Technological decoupling? The impact on innovation of US restrictions on Chinese firms

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European Winter Meeting of the Econometric Society

The authors' findings, interpretations, and conclusions are entirely theirs. They do not necessarily represent the views of the IBRD/World Bank and its affiliated organizations, or those of the Executive Directors of the World Bank or the governments they represent.

Introduction

- China has made rapid progress in innovation since it acceded to the WTO and opened to international markets for trade, investment, and innovation

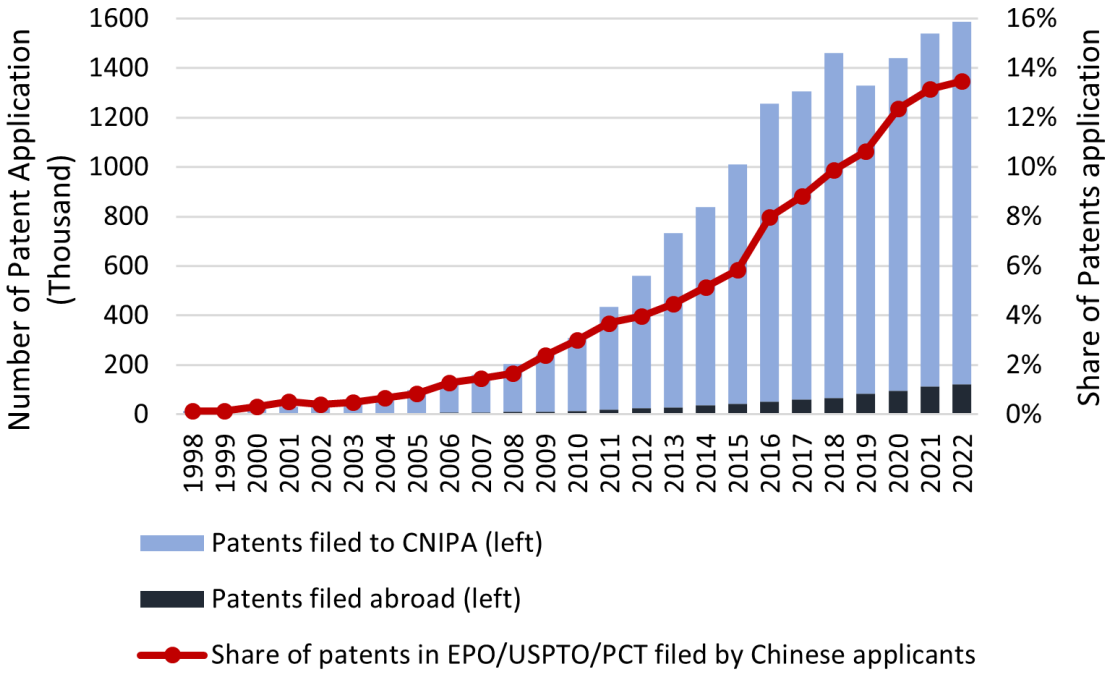


Figure 1: Rapid growth in China's innovation

Introduction

- Access to international markets $\rightarrow$ influx of foreign firms $\rightarrow$ technology diffusion and innovation (Branstetter, 2012; Jiang et al., 2018).
- But technology has become a focal point for rising tensions between the US and China (Goes and Bekkers, 2022)
- Concerns over technology transfer, intellectual property theft (and human rights violations) $\rightarrow$ Entity List, started in 1997, expanded in 2018
  - The Entity List subjects to licensing requirements for exporting, re-exporting, and/or transferring specific technologies or goods
- Question: What is the impact of US exports restrictions and licensing requirements on Chinese firms' innovation?

Data: Sample Construction

- **Data Source**
  - PATSTAT Global 2022 Spring Version Patent information: application dates, applicant's name and location, technology fields, forward/backward citations
  - U.S. dept. of Commerce: Entity List: entity's name and location
- **Sample construction**
  - Exclude entities located in Xinjiang Province
  - Continuous innovating firms: patenting $\geq$ 3 years from 2006 to 2020
  - 28,000 Chinese firms, 375 sanctioned Entities

Measuring innovation outcomes

1. Overall patent counts: earliest patent filing I.D. for multiple filing
2. International Filings: patents filed either at USPTO, EPO, or WIPO
3. Scientific Importance:
   - Triadic patents: concurrently field in EPO, USPTO and JPO
   - High-tech patents: classified based on EPO criteria using IPC code
4. Quality: forward citations received within 3 years of its publication date, adjusted by application-year-tech-class-patent-office-domestic cohort

Balance in innovation outcomes?

