China Economic Review 92 (2025) 102425

Contents lists available at ScienceDirect

China Economic Review

journal homepage: www.elsevier.com/locate/chieco

The cross-border spillover effect of U.S. government subsidies on firms' innovation: Evidence from the Sino-US supply chain

Beibei Hu [a], Qiao Luan [b], Kai Wang [c,*], Linke Zhu [b]

[a] School of Business, Shanghai University of International Business and Economics, Shanghai, China
[b] College of Business, Shanghai University of Finance and Economics, Shanghai, China
[c] Collaborative Innovation Center of China Free Trade Zone, Shanghai University of Finance and Economics, Shanghai, China

ARTICLE INFO

Keywords:
U.S. government subsidies
Firms' innovation
Sino-US supply chain
Cross-border spillover effect

ABSTRACT

This study systematically assessed the cross-border spillover effects of U.S. government subsidies on the Sino-US supply chain using a multi-period difference-in-differences approach. Our findings indicate that the U.S. government's subsidy policies had an overall positive effect on the innovation of related Chinese firms throughout the supply chain. However, these policies had a significant negative impact on the innovation performance of Chinese suppliers to U.S. subsidized firms, while positively affecting the innovation performance of Chinese customers and competitors. Additionally, we found that the U.S. government's subsidy policy has facilitated the reestablishment of the U.S. industrial chain, indirectly promoting the development of production advantages for downstream firms in China. This has compelled the Chinese government to increase subsidies for related competitive industries as well.

1. Introduction

Countries worldwide extensively employ government subsidies to foster domestic technological innovation, enhance international competitiveness, and bolster industry growth (Irwin & Klenow, 1996; Meriggi, Bulte, & Mobarak, 2021; Schwartz & Clements, 1999). Particularly following the financial crisis, there has been a significant surge in the implementation of subsidy policies by various countries. For example, according to data from the Global Trade Alert database, the United States has implemented the highest number of subsidy policies in recent years. To date, the U.S. has enacted a total of 512 subsidy policies since 2008, representing 37.65 % of the global total. In the contemporary global economic landscape, characterized by intricate interconnections and a tightly integrated global supply chain, the economic policies of any single nation inevitably trigger cross-border spillover effects. However, existing literature primarily examines the effects on firms within the implementing country (Görg & Strobl, 2007; Howell, 2017; Xu, Shen, Liu, et al., 2023), with limited understanding of their spillover impact on firm innovation across the supply chain.

Previous research has demonstrated that government subsidies can stimulate firms' engagement in international market competition and encourage the establishment of supply relationships with foreign suppliers (Qian, Liu, & Wang, 2018). Furthermore, these subsidies can lower the prices of subsidized firms' products, thereby providing them with a competitive edge and fostering innovation in the global market, potentially eroding market share for firms from other nations (Defever & Riano, 2017; Kalouptsidi, 2018). These findings prompt several inquiries: How do government subsidies in one country impact innovation among firms from other countries involved in the supply chain? Will this impact vary for firms in different roles, such as suppliers, customers, or competitors?

* Corresponding author.
E-mail address: wkai@mail.shufe.edu.cn (K. Wang).

https://doi.org/10.1016/j.chieco.2025.102425
Received 11 March 2024; Received in revised form 28 February 2025; Accepted 3 May 2025
Available online 8 May 2025

Additionally, how do these subsidy policies influence decision-making processes for associated firms and foreign governments?

In this study, we examine the spillover effects of U.S. government subsidies on Chinese firms interconnected through Sino-US supply chains. Our focus lies in understanding how these subsidies influence the innovation performance of Chinese suppliers, customers, and competitors of U.S. firms receiving subsidies within cross-border supply chains. Our results reveal that U.S. government subsidies generally foster innovation among Chinese firms engaged in the supply chain. However, the impact varies notably across different stages of the supply chain, presenting significant disparities.

First, our research reveals that U.S. firms receiving subsidies significantly hinder the innovation performance of their Chinese suppliers. This stems primarily from the fact that U.S. government subsidies facilitate the restructuring of supply chain configurations. Specifically, these subsidies promote the establishment of supply relationships between subsidized U.S. firms and U.S. suppliers, while simultaneously causing the dissolution of supply relationships between subsidized U.S. firms and Chinese suppliers. Consequently, Chinese suppliers experience a loss of market share and a decline in profitability, thereby reducing their capacity to invest in R&D.

Second, our findings suggest that U.S. firms receiving subsidies have a notably positive impact on the innovation performance of their Chinese customers. This is because subsidies from the US government substantially reduce the unit production costs for subsidized US firms. As a result, decreased upstream production costs in the supply chain translate to reduced unit production costs for their Chinese customers. This, in turn, facilitates the expansion of production scales for these Chinese customers, leading to a significant enhancement in profitability and an increase in R&D investment.

Lastly, our empirical investigation explored the effects of U.S. government subsidies on the innovation activities of Chinese competitors. We found that subsidies granted to U.S. firms have beneficially influenced the innovation performance of their Chinese counterparts. We found that, on the one hand, the enhanced innovation capabilities of subsidized U.S. firms may have exerted competitive pressure on the Chinese market, prompting the Chinese government to also adopt subsidies to encourage local firms to compete effectively, resulting in positive advancements. On the other hand, it is possible that, supported by government subsidies, Chinese competitors succeeded in less competitive sectors by employing an escape-from-competition strategy (Aghion, Bloom, Blundell, et al., 2005).

This paper contributes to the burgeoning literature that examines the effects of government subsidies on innovation performance. The outcomes of existing research are diverse; some argue for the positive influence of government subsidies in enhancing innovation capabilities, while others contend the contrary. Notable studies that demonstrate positive impacts include those by Howell (2017), Feldman and Kelley (2006), Sung (2019), Czarnitzki & Hussinger (2004), Xu et al. (2023), Qian et al. (2018), and Guo, Guo, and Jiang (2016). Specifically, Sung (2019) investigated the effects of government subsidies on innovation within the Korean renewable energy technology sector, identifying a bidirectional causal relationship between government subsidies and firm innovation: subsidies not only bolster firm innovation but also the enhancement in innovation increases the likelihood of obtaining further subsidies. Feldman and Kelley (2006) postulated that government subsidies lend governmental credibility to recipient firms, facilitate their collaborations with other entities, and ease access to funding, thereby fostering innovation. Conversely, studies indicating negative outcomes, such as those by Görg and Strobl (2007), Liu, Chen, Liu, et al. (2019), and Lazzarini (2015), suggest that government subsidies may lead firms to depend excessively on public funding for research and development, curtailing their own initiative in these areas.

There are a few studies that explore the spillover effects of government subsidies on international markets. Qian et al. (2018) demonstrated that government subsidies enable firms to establish supply chains with overseas suppliers, facilitating the importation of strategic innovation resources, which positively impacts foreign suppliers. Defever and Riano (2017) developed a two-country trade model revealing that government subsidies serve as a pivotal support for firms to reduce their product prices, which in turn, grants these firms a competitive edge in international markets and adversely affects foreign competitors. Furthermore, Kalouptsidi (2018) analyzed the Chinese shipbuilding industry and found that subsidies led to a significant global redistribution of ship production. Lou, Tian, and Wang (2020) also noted that the competitive pricing advantage of subsidized firms not only challenges international competitors but also obstructs the entry of foreign products into their domestic markets.

The existing literature on government subsidies largely concentrates on their domestic consequences within the countries implementing such policies. However, the international spillover effects of government subsidies have received scant attention, with existing studies primarily confined to theoretical analyses or specific industries. This gap underscores the necessity for a thorough and systematic examination of the international repercussions of government subsidies, a prevalent economic policy. To our knowledge, our study pioneers the investigation of the cross-border spillover effects of government subsidies, focusing on the Sino-US supply chain at the firm level. We specifically examine how U.S. government subsidies affect the innovation performance of Chinese firms, including listed suppliers, competitors, and customers of subsidized U.S. firms.

The structure of this paper is as follows: Section 2 details the data and empirical methodology; Section 3 discusses the empirical findings; and Section 4 provides the conclusion.

