Separation Rate$_{i,j,t}$	56,497	0.12	0.00	0.22	0.00	0.50
Net Hiring Rate$_{i,j,t}$	56,497	0.04	0.00	0.38	-0.33	0.50
Turnover Rate$_{i,j,t}$	56,497	0.28	0.14	0.49	0.00	1.00
Log(FirstJobEmp$_{i,j,t}$)	68,949	0.95	0.69	1.23	0.00	3.50
Log(ExprEmp$_{i,j,t}$)	68,949	1.56	1.10	1.52	0.00	4.60
Log(JunPosEmp$_{i,j,t}$)	68,949	1.45	1.10	1.50	0.00	4.47
Log(MidSenPosEmp$_{i,j,t}$)	68,949	1.04	0.69	1.29	0.00	3.66
Panel B: Regional U.S. Chip Manufacturer Workforce						
	N	Mean	Median	SD	P5	P95
Log(Emp$_{i,c,j,t}$)	231,696	1.24	0.69	1.24	0.00	3.83
Log(Hiring$_{i,c,j,t}$)	231,696	0.36	0.00	0.72	0.00	2.08
Log(Separation$_{i,c,j,t}$)	231,696	0.33	0.00	0.67	0.00	1.79
Log(Turnover$_{i,c,j,t}$)	231,696	0.53	0.00	0.89	0.00	2.56
Hiring Rate.$_{i,c,j,t}$	166,411	0.12	0.00	0.27	0.00	0.75
Separation Rate$_{i,c,j,t}$	166,411	0.10	0.00	0.22	0.00	0.50
Net Hiring Rate$_{i,c,j,t}$	166,411	0.01	0.00	0.29	-0.46	0.50
Turnover Rate$_{i,c,j,t}$	166,411	0.23	0.00	0.39	0.00	1.00
Log(FirstJobEmp$_{i,c,j,t}$)	231,696	0.60	0.00	0.86	0.00	2.40
Log(ExprEmp$_{i,c,j,t}$)	231,696	1.02	0.69	1.20	0.00	3.58
Log(JunPosEmp$_{i,c,j,t}$)	231,696	0.98	0.69	1.15	0.00	3.43
Log(MidSenPosEmp$_{i,c,j,t}$)	231,696	0.65	0.00	0.93	0.00	2.71
Panel C: Educational Cohorts of Chip Manufacturing Employees						
	N	Mean	Median	SD	P5	P95
Log(Classmates$_{c,d,j,t}$)	35,496	1.21	0.69	1.56	0.00	4.44
Log(Avg. Salary$_{c,d,j,t}$)	35,496	6.02	9.42	5.14	0.00	11.29
Avg. Seniority$_{c,d,j,t}$	35,496	1.51	1.50	1.56	0.00	4.33
Log(Tenure$_{c,d,j,t}$)	35,496	3.18	5.02	2.79	0.00	6.19

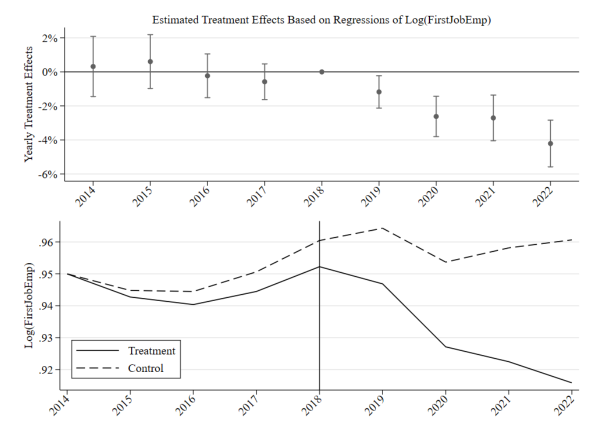
Total Employment by Job Category in U.S. Chip Manufacturing Firms