Matching:

- Similar patent trajectories before being sanctioned
- Patent age, patent stock, and previous year's patent application

	Sanctioned		Unsanctioned		Difference	
	Mean	Std. Dev	Mean	Std. Dev	Diff	Std
Total Patents	30.63	62.78	27.99	63.12	2.63	(3.60)
High-Tech Patents	14.38	28.25	12.01	29.95	2.37	(1.67)
Domestic Patents	30.48	62.56	27.86	63.05	2.62	(3.59)
EPO/USPTO/PCT Patents	4.90	15.56	3.65	18.96	1.26	(0.99)
Triadic Patents	0.51	2.97	0.22	1.51	0.29**	(0.13)
Controls						
Patent Age	5.07	3.08	5.07	3.16	0.00	(0.18)
Patent Stock (log)	2.53	1.68	2.53	1.65	0.00	(0.10)
Prior Average Paent App.	0.47	0.54	0.48	0.57	0.00	(0.00)
Dummy Patent	0.78	0.42	0.78	0.42	0.00	(0.02)
Lagged Total Patent App (log)	2.02	1.58	2.02	1.60	0.00	(0.09)

U.S. sanctions negatively affect Chinese innovation..

$$y_{ij,t} = \beta \times Treatment_{ij} \times Post_{ij,t} + \gamma X_{ij,t-1} + \psi_i + \delta_{j,t} + \varepsilon_{it}$$

- Controls: patent stock at $t-1$, dummy whether patented at $t-1$.
- Sample year: 2006-2020, drop firms being sanctioned before 2013

	Total	International	Tradic	High-Tech
	(1)	(2)	(3)	(4)
Treatment×Post	-0.104***	-0.171***	-0.077***	-0.036
	(0.026)	(0.012)	(0.013)	(0.037)
No. Obs.	6,334	6,334	6,334	6,334
R-squared	0.63	0.611	0.392	0.645
Sector-year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

..even when adjusting for quality..

- Quality adjustment to compare patents across different technology fields and levels of technological complexities
- Patent stock is calculated as a deflated sum of past citation-adjusted patent applications up to that year

	Total	International	Tradic	High-Tech
	(1)	(2)	(3)	(4)
Treatment×Post	-0.151***	-0.193***	-0.092***	-0.102*
	(0.05)	(0.012)	(0.024)	(0.053)
No. Obs.	6,334	6,334	6,334	6,334
R-squared	0.621	0.55	0.361	0.616
Sector-year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

.. or using staggered DiD (total patents)

$$y_{ij,t} = \sum_{k=-5}^{5} \alpha_k \times Treatment_{ij} \times Post_{ij,t+k} + \gamma X_{ij,t-1} + \psi_i + \delta_{j,t} + \varepsilon_{it}$$

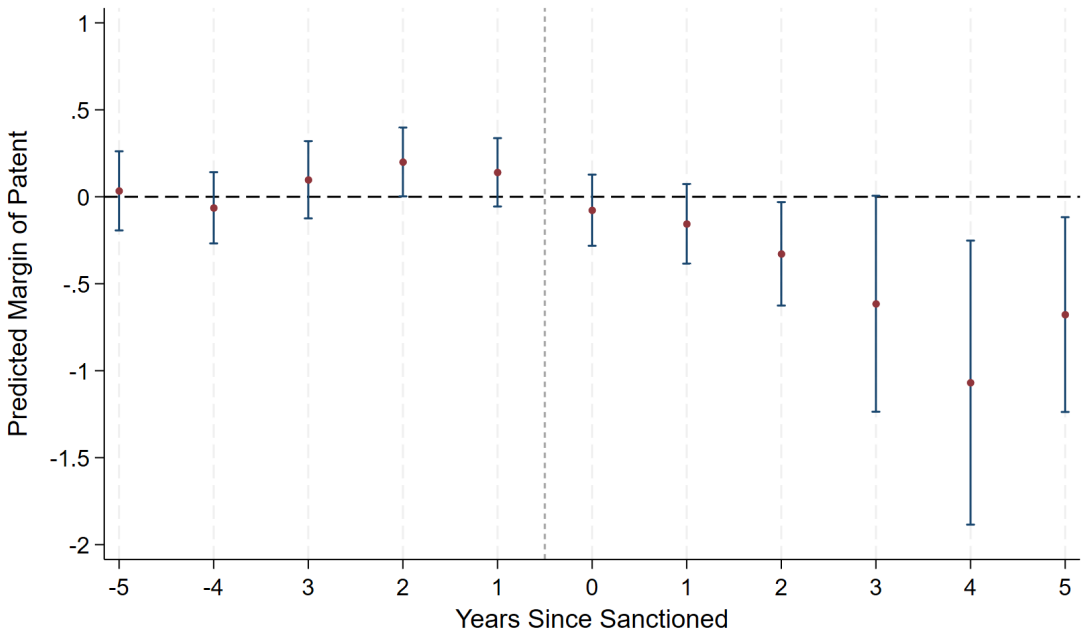


Figure 2: Effect of U.S. sanctions on **total** patent applications

.. or using staggered DiD (high tech)

$$y_{ij,t} = \sum_{k=-5}^{5} \alpha_k \times Treatment_{ij} \times Post_{ij,t+k} + \gamma X_{ij,t-1} + \psi_i + \delta_{j,t} + \varepsilon_{it}$$