2. Data and empirical strategy

2.1. Data source

This study utilizes data sourced from four distinct databases. First, data concerning U.S. government subsidies were extracted from the Subsidy Tracker database by Good Jobs First, which compiles information on subsidy recipients across more than 1000 state, local, and federal economic development initiatives, as well as various other types of corporate financial support in the United States, from 1975 to the present.

Second, data on supply relationships between Chinese and U.S. firms were gathered from FactSet Relationship database, which provides detailed records of the inception and termination dates of supply relationships, firm names, and ISIN codes. It also categorizes each supply connection by its nature, identifying whether it pertains to suppliers, customers, collaborators, or competitors, facilitating the identification of Chinese suppliers, customers, and competitors of U.S. companies.

Furthermore, patent data for Chinese listed firms were acquired from Google Patent, which documents the application date, IPC type, citation count, applicant details, and other relevant information for this research.

Lastly, publicly available financial data for Chinese listed companies were sourced from the CSMAR database.

2.2. Data description

This study commenced by calculating the quantity of U.S. firms that have received subsidies,

the cumulative sum of government subsidies disbursed, and the annual count of subsidy measures implemented since 2000. As illustrated in Fig. 1, the number of U.S. firms receiving government subsidies has steadily surpassed 20,000 in the latter years. The magnitude of subsidies dispensed by the U.S. government exhibits an ascending trajectory, peaking in the aftermath of the COVID-19 pandemic outbreak in 2021. Additionally, the variety of subsidy measures has recently surpassed 200.

We then utilized the FactSet database to analyze data from 2003 to 2021, focused on Chinese competitors, customers, and suppliers of U.S. firms. Fig. 2 demonstrates a consistent increase in the number of Chinese competitors, customers, and suppliers to U.S. firms over these years. Notably, the expansion rate of related Chinese firms experienced an acceleration in recent years. This trend underlines the progressively intensifying symbiosis within the industrial linkage between China and the United States.

2.3. Empirical strategy

To examine the impact of U.S. government subsidies on the innovation performance of Chinese firms, we adopted an empirical methodology integrating Event Study and multi-period Difference-in-Differences (DID) analysis. This approach facilitated the empirical investigation of the policy's cross-border spillover effects at the firm level. We employed three key indicators to measure the innovation performance of Chinese listed firms: the number of patents, the diversity of International Patent Classification (IPC), and the patent citations.

2.3.1. Event study

For our analysis, we selected comparable Chinese listed firms within the same industry as the control group, contrasting them against those potentially influenced by U.S. government subsidies. Specifically, within the overall China section, the control group consists of Chinese listed firms in the same industry and with similar supply chain or competitive relationships with U.S. listed firms as those in the treatment group. Throughout the period during which these firms maintained such supply chain or competitive relationships with U.S. listed firms, they were not influenced by U.S. government subsidies. In the Chinese suppliers section, the control group includes Chinese listed firms in the same industry that also have American clients, but without experiencing any impact from U.S. government subsidies during their ongoing supplier relationship with U.S. listed firms. In the Chinese customers section, the control

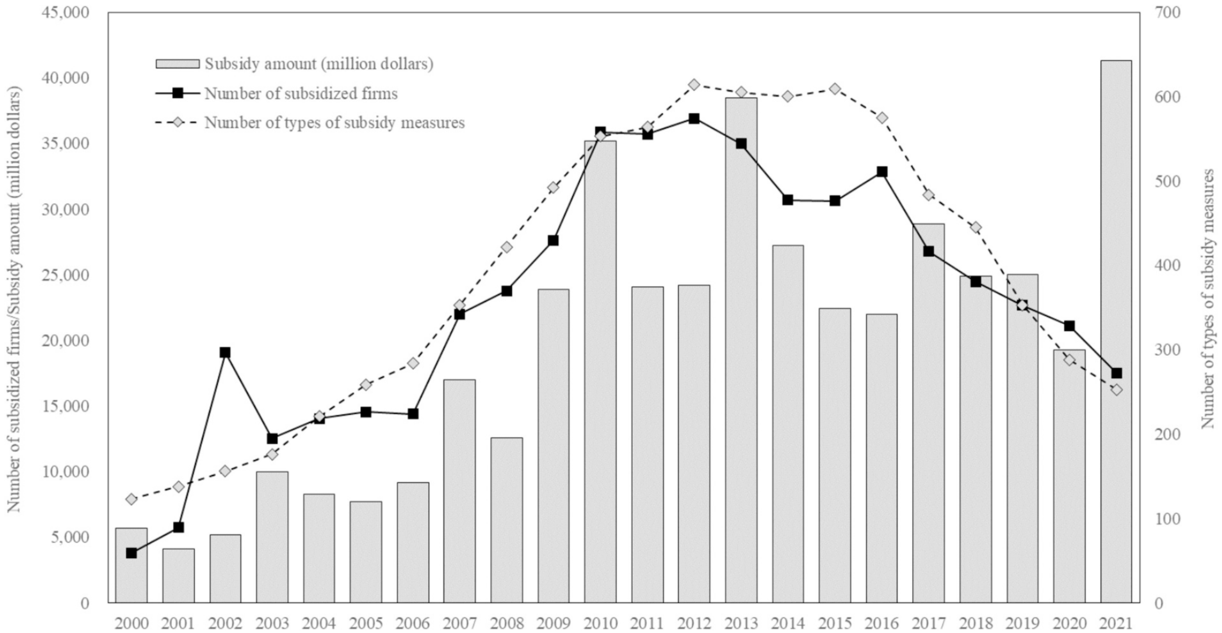

Fig. 1. The scope and intensity of U.S. government subsidies during 2000–2021.

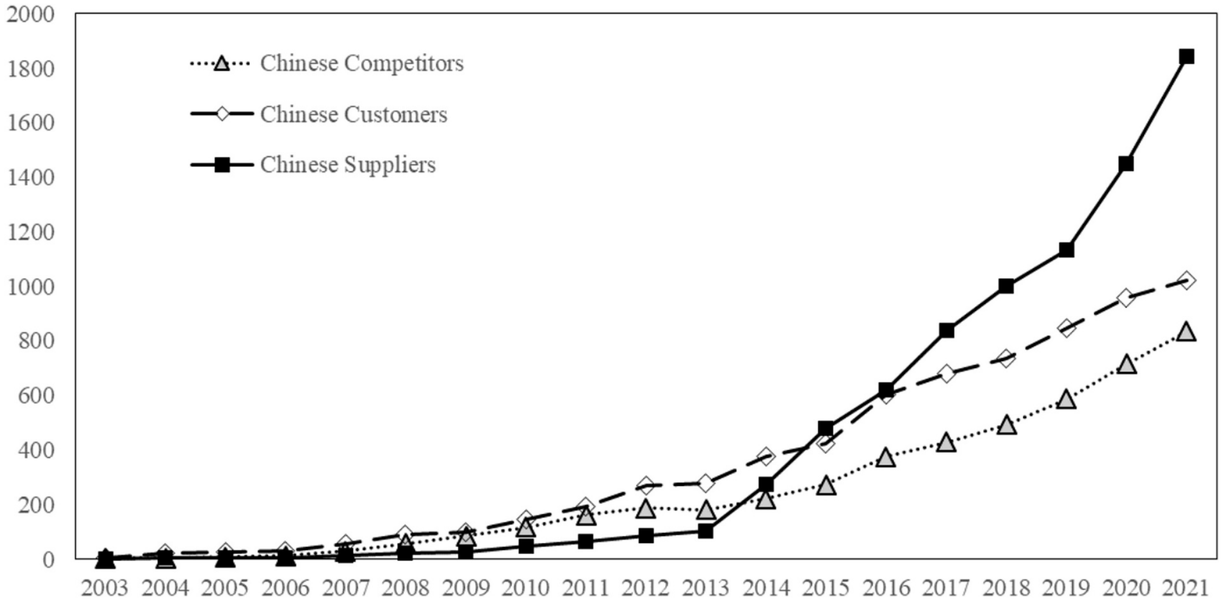

Fig. 2. The number of Chinese firms related to the U.S. subsidy policy.

