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FDI technology spillovers in Chinese supplier-customer networks

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ABSTRACT

This paper examines foreign direct investment (FDI) technology spillovers between firms in a supply chain and analyzes the mechanism behind their occurrence. Results using firm-level transaction data from China between 2009 and 2020 show that, unlike inter-industry linkage effects, in the Chinese market, FDI technology spillovers can directly occur through connections between suppliers and customers, demonstrating the existence of inter-firm technology spillover effects of FDI. Further analysis reveals that FDI technology spillovers between firms are generated through channels of knowledge transfer and optimized supply chain configurations, predominantly observed in state-owned firms, small and medium-sized firms, the manufacturing sector, and high-tech industries. Upon analyzing the detailed breakdown of FDI sources, it was found that FDI from developed countries exhibits inter-firm technology spillover effects. In contrast, FDI from Hong Kong, Macao, and Taiwan regions, developing countries, and tax havens such as the British Virgin Islands and the Cayman Islands show insignificant effects on inter-firm technology spillovers. These conclusions offer policy insights for China and other developing countries to better utilize FDI to promote the development of local firms in the context of the sustained global supply chain restructuring.

1. Introduction

Attracting Foreign Direct Investment (FDI) to promote domestic economic growth and technological advancement has become a crucial economic strategy for most developing countries. Despite a series of empirical studies at both macroeconomic and industry levels confirming the rationale of policies to attract FDI (e.g., Abebe, Mcmillan, & Serafinelli, 2022; Lai, Bao, Peng, & Zhang, 2005; Li & Luke Chan, 2009), the firm-level evidence of FDI technology spillovers remains mixed and uncertain (Harrison & Rodriguez-Clare, 2010; Keller & Wolfgang, 2021). Doubts surrounding the "foreign investment crowding out" theory and the "foreign investment uselessness" theory persist. As the leading developing country in attracting FDI, China's foreign-funded firms, accounting for 2% of the market entities, have generated employment for approximately 40 million jobs, making up 1/10 of urban employment. These firms contribute 2/5 of the China's imports and exports activities and 1/6 of the tax revenue.[1] Therefore, the question arises: Can domestic firms benefit from these multinational superstar firms' technology spillovers to boost productivity? The answer has major implications for China and other developing countries in leveraging FDI to promote the survival and development of local businesses.

Literature on FDI technology spillovers typically combines enterprise panel data with input-output tables at the industry (sector) level, finding a correlation between the increases in regional industry FDI and the improvement in domestic firms' productivity (Xu, Wei, Lai, & Wang, 2007; Gorodnichenko, Svejnar, & Terrell, 2015). However, the results are mixed. A key reason is that supply linkages between firms may be endogenous. Examining only industry-level data without observing actual inter-firm connections makes it hard to accurately assess the extent of technological diffusion from multinationals to domestic firms (Gong, 2023). Additionally, FDI and the host country's economic development are endogenous, and thus macro-level data struggle to disentangle the causal relationship between foreign connections with multinational corporations and corporate performance (Alfaro-Urena, Manelici, & Vasquez, 2022; Mei, 2021; Okubo & Watabe, 2023). Therefore, shifting focus from industry-level FDI changes to changes in actual inter-firms provides new opportunities to deeply investigate FDI

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[1] The data is sourced from the speech of Wang Wentao, the Minister of Commerce, during a press conference held by the State Council Information Office on August 23, 2021.

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technology spillovers.

This study explores FDI technology spillovers in supplier-customer networks from a business relationship perspective. We particularly focus on the significant role of direct supply relationships between firms in FDI technology spillovers, Not at the industry level.

We use Chinese firms from 2009 to 2020 as our research sample. In contrast to existing studies that measure the degree of FDI correlation between industries, we identify whether the top five customers of listed firms are foreign-invested firms based on registration information and data from the QCC website.[2] Drawing on previous research (Alfaro-Urena et al., 2022; Amiti, Duprez, Konings, & Reenen, 2023; Bao & Liao, 2023), after manual sorting, we calculate the degree of listed firms sales to foreign-invested firms among the top five customers, and further analysis revealed that In the Chinese market, FDI generates technology spillovers directly through supplier-customer networks, indicating the existence of inter-firm technology spillovers from FDI.

We conducted a series of robustness tests to eliminate the influence of other factors. After excluding the effects of listed firm customers, removing the impact of foreign-invested firm suppliers, mitigating the impact of newly hired executives with overseas backgrounds and work experience, changing variable measurements, adjusting the original model, and other testing methods, we found that the results still hold. Additionally, to mitigate endogeneity in the model, we conducted analyses using the Heckman two-step method and constructing instrumental variables, and the results remained robust.