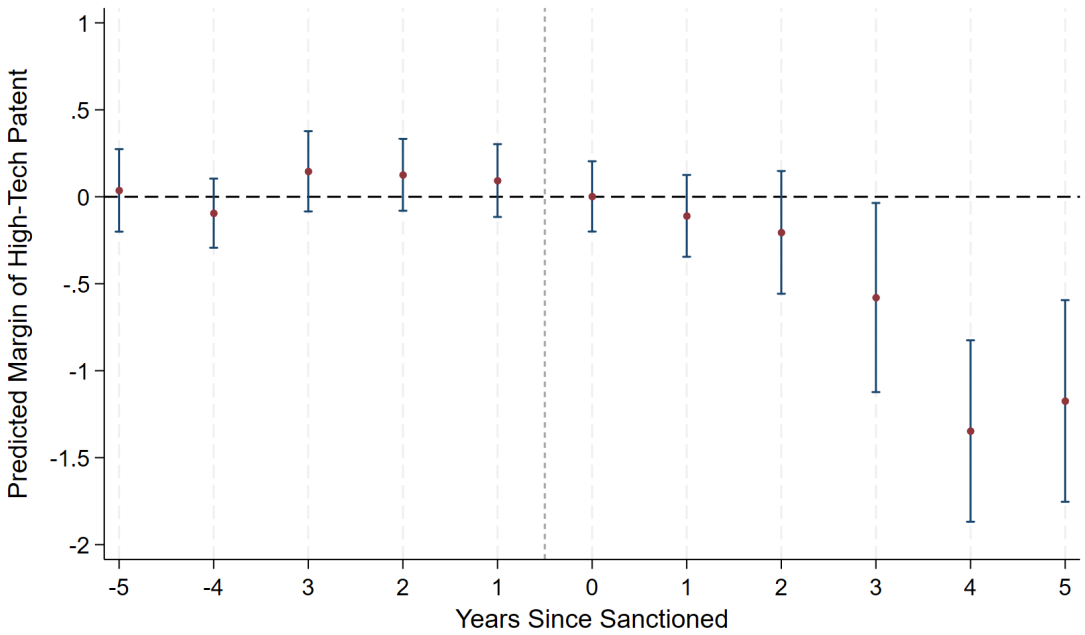


Figure 3: Effect of U.S. sanctions on **high-tech** patent applications

Mechanism: The importance of collaboration

- Knowledge can diffuse through:
  - Trade flows (Grossman and Helpman 1990, Coelli et al, 2022)
  - Foreign Investment (Liu 2009, Gorodnichenko et al, 2014)
  - R&D collaborations (Alnuaimi et al, 2012; Kerr and Kerr, 2018)
- International collaboration important for knowledge transfer from advanced to developing countries
  - access to frontier knowledge, improving innovation capacity (Giuliani et al, 2016)
  - introduction to diverse knowledge, sparking creativity (Singh and Fleming, 2010)
  - promoting current and long-term innovation (Branstetter et al, 2015; Azoulay et al, 2021)

Int'l collaborations matter for Chinese patenting activity

- Patent production function (Akcigit et al., 2018): $y_{ij,t} = z_{ij,t}^{1-\eta} n_{ij,t}^{\eta}$
- Estimate patent elasticity on collaboration η:
  $y_{ij,t} = \sum_{r=1}^{4} \eta_r Col_{r,it} + \gamma X_{ij,t-1} + \psi_i + \delta_{j,t} + \varepsilon_{it}$

	Current Collaboration			Past Collaboration		
	Total	International	High-Tech	Total	International	High-Tech
	(1)	(2)	(3)	(4)	(5)	(6)
U.S.	0.147***	0.057***	0.130***	0.472***	0.129***	0.428***
	(0.010)	(0.010)	(0.011)	(0.021)	(0.028)	(0.017)
Euro+	0.102***	0.082***	0.068***	0.087*	0.121***	0.138***
	(0.026)	(0.006)	(0.006)	(0.046)	(0.017)	(0.024)
Adv. Asia	0.143***	0.074***	0.123***	0.239***	0.111***	0.208***
	(0.028)	(0.011)	(0.024)	(0.014)	(0.013)	(0.036)
No. Obs.	5,317	5,317	5,317	5,317	5,317	5,317
R-Squared	0.687	0.652	0.706	0.716	0.658	0.730
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Se-year FE	Yes	Yes	Yes	Yes	Yes	Yes

Sanctions lead to fewer collaborations w/ US

$$col_{ij,t} = \beta \times Treatment_{ij} \times Post_{ij,t+k} + \gamma X_{ij,t-1} + \psi_i + \delta_{j,t} + \varepsilon_{it}$$

	Share of Patents Collaborated with			Average Collaborator per Patent		
	U.S.	European+	Advanced EAP	U.S.	European+	Advanced EAP
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment×Post	-0.117***	-0.048***	0.028	-0.115***	-0.041**	0.012
	(0.038)	(0.011)	(0.070)	(0.038)	(0.009)	(0.052)
No. Obs.	5,442	5,442	5,442	5,442	5,442	5,442
R-squared	0.401	0.198	0.377	0.367	0.174	0.398
Sector-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Firms w/ prior US collaborations see larger drop in patenting

- 86% of sanctioned firms have prior-sanction US collaboration

	Patent Application (Intensive Margin)			Average Collaborator per Patent		
	Total	Intl.	High-Tech	U.S.	European+	Advanced EAP
	(1)	(2)	(3)	(4)	(5)	(6)
Treat×Post	0.096	0.134	0.073	0.257**	-0.070**	0.305***
	(0.102)	(0.102)	(0.081)	(0.091)	(0.023)	(0.124)
Treat×Post×pre-US	-0.267**	-0.432***	-0.296***	-0.446***	0.035*	-0.351**
	(0.104)	(0.104)	(0.075)	(0.134)	(0.019)	(0.158)
No. Obs	5,442	2,040	3,690	5,442	5,442	5,442
R-squared	0.653	0.516	0.61	0.379	0.198	0.399
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	Yes	Yes	Yes