group consists of Chinese listed firms in the same industry that also have American suppliers, but without experiencing any impact from U.S. government subsidies during their ongoing customer relationship with U.S. listed firms. In the Chinese competitors section, the control group involves Chinese listed firms in the same industry that also compete with U.S. listed firms, but without experiencing any impact from U.S. government subsidies during their competitive relationship with these U.S. listed firms. Our DID analysis is predicated on the assumption that, before the implement of U.S. subsidies, the treated firms would exhibit trends akin to those of the control group. To verify the parallel trend assumption between the treatment and control groups prior to the impact of subsidies and to methodically examine the persistence of the cross-border spillover effects, we conducted an event study analysis with a 5-year observational window surrounding the subsidy event in each analyzed segment. The formulation for the event study estimation is detailed subsequently:

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$$Y_{ft} = \sum_{k \geq -5, k \neq -1}^{5} D_{ft}^{k} \delta_k + X_{ft}\gamma + \theta_f + \mu_{it} + \varepsilon_{ft} \quad (1)$$

where Y_{ft} is the dependent variable and represents the logarithm of the number of patents (*lnPatent*), the number of patents' IPC varieties (*lnIPC*), and the patent citations (*lnCitation*) of firm f at time t. We define t_f as the year in which firm f was initially affected by U.S. government subsidies, i.e., t_f is the year when a Chinese listed firm's U.S. supplier/customer/competitor first received subsidies during the course of their supply relationship. The dummy variable D_{ft}^{k} represents the event in which the firm was initially affected by the U.S. government subsidies and we define D_{ft}^{-5-}=1 if $t - t_f \leq -5$, and 0 otherwise, $D_{ft}^{5+} = 1$ if $t - t_f \geq 5$, and 0 otherwise, as well as define $D_{ft}^{k} = 1$ if $t - t_f = k$, and 0 otherwise. Further, the range of k was $[-5, 5]$. X_{ft} represents a set of time-varying firm-level control variables that may affect a firm's innovation performance, including the log of total assets (*lnAsset*), the age of firms since establishment time (*lnAge*) and firms' capital intensity (*lnCapital*), due to the importance of firm size and establishment time in accumulating experience and acquiring resources for firms' innovation capabilities (Audretsch & Acs, 1991; Balasubramanian & Lee, 2008). Additionally, we include total factor productivity (*TFP*) to control for heterogeneity in productivity, the calculation method is taken Ackerberg, Caves, and Frazer (2015) for reference. We further include firms' financing constraints (*FC*) to measure the convenience of obtaining financing for firms, due to data limitations, we respectively take Hadlock and Pierce (2010) for reference to calculate the financing constraints of Chinese listed firms. Finally, we also include firms' sales costs to measure firms' operation costs as *lnSalecost* and firms' debt level (*lnDebt*), which is publicly disclosed data for public firms. We have lagged all control variables by one year in our analysis. Moreover, θ_f is the firm-fixed effect, which captures all time-invariant characteristics of firms that may influence their innovation performance, μ_{it} represent the industry-year fixed effects.

2.3.2. Multi-period DID

We show the multiple-period DID estimation equation as follows:

- $$Y_{ft} = \beta_0 + \beta_1 Subsidy\_us_{ft} + \gamma X_{ft} + \theta_f + \mu_{it} + \varepsilon_{ft} \quad (2)$$

$Subsidy\_us_{ft}$ represents a dummy indicator that takes the value of 1 if firm *f* is affected by U.S. government subsidy in year *t*, and 0 otherwise. Specifically, we define the core explanatory variable as 1 if the U.S. suppliers, customers or competitors of Chinese listed firms receive government subsidies. Therefore, β_1 captures the average difference in innovation performance between Chinese listed firms affected by U.S. government subsidy and those that are not affected.

The existing literature suggests that the use of two-way fixed effects may encounter challenges related to negative weights, particularly when average treatment effects vary across different groups or time periods, as highlighted by Goodman-Bacon (2018), De Chaisemartin and d'Haultfoeuille (2020), and Borusyak, Jaravel, & Spiess (2024). These challenges raise concerns about the reliability of coefficient estimates. To mitigate these issues, we employed the methodologies recommended by De Chaisemartin and d'Haultfoeuille (2020) and applied the Difference-in-Differences with Multiple Time Periods (DID-M) estimation approach in our baseline regression.

3. Empirical results

In this section, we begin by examining the overall impact of U.S. government subsidies on the innovation activities of Chinese firms throughout the supply chain. We then explore the different effects on various roles within the supply chain, including suppliers, customers, and competitors of the subsidized U.S. firms in China.

3.1. Overall results

3.1.1. Baseline results

To verify the existence of parallel trends between our treatment and control groups before the implementation of U.S. subsidy policies, and to investigate the lasting effects of these policies on Chinese firms, we initially present our findings from the Event Study analysis, as illustrated in Fig. 3. The data reveal a stable trend in patent counts, IPC classification, and citations among Chinese firms, both affected and unaffected by U.S. government subsidies, prior to the receipt of subsidies by U.S. firms. Notably, a significant increase in the number of patents, IPC classification, and citations is observed among Chinese firms with supply chain connections to subsidized U.S. firms, commencing two years post-subsidy.

Table 1 displays the results of the multi-period DID analysis, indicating that the coefficients for the primary explanatory variable are significantly positive. This demonstrates that subsidies received by U.S. firms positively influence the innovation of Chinese firms linked through supply chains.

3.1.2. Robustness checks

3.1.2.1. Supplementary control variables. Prior research emphasizes the crucial role of R&D investment and government subsidies in enhancing firms' innovation outputs (Guo et al., 2016; Shefer & Frenkel, 2005). Nevertheless, within our study period, R&D and government subsidy information for Chinese listed companies was not compulsory, leading to a significant shortage of data for these variables. Direct inclusion of these variables in the main regression might result in substantial sample reduction and potentially skewed findings. Hence, to affirm the reliability of our initial regression outcomes, we incorporate these variables as controls in a robustness check. The adjusted results, presented in Panel 1 of Table 2, Columns (1) to (3), affirm that the effect of U.S. subsidies remains significantly positive, affecting the number of patents, diversity of patent IPC classifications, and citations, even after accounting for R&D investment and Chinese government subsidies.

3.1.2.2. Adjustment for clustering standard error. Recognizing the potential for firm clustering within industries, we revised our benchmark regression's standard error calculation. Following Wang, Milner, and Scheffel (2021) and Liu and Ma (2020), we clustered standard errors at the industry level. The revised regression outcomes, shown in Panel 1 of Table 2, Columns (4) to (6), indicate that the coefficients of Subsidy_us continue to be positively significant, further substantiating the robustness of our benchmark regression findings.

3.1.2.3. Addressing estimation bias from log(1 + x) transformation for count data. Considering that patent data often contains a large number of zero values and that patent data is count data, using log(1 + x) transformation may be problematic in this context (Chen & Roth, 2024). To address potential estimation bias caused by this issue, we conducted a PPML regression using the raw patent data without logarithmic transformation. The regression results are presented in Panel 2 of Table 2, demonstrating the robustness of our findings.