To better understand the potential mechanisms of technology spillovers in supplier-customer networks through FDI, we conducted an analysis. Firstly, we delineated the knowledge transfer channels from three dimensions: innovation input, innovation output, and innovation boundary. Secondly, we examined the optimizing supply chain configuration channels from three dimensions: supply chain inventory configuration efficiency, supply chain capital configuration efficiency, and supply chain resource configuration methods. In summary, our study validates two channels: knowledge transfer and optimized supply chain configuration.

To analyze the differentiated impact of FDI technology spillovers in supplier-customer networks, We first explored the influence of ownership and industry attributes, finding that state-owned enterprises and high-tech manufacturing firms are more likely to benefit from FDI technology spillovers within supplier-customer networks. Considering that multinational enterprises can propagate crises through internal capital markets (Biermann & Huber, 2022), there is a significant linkage between FDI and external risk factors. Therefore, the impact of risk-taking levels was also considered, and we found that firms with higher levels of risk-taking are more likely to benefit from it.

Finally, previous studies have explored the potential influence of the source of FDI on its technology spillovers (Griffith, Redding, & Reenen, 2004; Lin, Liu, & Zhang, 2009). To delve into this issue with more detailed micro-level data, we further divided the FDI sources based on firms' equity network data. This division includes FDI from Hong Kong, Macau, and Taiwan, FDI from developed countries, FDI from developing countries, and FDI from tax havens. We found that only FDI from developed countries can generate technology spilloves in supplier-customer networks.

This study contributes to the literature in several ways. Firstly, our work, explores FDI technology spillovers in supplier-customer networks using Chinese firm-to-firm transaction data. This enriches FDI technology spillover theory and complements the vertical spillover literature from a business association perspective. Existing research often combines firm panel data with industry input-output tables to measure FDI vertical spillovers (Blalock, 2001; Xu et al., 2007). However, as participants in the supply chain, even firms in the same industry exhibit significant differences. To some extent, this paper echoes calls for a more accurate FDI spillover measurement (Keller & Wolfgang, 2021; Lu, Chen, Zhou, & Li, 2024) and confirms the pivotal channel through which firms acquire FDI technology spillovers—direct spillovers in supplier-customer networks.

Secondly, this paper, based on the theory of supply chain coordination, integrates the production linkages between domestic firms and foreign-invested firms into the analysis of global value chain activities through inter-firm transaction data. Unlike studies focusing solely on domestic supply chains or global value chains, we pay more attention to the economic effects of global value chain activities of multinational enterprises' overseas branches. Moreover, the transnational supply chains within supplier-customer networks better reflect the dynamic characteristics of firms participating in international division of labor. In conclusion, our work will offer new evidence to evaluate the role of FDI in improving the quality of China's domestic supply chain, and clarifying the mutual relationship between domestic and international supply chains.

Thirdly, this paper subdivides FDI sources based on equity data to explore differentiated impacts on technology spillovers in Chinese supplier-customer networks. Existing literature often categorizes Chinese FDI simply as HMT (Hong Kong, Macao, Taiwan) vs. non-HMT. However, in reality, non-HMT investments vary significantly - e.g. developing vs. developed country sources, "tax havens", etc. These differences are hard to capture in regional and industry data. By subdividing the sources of FDI more meticulously, we aim to provide theoretical support for attracting high-quality foreign investment in China and other developing countries.

The remainder of this paper is organized as follows. Section 2 presents the literature review and hypothesis development; Section 3 outlines the research design; Section 4 discusses the empirical results; Section 5 includes an extended analysis; and finally, Section 6 presents the conclusion remarks.

2. Literature review and hypothesis development

2.1. Literature review

Our paper connects to many other papers in the literature. First, there is a literature that looks at spillovers from FDI or multinationals. Early literature on FDI technology spillovers often focused on the industry in which firms operate, manifest in two forms - horizontal spillovers and vertical spillovers, and commonly suggests that FDI technology spillovers are transmitted through channels such as demonstration learning effects (Lake, 1979), competitive effects (Kokko, 1994), human capital effects (Shen & Geng, 2001), among others.

With the call for FDI technology spillovers research to adopt more detailed micro-level data, recent literature has begun to focus on the mechanisms through which FDI operates among firms. As pointed out by Alfaro and Laura (2017), Although direct supply chain connections are not the only means through which FDI enhances the performance of domestic subsidiaries in multinational firms, it is considered one of the most promising channels. Many case studies have found that multinational enterprises positively impact their domestic suppliers. For instance, Iacovone, Javorcik, Keller, and Tybout (2015) discussed the impact of Walmart's entry into Mexico, finding that firms that began supplying to "Walmart-mex" experienced improvements in productivity, innovation, and other aspects. Empirically, only Abebe et al. (2022) and Amiti et al. (2023) used firm-to-firm sales data to show that domestic firms directly selling to multinationals increase total factor productivity (TFP). The phenomenon of FDI technology spillovers occurring directly between suppliers and customers is essential for understanding FDI's impacts on local firms. However, it has been largely overlooked in the existing literature.