Top innovators see lower drop in patenting

- High innovation capacity (top 10% of innovating firms in its sector) $\rightarrow$ less reliant on U.S. $\rightarrow$ less negative impact

	Patent Application		
	(1) Total	(2) Intl.	(3) High-Tech
Treatment×Post	-0.163***	-0.223***	-0.058
	(0.040)	(0.039)	(0.267)
Treatment×Post×Top	0.156***	0.140*	0.060
	(0.037)	(0.078)	(0.046)
No. Obs	6,334	6,334	6,334
R-squared	0.63	0.611	0.645
Firm FE	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes

Sectors near frontier or reliant on domestic tech suffer less

- Distance: $\frac{\text{CN patent stock}}{\text{US+CN patent stock}}$
- Sourcing: share of citations to CN patents in each 2-digit ISIC sectors
- Adoption: 1- share of patents first filed outside of CN
- Collaboration: share of patents filed by CN firms w/ only CN inventors

	(1)	(2)	(3)	(4)
	Patent Application			
Treatment×Post	-0.666***	-1.416**	-3.199**	-8.297*
	(0.195)	(0.511)	(1.417)	(4.290)
Treatment×Post×TechDist	0.033***			
	(0.009)			
Treatment×Post×Sourcing		0.023**		
		(0.008)		
Treatment×Post×Adoption			0.039**	
			(0.017)	
Treatment×Post×Collaboration				0.087*
				(0.045)
No. Observation	6,334	6,334	6,334	6,334
R-Squared	0.631	0.631	0.631	0.630
Firm FE	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	Yes

Any spillover effect?

- Sanctioned IPC field if:
  - the sanctioned firms are among the top 10% of Chinese innovating firms in their primary IPC field
  - the sanctioned firms patented $>=$ 10% of total patents in their primary IPC field
- 40 sanctioned IPC fields, mostly semiconductor and electrical-related sectors
- 10,000 Chinese firms and 7,800 US firms patented in the sanctioned IPC after sanctions were imposed

CHN patenting in sanctioned IPC ↓ patent app..

	Patent Application			Average Collaborator		
	Total	Intl.	High-Tech	U.S.	European+	Adv. Asia
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment×Post	-0.069**	-0.095***	-0.035***	-0.025	0.001	0.030**
	(0.026)	(0.011)	(0.012)	(0.015)	(0.004)	(0.010)
No. Obs	193,851	193,851	193,851	158,421	158,421	158,421
R-squared	0.410	0.425	0.481	0.409	0.269	0.390
R-squared	0.409	0.425	0.498	0.407	0.36	0.449
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	Yes	Yes	Yes

.. spillovers magnified w/ prior US collab

	Patent Application			Average Collaborator per Patent		
	Total	Intl.	High-Tech	U.S.	European+	Advanced EAP
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment×Post	0.041	0.125***	0.084**	0.357***	-0.015***	-0.066
	(0.026)	(0.034)	(0.035)	(0.025)	(0.005)	(0.042)
Treatment×Post×pre-US	-0.134**	-0.268***	-0.146**	-0.464***	0.020**	0.116**
	(0.055)	(0.033)	(0.055)	(0.026)	(0.009)	(0.051)
No. Obs	193,851	193,851	193,851	158,421	158,421	158,421
R-squared	0.410	0.428	0.481	0.410	0.269	0.390
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes	Yes	Yes	Yes

Spillovers through the tech network

- *Downstream* firms using tech in sanctioned IPC fields
  $Downstream_{j,t} = \sum_{n \neq j} \frac{\text{Citations made by } j \text{ to } n}{\text{total citations made by } j} \times sanction_{n,t}$
- *Upstream* firms producing tech used by sanctioned fields
  $Upstream_{j,t} = \sum_{n \neq j} \frac{\text{Citations made by } n \text{ to } j}{\text{total citations to } j} \times sanction_{n,t}$

	Total	International	High-Tech
	(1)	(2)	(3)
Downstream degree	-0.547**	-0.171	0.034
	(0.278)	(0.190)	(0.220)
Upstream degree	0.531**	0.237	0.003
	(0.248)	(0.168)	(0.192)
No. Observation	192,262	192,262	192,262
R-squared	0.411	0.426	0.484
Firm FE	Yes	Yes	Yes
Sector-year FE	Yes	Yes	Yes

US sanctions indirectly affect US firms too

U.S. firms in sanctioned technology field

- Breakup collaboration, supply chain disruption → negative impact
- Limit tech. access to Chinese firms → reduced competition → opportunity

Post-sanction: decrease patent app. if with prior-sanction CN collaboration

	Total	Intl.	High-Tech	Total	Intl	High-Tech
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment×Post	-0.003	-0.016	-0.006	0.209***	0.218***	0.177***
	(0.012)	(0.017)	(0.010)	(0.018)	(0.018)	(0.024)
Treatment×Post×Pre-CN				-0.266***	-0.293***	-0.229***
				(0.014)	(0.011)	(0.022)
No. Obs.	219,728	219,728	219,728	219,728	219,728	219,728
R-squared	0.224	0.232	0.362	0.226	0.236	0.365
Sector-year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Main findings/Conclusions

- Impact of U.S. sanctions on sanctioned firms
  - Significant **negative impact** on the patents' quantity and quality
  - Negative effect primarily driven by **reduced collaboration** with US
  - Firm's own innovation capacity could mitigate the negative impact
- **Negative spillover effect** through innovation network or supply chain
  - CN firms in sanctioned sectors w/ prior-sanction US collaboration
  - CN firms in downstream sectors relying on sanctioned sectors
  - US firms in sanctioned sectors w/ prior-sanction CN collaboration

Thank you !