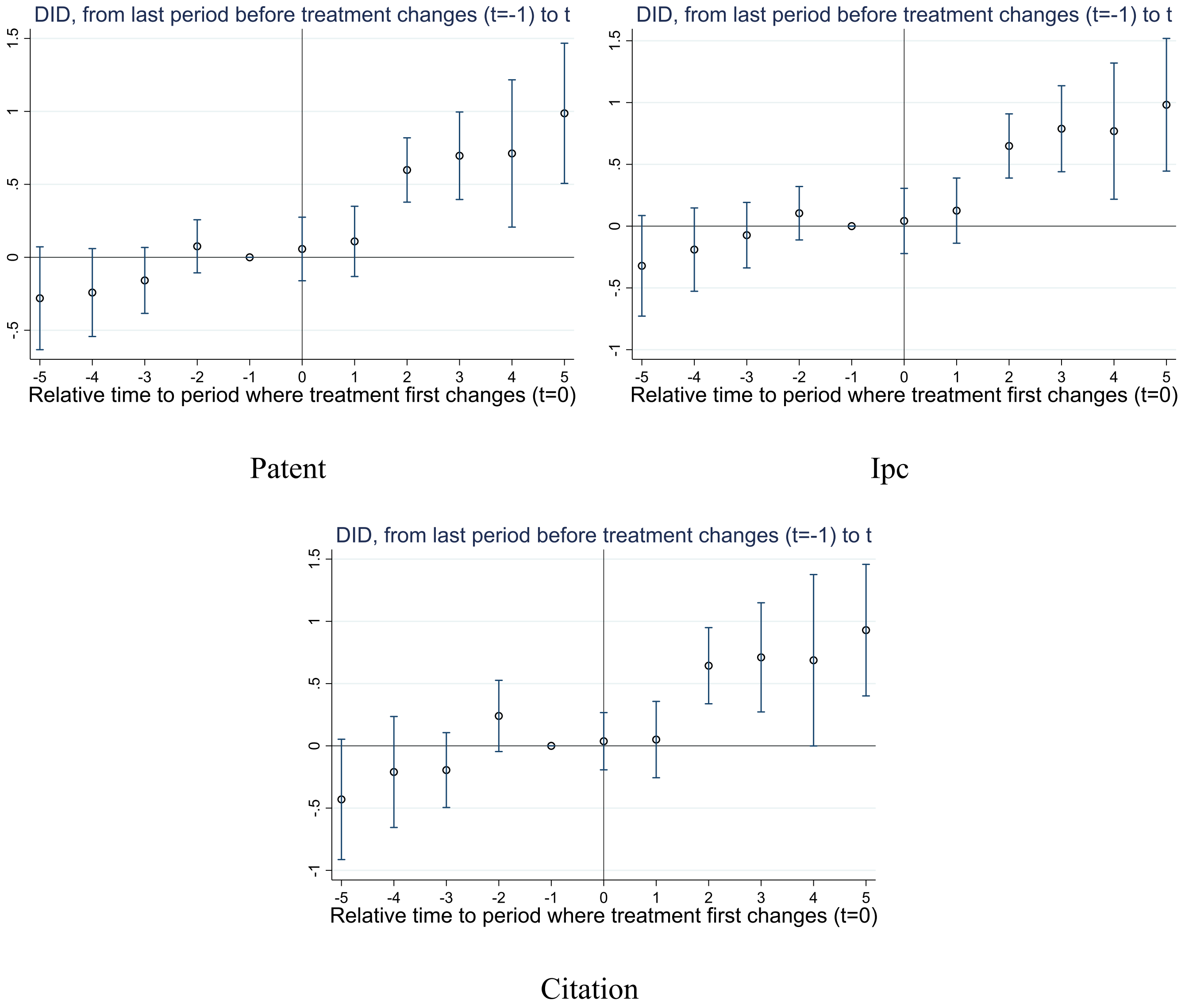

Fig. 3. Results of event study for Chinese firms.

Table 1
Results of multi-period DID for Chinese firms.

	(1)	(2)	(3)
	lnPatent	lnIpc	lnCitation
Subsidy_us	0.4515***	0.4810***	0.4357**
	(0.1108)	(0.1221)	(0.1447)
Control variables	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes
N	6809	6809	6809

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level.

Table 2
Results of robustness check for Chinese firms.

Panel 1	Supplementary control variables			CSE		
	(1)	(2)	(3)	(4)	(5)	(6)
	lnPatent	lnIpc	lnCitation	lnPatent	lnIpc	lnCitation
Subsidy_us	0.2334**	0.2596**	0.3181**	0.3084**	0.3020**	0.2918*
	(0.1106)	(0.1241)	(0.1444)	(0.1261)	(0.1435)	(0.1680)
Panel 2			PPML			
	lnPatent		lnIpc			lnCitation
Subsidy_us	0.2941***		0.3063***			0.3496***
	(0.1102)		(0.1050)			(0.1086)
Panel 3		Continuous DID		Considering spillover effects based on firm composition		
lnSubsidy	0.0141**	0.0140**	0.0133*			
	(0.0065)	(0.0067)	(0.0077)			
Shock_size				0.0249***	0.0307***	0.0625***
				(0.0089)	(0.0108)	(0.0139)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	4182	4182	4182	6809	6809	6809
r2	0.8369	0.8265	0.8255	0.8216	0.8121	0.8041

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors. The regressions in columns (1) to (3) use standard errors clustered at the firm level, while the regressions in columns (4) to (6) use standard errors clustered at the industry level.

3.1.2.4. Continuous DID. To further validate our regression results, we implemented the continuous DID method, influenced by Nunn and Qian (2011). In these robustness tests, we focused on the interaction between the U.S. government subsidies received by Chinese firms' US customers and the time variable. The findings, detailed in Panel 3 of Table 2, Columns (1) to (3), reveal that our core explanatory variables' coefficients consistently remain significantly positive. This applies to regressions on the number of patents, patents' IPC classifications, and citations, underscoring the reliability of our primary regression outcomes. Furthermore, considering that the spillover effects along supply chains depend on the composition of suppliers and customers (Chu, Tian, & Wang, 2019), we have re-quantified the magnitude of cross-border shocks faced by Chinese suppliers, customers, and competitors. This re-quantification is based on the ratio of the subsidies received by U.S. firms to their total sales, as well as the significance of these subsidized U.S. firms to their Chinese suppliers, customers, and competitors. The new approach for quantifying these shocks is as follows:

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$$Shock\_size_{ft} = \sum_{k \in \Omega_f^{US}} \frac{Subsidy_{kt}^{US}}{Sales_{kt}^{US}} \times \frac{Supply_{ft}^{US}}{Supply_{ft}^{T}} \tag{3}$$

where the subscript f represents the Chinese firms in our sample, t represents the year, and k denotes each U.S. firm that received government subsidies during its ongoing supply relationship with a Chinese listed firm. Ω_f^{US} refers to the set of all U.S. firms within the supply chain network of Chinese firm f. $Subsidy_{kt}^{US}$ is the amount of subsidy received by a US listed firm k in year t, and $Sales_{kt}^{US}$ is the total sales of firm k in year t, $Supply_{ft}^{US}$ represents the number of U.S. suppliers, customers, or competitors of Chinese firm f in year t that have received U.S. government subsidies, while $Supply_{ft}^{T}$ denotes the total number of suppliers, customers, or competitors of Chinese firm f in year t. The first term in the formula, $\frac{Subsidy_{kt}^{US}}{Sales_{kt}^{US}}$ captures the impact of subsidy on each US firm, and the second term, $\frac{Supply_{ft}^{US}}{Supply_{ft}^{T}}$, captures the relative importance of a US firm in firm f's supply chain network. The regression results are presented in Panel 3 of Table 2, Columns (4) to (6) of Table 4. It can be observed that, even after thoroughly accounting for the spillover effects along supply chains, which depend on the composition of suppliers, customers, or competitors, our regression results remain robust.

3.1.2.5. Addressing endogeneity issues. Our research may also exist endogeneity issues, primarily due to the possibility that U.S. subsidy policies have been implemented in response to the improvement of China's innovation capabilities. This is particularly evident after the United States defined China as a "strategic competitor" in its National Security Strategy released in December 2017, which emphasized the challenges posed by China to U.S. interests and security, and indicated measures to counter China's expanding global influence. Subsequently, to ensure America's technological leadership and maintain its competitive advantage in key areas of technology, the U.S. has implemented a series of measures to promote and protect domestic industry development, such as the U.S.-China trade war initiated in 2018, the Inflation Reduction Act, the Critical and Emerging Technologies List, and the CHIPS and Science Act. These actions suggest that some of the U.S. subsidy policies studied in our paper may not be entirely exogenous. To mitigate potential endogeneity issues, we employ three main strategies: a. Restricting the sample period to years before 2018, when US-China trade conflicts started. b. Examining the effects of local or state-level subsidy policies, which are less likely to be driven by global market shocks or national-level IP initiatives. c. Excluding cases involving strategic industries for either US or Chinese firms. The related regression results are presented in Table 3.

3.1.2.6. Placebo test analysis. We also conducted a permutation test to ensure the robustness of our regression results, with the findings presented in Fig. A1 of the appendix.