Effect Dynamics: Remaining Variables

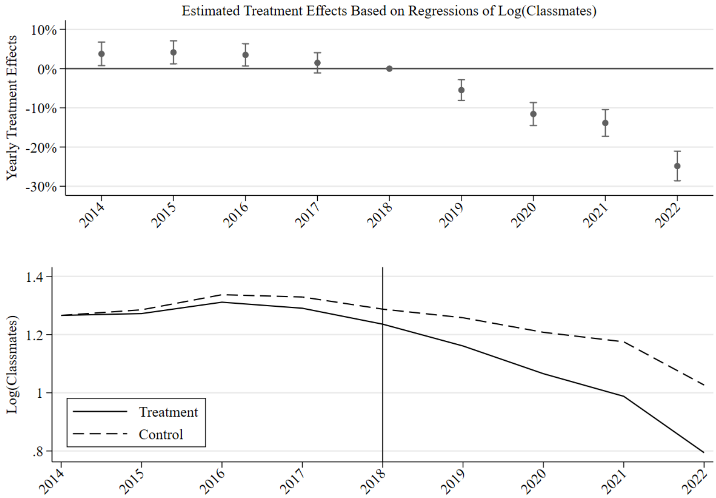


Effect Dynamics: First-Job Employees at U.S. Chip Manufacturers

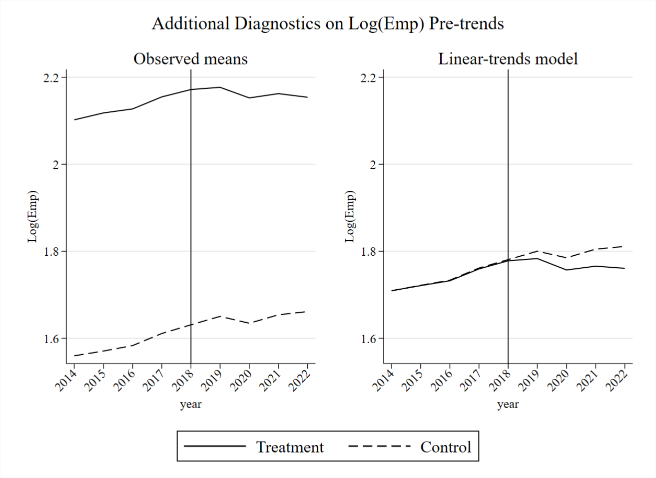


Means

Effect Dynamics: Shift Away from Science and Engineering



Effect Dynamics: Additional Diagnostics (I)



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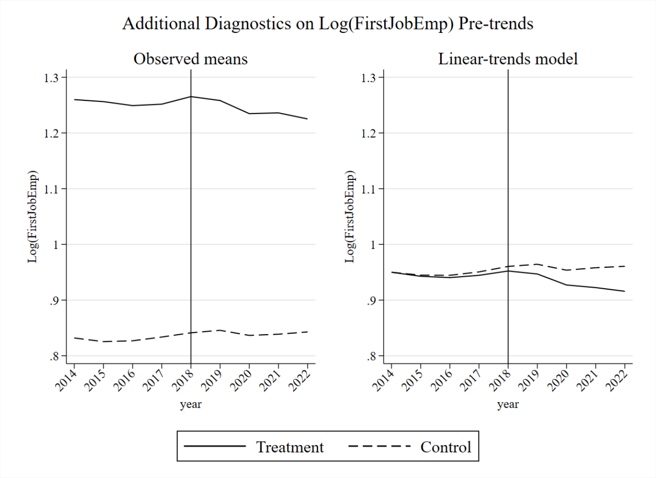
Effect Dynamics: Additional Diagnostics (II)



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U.S. Job Postings for Scientists and Engineers

	Panel A: Job Posts for Engineers and Scientists		
	Log(JobPostCreation$_{j,t}$)	Log(JobPostDeletion$_{j,t}$)	Log(ActiveJobPosts$_{j,t}$)
	(1)	(2)	(3)
Treated$_j$ $\times$ Post$_t$	0.11**	0.11**	0.13***
	(2.40)	(2.49)	(2.82)
Job Category FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	432	432	432
R-squared	0.981	0.981	0.983
	Panel B: Findings After Excluding Job Posts for Software Engineers, IT, and Data Science		
	Log(JobPostCreation$_{j,t}$)	Log(JobPostDeletion$_{j,t}$)	Log(ActiveJobPosts$_{j,t}$)
	(1)	(2)	(3)
Treated$_j$ $\times$ Post$_t$	0.12**	0.12***	0.13***
	(2.69)	(2.70)	(3.18)
Job Category FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	387	387	387
R-squared	0.981	0.981	0.983

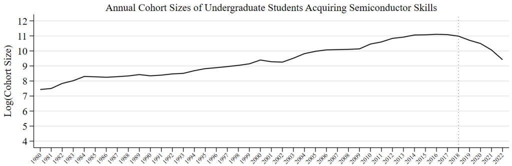
Main Findings (V): Student Cohort Sizes Obtaining Chip Manufacturing Education

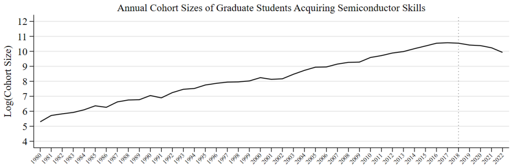
	Log(Classmates$_{c,d,j,t}$)			
	(1)	(2)	(3)	(4)
Treated$_j$ × Post$_t$	-0.14***	-0.15***	-0.14***	-0.17***
	(-11.92)	(-13.61)	(-11.63)	(-14.10)
Country × Job Category × Degree FE	Yes	Yes	Yes	Yes
Year FE	Yes	No	No	No
Country × Year FE	No	Yes	No	Yes
Degree × Year FE	No	No	Yes	Yes
Observations	35,496	35,424	35,496	35,424
R-squared	0.940	0.950	0.945	0.956

Figure

Student Cohort Sizes Obtaining Chip Manufacturing Education in the U.S.

- A sharp decline in student cohorts after 2018.
  - In 2018, 131,937 undergraduate engineering degrees were awarded in the U.S., with ME leading at 31,936, followed by CS at 19,082, and EE at 13,767. (ASEE)





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Semiconductor Talent Crunch