- ★ Questions? Comments? Email us at francesca.denicola@imd.org or ycao5@worldbank.org

Extra slides

Sample Construction

Merging two samples:

- Affected corporations: exact entities + subsidiaries/ affiliates

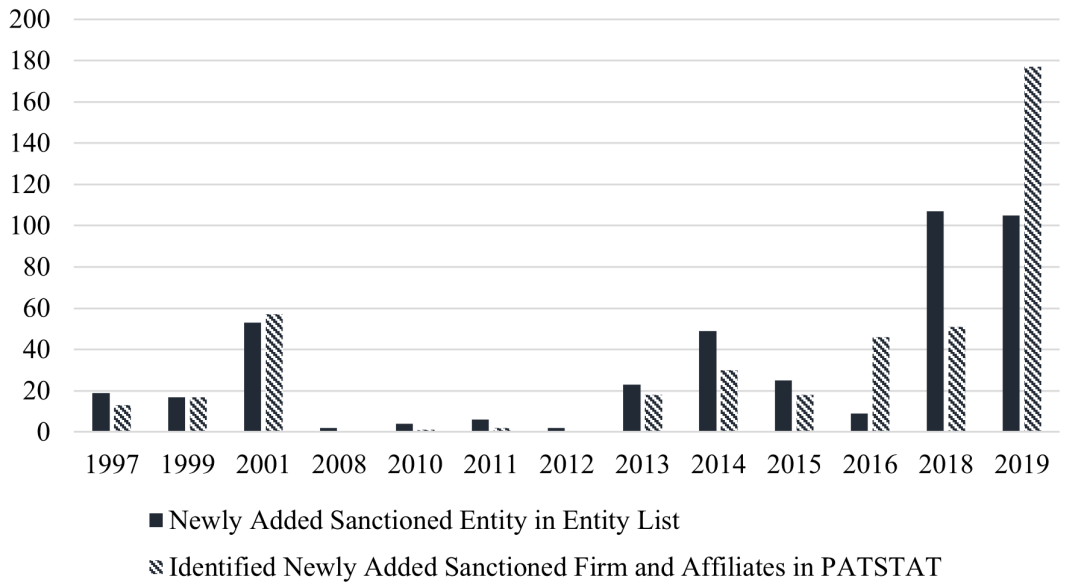


Figure 4: Newly Added Sanctioned Firms in Entity List and PATSTAT

Main Measurement: innovation outcome

	Firms in the Entity List			other Firms in PATSTAT		
	Mean	Medium	Std. Dev.	Mean	Medium	Std. Dev.
Total Patents	81.46	6.00	501.43	14.08	2.00	108.95
Domestic Patents	79.87	5.00	486.94	13.90	2.00	108.54
EPO/USPTO/PCT Patents	39.60	0.00	339.22	1.65	0.00	18.23
High-Tech Patents	46.59	1.00	324.80	4.21	0.00	39.59
Triadic Patents	3.51	0.00	37.41	0.19	0.00	2.27
Basic Patents	27.65	1.00	188.52	4.98	0.00	48.46
Advanced Basic Patents	14.90	0.00	115.76	2.56	0.00	25.66
Patent Stock	120.77	4.87	898.56	23.10	4.43	187.56
Patent Quality	1.28	0.91	1.38	1.64	1.00	3.31
Priori Average Patent Application	0.79	0.00	8.20	0.23	0.00	2.97
Patent Age	9.08	9.00	3.60	12.16	10.00	7.22
No of Observations	2,138			347,521		

Patterns on cross-border collaboration

- Decline in US collaboration since 2012
- Since 2016 CHN collaborate more w/ EU+ and EAP