3.1.2.7. Changing the identification method for subsidy shocks. Considering the diversity of subsidy policies and the complexity of international supply chains, it is possible that a Chinese firm may have varying numbers of subsidized suppliers/customers/competitors in different years. Additionally, subsidy policies may be adjusted according to changes in international circumstances, leading to the potential termination of subsidies for certain firms. Therefore, using a simple 0–1 dummy variable to measure the impact of subsidies on the supply chain in our baseline regression, and assuming that the effects of subsidies persist indefinitely, may introduce estimation errors. To address this concern, we replaced the 0–1 dummy variable with the actual number of U.S. suppliers/customers/competitors receiving government subsidies each year (*Shock_size*) in our baseline regression. We also considered the possibility of subsidy termination: when subsidies are present during the supply relationship period, *End_Subsidy*=1; when subsidies terminate during this period, *End_Subsidy*=0. The event study and multiple-period DID regression results are presented in Fig. A2-A3, and Table A1 of the appendix. As can be seen, even after changing the measurement method for subsidy shocks, our core explanatory variables remain positive and significant, demonstrating that the conclusions of this study are robust.

Table 3
Restricting the sample period to years before 2018.

Panel 1		Restricting the sample period to years before 2018				
		(1)		(2)	(3)	
		lnPatent		lnIpc	lnCitation	
Subsidy_us		0.4176***		0.3717**	0.3725**	
		(0.1569)		(0.1732)	(0.1852)	
Panel 2		Local/State subsidy effects			Exclusion of strategic industries	
SL_Subsidy	0.2580***	0.2651**	0.2339**			
	(0.0975)	(0.1085)	(0.1107)			
nonstra_Sub				0.3611**	0.3952**	0.4482**
				(0.1483)	(0.1711)	(0.2017)
Control variables		Yes		Yes	Yes	
Firm fixed effects		Yes		Yes	Yes	
Industry-Year fixed effects		Yes		Yes	Yes	
N		4876		4876	4876	
r2		0.8542		0.8405	0.8306	

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level. The variable *SL_Subsidy* represents subsidies implemented only at the local or state level. The variable *nonstra_Sub* denotes subsidy policies for non-strategic industries. We matched the technologies and industries mentioned in the U.S. National Strategy for Critical and Emerging Technologies and excluded industries involving strategic technologies from both Chinese and American firm samples.

3.2. Chinese suppliers

To investigate the influence of U.S. government subsidies on the roles of Chinese firms within the supply chain further, this study analyzes the impact of these subsidies on the innovation performance of Chinese suppliers engaged with subsidized U.S. firms.

The DID analysis results, presented in Table 4, reveal statistically significant and negative coefficients for *Subsidy_us*, corroborating the observations in Fig. A4 of the appendix. The enactment of U.S. government subsidies has led to a decrease in the average number of patents, IPC types, and citations among Chinese suppliers.

The U.S. has experienced a consistent decline in the share of manufacturing employment, with this downward trend becoming notably pronounced since the year 2000. This reduction in employment has led to increased import competition from China, prompting U.S. firms to relocate labor-intensive and low-productivity sectors overseas (Autor, Dorn, & Hanson, 2015; Contractor, 2021; Fort, Pierce, & Schott, 2018; Jaimovich & Siu, 2019; Michaels, Natraj, & Van Reenen, 2014). The U.S. government has implemented policies aimed at fostering the resurgence of domestic industries. These initiatives comprise a range of government subsidies designed to mitigate labor cost disadvantages and significant investments in R&D. This raises a critical inquiry: Do government subsidies in the U.S. bolster U.S. firms in reconfiguring their supply chains, thereby adversely affecting Chinese suppliers?

To explore this pressing issue, we conducted a comprehensive analysis by recording the number of Chinese firms with which a U.S. firm initiates (*CHN_start*) and discontinues (*CHN_end*) supply relationships, as well as the number of domestic firms with which it begins (*US_start*) and concludes (*US_end*) supply agreements annually. This information was sourced from the Relationship database in FactSet. Utilizing these four metrics as dependent variables and the level of U.S. government subsidies as the primary explanatory variable, we performed regression analysis focusing on subsidized U.S. firms. The findings, detailed in columns (1) through (4) of Table A2 in the appendix, indicate that U.S. government subsidies significantly motivate U.S. firms to terminate supplier relations with Chinese entities. Conversely, these subsidies appear to have negligible influence on the formation of new supplier connections between U.S. and Chinese firms. Moreover, the subsidies markedly encourage the creation of supplier relationships between U.S. firms and domestic partners, while having no significant impact on the dissolution of such partnerships. These results imply that U.S. government subsidies have effectively facilitated the reshoring of supply chains by U.S. firms, negatively impacting Chinese suppliers.

Expanding upon these insights, we investigated the implications of changes and reconfigurations in the U.S.-China supply chain, prompted by U.S. government subsidies, on the profitability and R&D investment capabilities of Chinese suppliers. We conducted regression analysis, utilizing the return on equity (*Roe*) and R&D expenditures (*lnRD*) of Chinese suppliers as the dependent variables. The outcomes of this analysis are illustrated in columns (5) and (6) of Table A2. Our analysis indicates that U.S. government subsidies have had an impact on the profitability of Chinese suppliers and have reduced their capacity to invest in R&D, adversely affecting their innovation potential.

3.3. Chinese customer

In this section, we examine the influence of U.S. government subsidies on the innovation capabilities of Chinese customers of subsidized U.S. firms.

The results are shown in Table 5. The estimated coefficients for *Subsidy_us* in the regression analysis are statistically significant and positive, indicating that the U.S. government subsidies have notably enhanced the average innovation performance of Chinese customers.

A significant body of research literature underscores the pivotal role of supply chains in facilitating knowledge spillover effects. Enhancements in an upstream supplier's production capacity and innovative production technology are transferred to downstream customers through the supply chain, thereby augmenting the customers' own production capacity (Blalock & Veloso, 2007; Keller, 2010; Willis, Genchev, & Chen, 2016). Given that U.S. government subsidies serve as an effective policy mechanism to reduce production costs and provide technical support for subsidized firms, it is pertinent to inquire whether these subsidies could extend their positive impacts to the Chinese customers of subsidized U.S. firms via the supply chain. To explore this, we analyzed the transmission effect of production advantages in the supply chain from a production cost perspective. Specifically, we initially conducted a regression analysis to examine the impact of U.S. government subsidies on the production cost per unit for subsidized U.S. firms. Subsequently, we validated the potential effect of U.S. government subsidies on the production cost per unit of their Chinese customers. Moreover, we

Table 4
Results of multi-period DID for Chinese suppliers.

	(1)	(2)	(3)
	lnPatent	lnIpc	lnCitation
Subsidy_us	−0.3331**	−0.4143**	−0.4988**
	(0.1509)	(0.1763)	(0.2334)
Control variables	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes
N	3286	3286	3286

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level.

Table 5
Results of multi-period DID for Chinese customers.

	(1)	(2)	(3)
	lnPatent	lnIpc	lnCitation
Subsidy_us	0.6567***	0.6784***	0.6892***
	(0.1596)	(0.1562)	(0.2529)
Control variables	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes
N	1745	1745	1745

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level.

investigated the possible impact mechanisms from various perspectives, including the scale of production, profitability, and R&D investment of the Chinese customers.

The results, as depicted in Table A3 of the appendix, indicate that U.S. government subsidies have significantly reduced the per-unit production costs for subsidized U.S. firms. This reduction at the supplier level has also been passed down to downstream Chinese customers, notably decreasing their per-unit production costs. However, despite the decline in per-unit costs, the overall production costs for Chinese customers have increased, suggesting an expansion in their production scale to capitalize on economies of scale, culminating in a marked increase in profitability. Moreover, this profit augmentation has spurred Chinese customers to enhance their R&D capabilities.

3.4. *Chinese competitor*

In this section, we investigate the effect of U.S. government subsidies on the innovation performance of Chinese competitors.

The estimated results are detailed in Table 6. Our analysis reveals significantly positive coefficients for *Subsidy_us* in the regression analysis, utilizing the number of patents, IPC varieties, and patent citations as dependent variables. This suggests that the U.S. government subsidies have effectively fostered the innovation performance of Chinese competitors.

Extensive research has established that market competition profoundly affects the innovation performance of firms (Ayyagari, Demirgüç-Kunt, & Maksimovic, 2011; Liu, Lu, Lu, et al., 2021; Tang, 2006). The subsidy policies of the U.S. government are argued to provide a substantial competitive edge to subsidized U.S. firms in areas such as production costs and R&D investments. This could lead to an increase in their innovation output and amplify the competitive challenges faced by Chinese competitors. Consequently, several critical questions emerge: Do subsidies from the U.S. government act as a positive incentive for the innovation output of subsidized firms? Do these policies, by intensifying market competition, prompt the Chinese government to increase subsidies for its competitors? And, do Chinese competitors enhance their R&D investments to accelerate self-driven innovation? To explore these inquiries, we analyze the mechanisms of impact by examining variables such as R&D investments and the number of patent applications by U.S.-subsidized firms, the scale of subsidies received from the Chinese government by Chinese competitors, and their respective R&D investments.

The findings presented in Table A4 indicate that the U.S. government's subsidy policies substantially encourage R&D investment among subsidized firms, which in turn leads to enhanced innovation output. Additionally, these policies have prompted a notable increase in the subsidies that the Chinese government provides to its domestic competitors. Consequently, with the growth in government subsidies, Chinese competitors have augmented their R&D investments, resulting in a positive impact on their innovation performance. The enhancement of innovation outcomes may, on one hand, result from increased competitive intensity within the same field, while on the other hand, it may also stem from Chinese firms actively developing in areas with lower competitive intensity to avoid direct competition.

4. Conclusion

In an era characterized by the progression of anti-globalization movements, intensified competition among leading nations, and persistent geopolitical conflicts, examining the cross-border spillover effects of government subsidies is crucial for understanding their political and economic ramifications. This study employs a comprehensive methodology, integrating an event study with a multi-period Difference-in-Differences (DID) analysis, to methodically assess the influence of U.S. government subsidy policies on the innovation activities of Chinese suppliers, customers, and competitors.

Our research indicates that U.S. government subsidies have generally exerted a positive influence on the innovation of Chinese firms that are integrally connected to the supply chains of subsidized U.S. entities. Nonetheless, the effect varies depending on the firm's position within the Sino-U.S. supply chain. Specifically, the innovation performance of Chinese suppliers to subsidized U.S. firms has suffered due to U.S. subsidy policies, whereas Chinese customers and competitors have experienced a significant positive impact on their innovation performance. Moreover, our study underscores the vital role of government subsidies in facilitating the fragmentation and reconfiguration of international supply chains. It also elucidates how these subsidies promote the transfer of production advantages within the supply chain and stimulate competitive innovation.

Table 6
Results of multi-period DID for Chinese competitors.

	(1)	(2)	(3)
	lnPatent	lnIpc	lnCitation
Subsidy_us	0.6054**	0.6354**	0.7539**
	(0.2356)	(0.3055)	(0.3660)
Control variables	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes
N	2824	2824	2824

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level.

Declaration of competing interest

None.

Acknowledgments

National fund of Philosophy and Social Science of China(Grant Number: 23BJL053).

Appendix A. The whole of Chinese firms

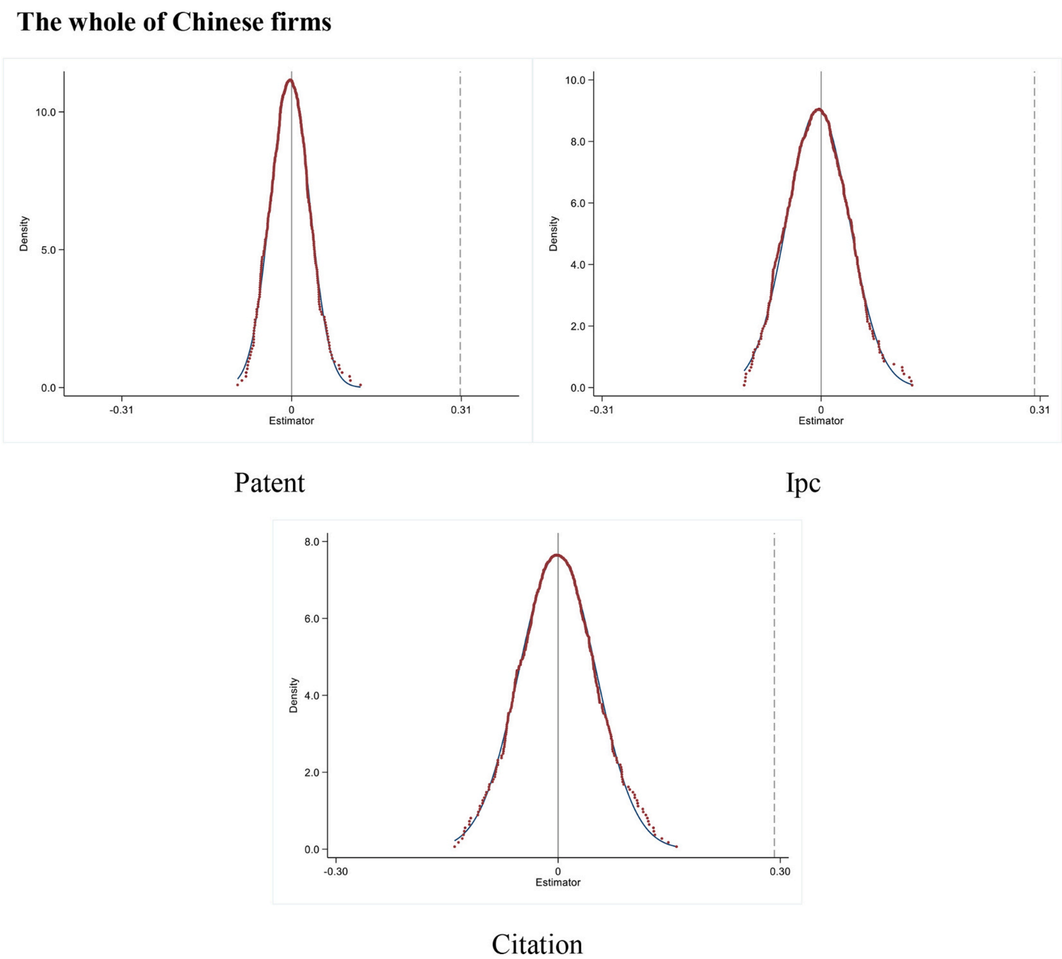


Fig. A1 Results of placebo test for Chinese firms.