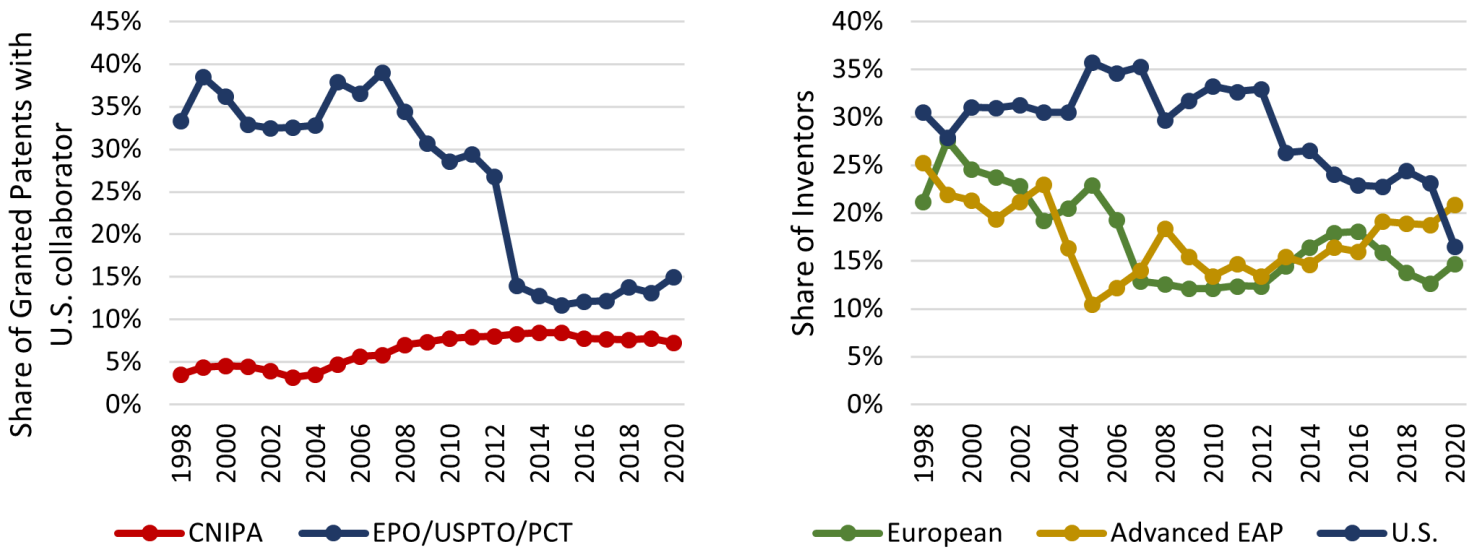


Figure 5: The importance of U.S. collaboration decreased in the recent decade

Spillover Effect: Identify treatment group

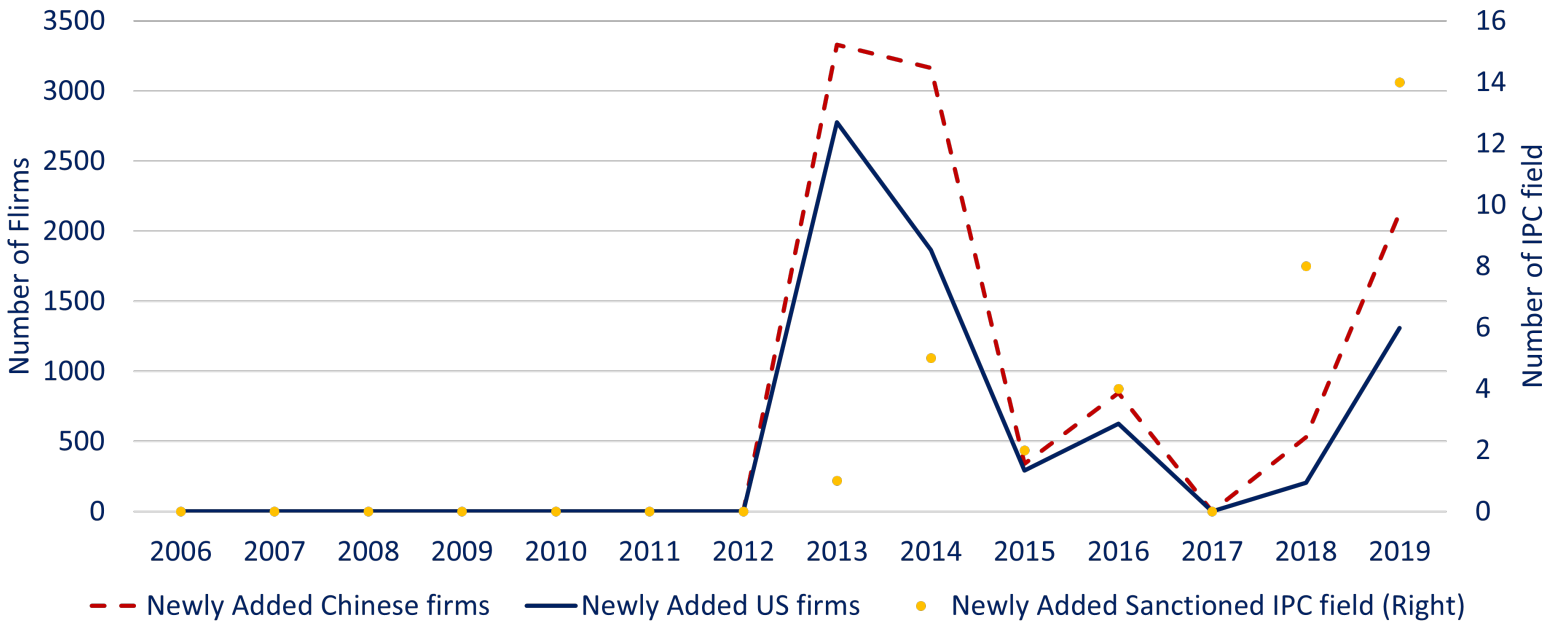


Figure 6: Newly added Sanctioned IPC and Firms under Sanctioned IPC

Distribution of Chinese firms across sanctioned IPC