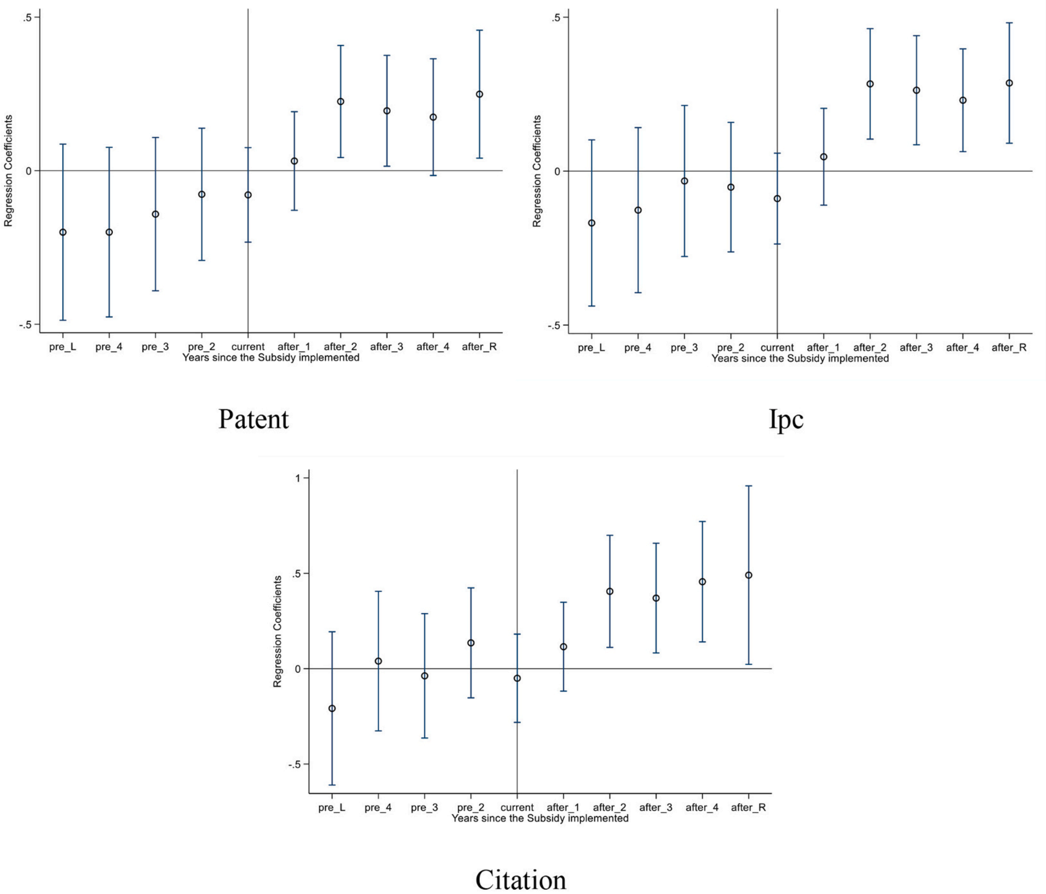
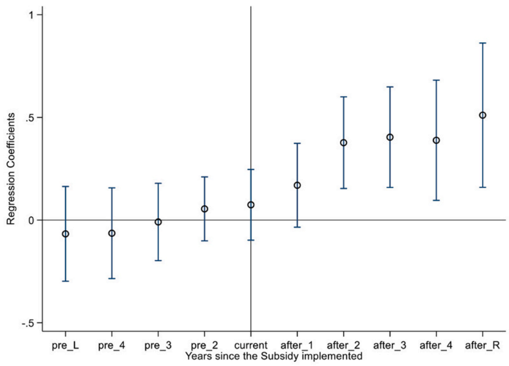
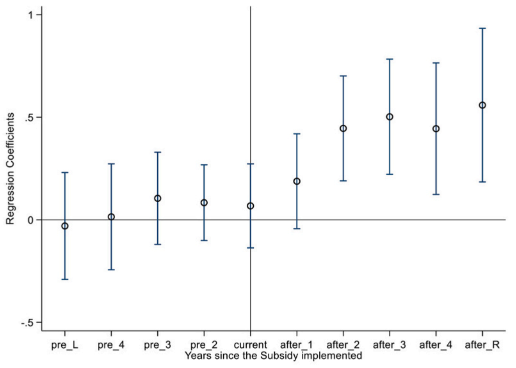


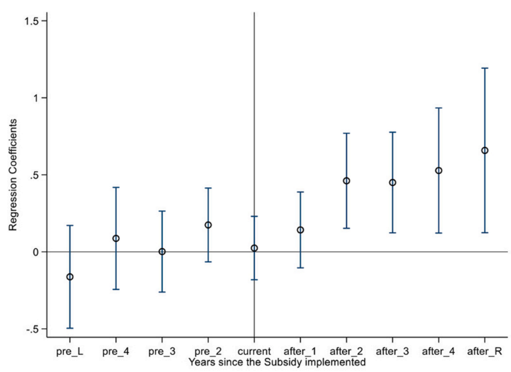
Fig. A2 Event study results: actual number of U.S. suppliers/customers/competitors receiving government subsidies.



Patent



Ipc



Citation

Fig. A3 Event study results: considering the possibility of subsidy termination.

Table A1. Changing the identification method for subsidy shocks.

	Actual number of U.S. suppliers/customers/competitors receiving government subsidies			Considering the possibility of subsidy termination		
	(1)	(2)	(3)	(4)	(5)	(6)
	lnPatent	lnIpc	lnCitation	lnPatent	lnIpc	lnCitation
Num_subsidy	0.2085***	0.2066***	0.3112**			
	(0.0721)	(0.0778)	(0.1241)			
End_subsidy				0.2947***	0.2805***	0.3309***
				(0.0977)	(0.1082)	(0.1263)
L_lnAsset	0.7913**	0.8863**	1.4972***	0.7842**	0.8747**	1.4444***
	(0.3644)	(0.4164)	(0.4801)	(0.3584)	(0.4105)	(0.4766)
L_lnDebt	0.0539	0.0423	0.0871	0.0482	0.0367	0.0794
	(0.0582)	(0.0679)	(0.0792)	(0.0578)	(0.0675)	(0.0785)
L_lnAge	−0.1665	−0.2294	−0.3378	−0.1695	−0.2322	−0.3413
	(0.1700)	(0.1969)	(0.2253)	(0.1694)	(0.1964)	(0.2245)
L_TFP	0.0390	0.0532	0.0662	0.0364	0.0505	0.0624
	(0.0615)	(0.0687)	(0.0824)	(0.0612)	(0.0686)	(0.0826)
L_lnCapital	−0.1539***	−0.1909***	−0.2018***	−0.1523***	−0.1894***	−0.1998***
	(0.0433)	(0.0506)	(0.0691)	(0.0432)	(0.0505)	(0.0692)
L_SA	−0.3853	−0.4053	−0.8826**	−0.3740	−0.3898	−0.8250**
	(0.3099)	(0.3479)	(0.4070)	(0.3044)	(0.3425)	(0.4058)
L_roa	0.1014	0.1602**	0.0886	0.1018	0.1604**	0.0874
	(0.0654)	(0.0773)	(0.1285)	(0.0655)	(0.0774)	(0.1282)
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	6809	6809	6809	6809	6809	6809
r2	0.8215	0.8121	0.8027	0.8217	0.8121	0.8025

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level.

A.1. Chinese suppliers

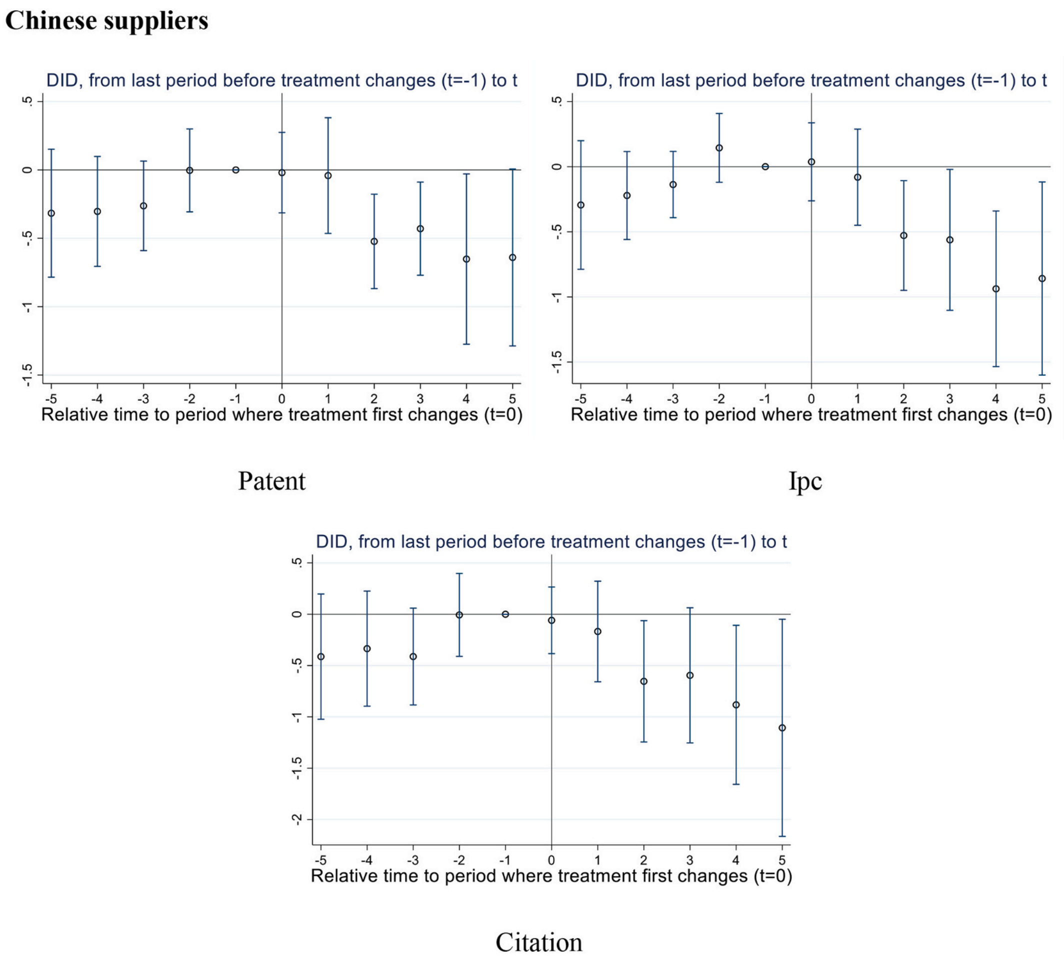


Fig. A4. The Event Study results using the ‘DID_M’ approach for Chinese suppliers.

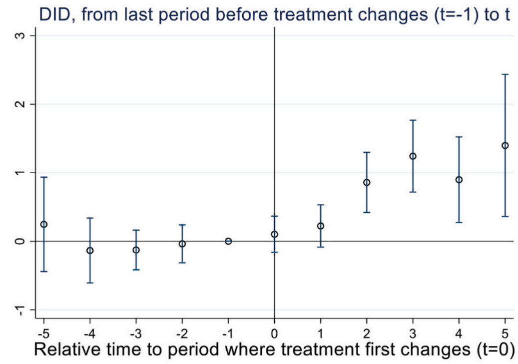
Table A2. Results of mechanism analysis for Chinese suppliers.

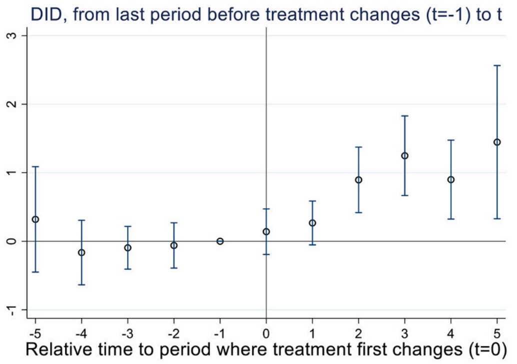
	(1)	(2)	(3)	(4)	(5)	(6)
	CHN_start	CHN_end	US_start	US_end	Roe	lnRD
Subsidy_us	0.0439	0.1563**	0.2661**	0.0201	−0.2684**	−0.0194**
	(0.0918)	(0.0780)	(0.1310)	(0.0695)	(0.1234)	(0.0088)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
N	5298	5298	20,838	20,838	3280	2040
R-square	0.6658	0.5502	0.4517	0.6111	0.3781	0.5448

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level.

A.2. Chinese customers

Chinese customers





Patent

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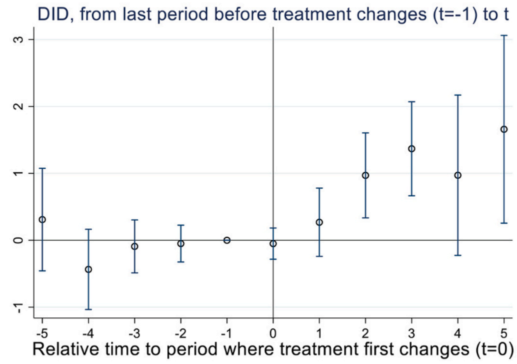

Citation

Fig. A5. The event study results using the ‘did_m’ approach for chinese customers.

Table A3. Results of mechanism analysis for Chinese customers.

	(1)	(2)	(3)	(4)	(5)
	Costper_us	Costper_chn	Sale_cost	Roe	lnRD
Subsidy_us	−2.4726**	−0.3000**	0.0925**	0.1178**	0.0640**
	(1.1294)	(0.1398)	(0.0445)	(0.0535)	(0.0295)
Control variables	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes	Yes	Yes
N	72,750	1745	1745	1730	1216
R-square	0.2793	0.4233	0.9734	0.2914	0.4120

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level.

A.3. Chinese competitors

Chinese competitors

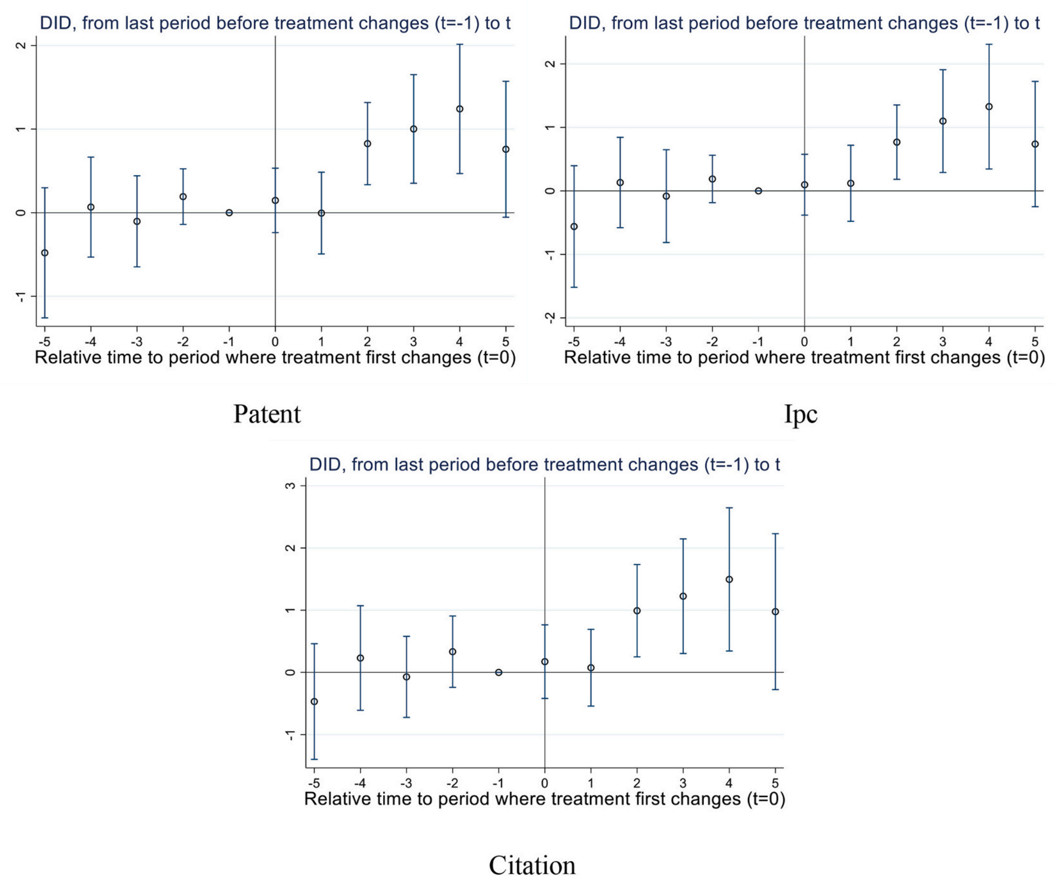

Fig. A6. The event study results using the 'DID_M' approach for Chinese competitors.

Table A4. Results of mechanism analysis for Chinese competitors.

	(1)	(2)	(3)	(4)
	lnPatent	lnRD_us	lnGovern	lnRD_chn
Subsidy_us	0.1283***	0.0454***	0.3219**	0.5367**
	(0.0352)	(0.0078)	(0.1513)	(0.2454)
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Industry-Year fixed effects	Yes	Yes	Yes	Yes
N	73,510	72,221	2361	1974
R-square	0.7977	0.9833	0.8245	0.9127

*, **, and *** denote significance at the 1 %, 5 %, and 10 % levels, respectively. Values in parentheses underneath the estimated coefficients are standard errors clustered at the firm level.

Data availability

The authors do not have permission to share data.

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