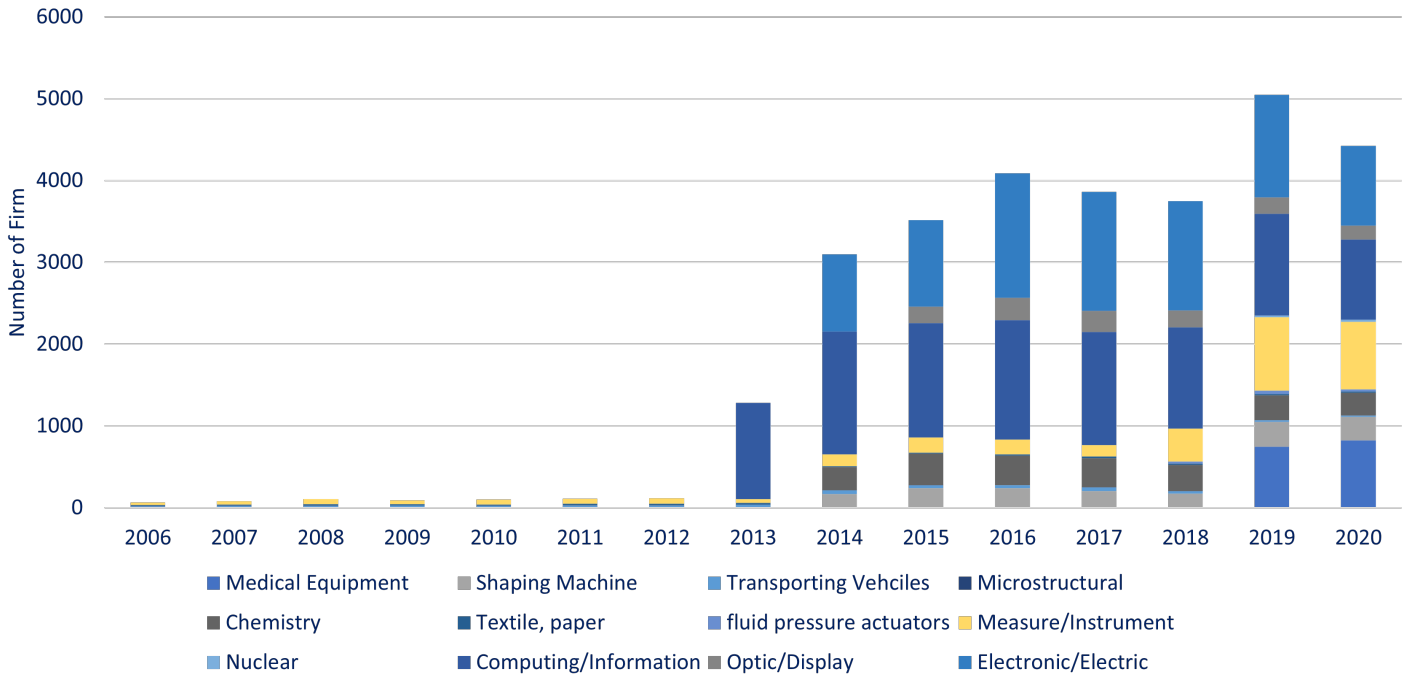


Figure 7: Number of Chinese Firms under Sanctioned IPC

Distribution of US firms across sanctioned IPC

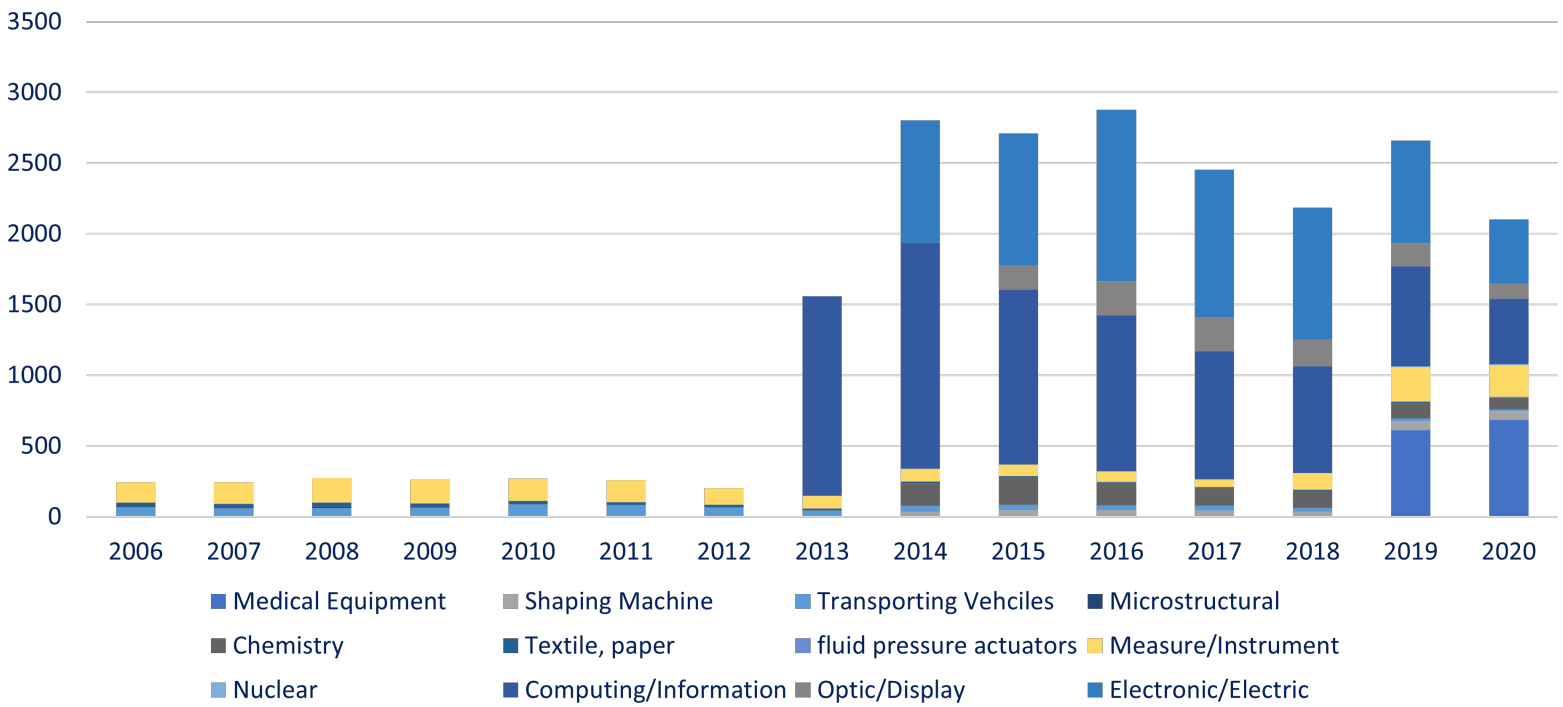


Figure 8: Number of U.S. Firms under Sanctioned IPC

Spillover Effect: indirectly connected firms

U.S. firms in sanctioned technology field

- Breakup collaboration, supply chain disruption → negative impact
- Limit tech. access to Chinese firms → reduced competition → opportunity

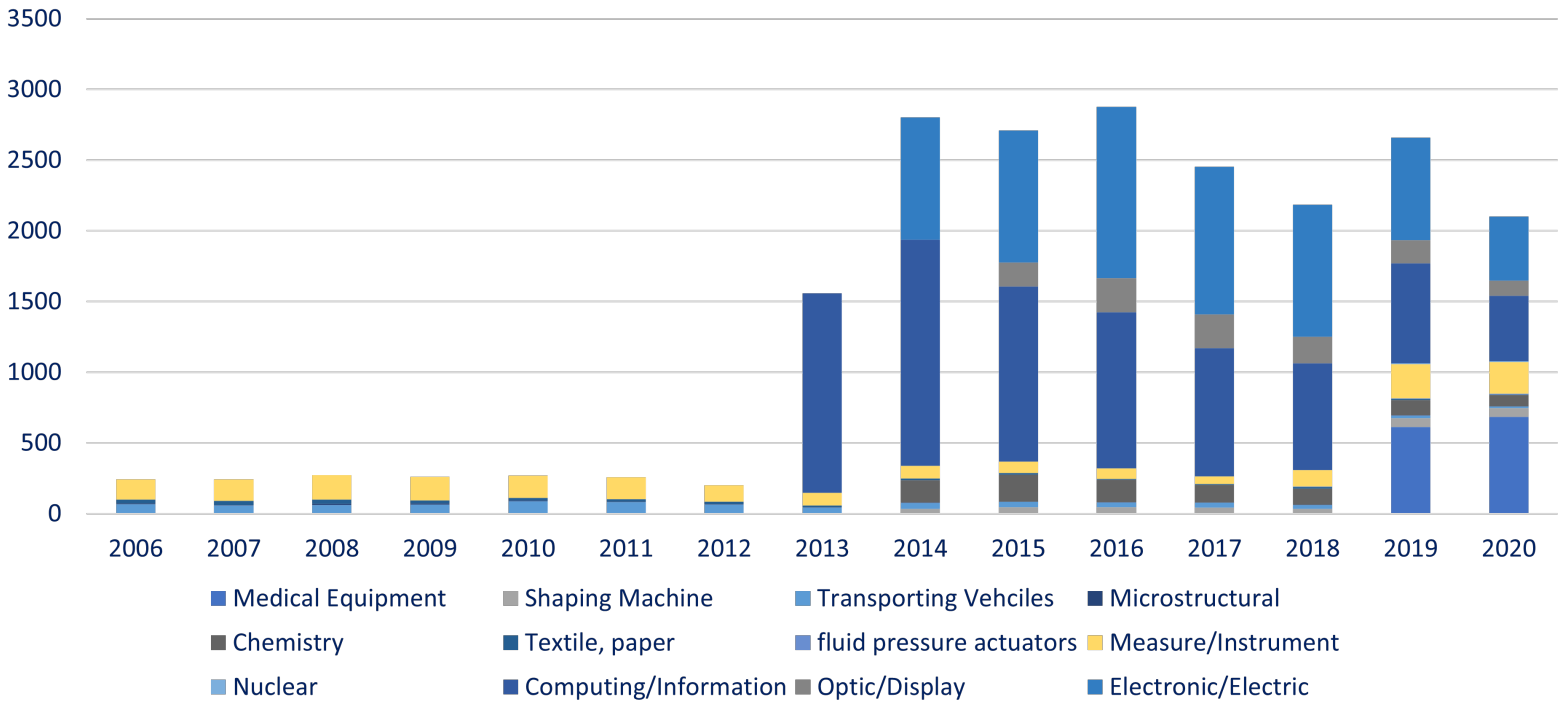


Figure 9: Number of US Patenting Firms Under the Sanctioned Technology Field