In China, foreign-invested firms not only belong to multinational corporations and serve as significant players in international division of labor, but also constitute a crucial part of the domestic production

[2] See https://www.qcc.com

network as entities established within Chinese borders. Therefore, our study is closely intertwined with the literature related to domestic production networks. With the deepening evolution of modern production organizational methods, the international production division cooperation between multinational enterprises is becoming increasingly tight, and domestic production networks are becoming more complex (Bao & Liao, 2023). Apart from multinational corporations, Greenstone, Hornbeck, and Moretti (2010) found that existing factories in counties hosting million-dollar factories exhibit higher productivity rates compared to existing factories in the second-ranked counties. This conclusion was corroborated by Bloom, Schankerman, and Reenen (2013). Subsequently, Iyoha (2021) empirically tested productivity spillovers within production networks based on data at the firm level in the United States. These studies laid a solid foundation for exploring the technology spillovers of FDI in domestic production networks.

Another relevant area of research examines supply chain interactive relationships. As the global value chain continues to deepen, there is a shared interest among companies in focusing on specific tasks, exchanging technologies, and mutual learning (World Bank, 2020), leading to a more aligned incentive mechanism between buyers and suppliers (Alfaro & Laura, 2017). In recent years, an increasing number of scholars have explored the technology spillovers on the supply chain in more detail from a business relationship perspective. For example, building on Alfaro and Laura (2017), Amiti et al. (2023) using sales data from Belgian firms, find that globality is not necessary for generating spillovers; domestic superstar firms generate comparable productivity spillovers to multinationals. Regarding China, Bao and Liao (2023) confirmed that Chinese exporters improve the productivity of upstream suppliers through indirect exporting. Li, Lan, and Wu (2022), Du, Lou, and Hu (2023) from the lens of digital transformation, confirm that Chinese-listed companies bring favorable effects to downstream customers through supplier-customer relationships. However, there is scarce literature that explores FDI technology spillovers in China using supplier-customer transaction data.

Overall, upon reviewing existing literature, it is observed that, firstly, research on FDI technology spillovers often begins at the industry level, with unclear micro-level evidence, which is currently advocated by scholars (Keller & Wolfgang, 2021). Secondly, multinational supply chains, primarily led by multinational corporations, serve as crucial links between domestic and international production networks. Yet, academic attention towards the technology spillovers on multinational supply chains remains limited. Lastly, the source of FDI is a significant influencing factor on its technology spillovers. However, few scholars have employed more detailed micro-level evidence to categorize the source of FDI and analyze the differences in technology spillovers from FDI originating from different regions within supplier-customer networks.

2.2. Hypothesis development

Based on FDI technology spillover theory, FDI is a potentially significant conduit for international technology diffusion by transferring knowledge across countries. Consequently, FDI is often seen as a crucial source for accumulating human capital and enabling technological change in developing countries. In studies regarding FDI technology spillovers, it is commonly believed that they facilitate inter-industry technology spillovers through mechanisms such as knowledge transfer and economies of scale (Javorcik, 2004), thereby promoting productivity enhancement among local firms. With the evolution of modern production organization, international production segmentation and cooperation among multinational enterprises are becoming increasingly detailed and integrated. Close collaboration between upstream and downstream enterprises within the same supply chain facilitates research and development (R&D) cooperation and information exchange among firms. An increasing body of evidence suggests that technology spillovers from multinational corporations exist not only between industries but also among firms. From the perspective of knowledge diffusion, Poole (2013) found evidence of knowledge sharing even across different industries through labor movements from multinational corporations to domestic firms. Abebe et al. (2022) also argue that the technology spillovers generated by multinational corporations, once absorbed by nearby domestic firms, gradually diffuse to more distant domestic firms.

On the other hand, supply chain coordination theory posits the supply chain, as a crucial channel for inter-firm connections, establishes a symbiotic relationship between customers and their upstream suppliers due to business contacts, making the supply chain an economic system conducive to the flow and diffusion of information. Relying on the supply chain, significant production technology and information spillover effects occur between upstream and downstream enterprises, becoming an important channel for international technology spillovers. Serpa and Krishnan (2018) empirically studies the productivity spillovers from customers to suppliers, concluding that productivity on the supply chain drives firm productivity. Therefore, multinationals with supply chains, as crucial nodes connecting domestic and international markets, may significantly influence domestic firm productivity by forging business ties. Alfaro-Urena et al. (2022) and Amiti et al. (2023) demonstrate using transaction data between companies in Costa Rica and Belgium that domestic suppliers experienced an improvement in total factor productivity after first selling goods to multinational buyers. This paper proposes:

H1. In the Chinese market, FDI generates technology spillovers directly through connections between supplier-customer networks, indicating the existence of inter-firm technology spillovers from FDI.

In general, international markets often have higher product and technology standards. When multinationals enter a host country, they demonstrate advanced design concepts, mature production technology, efficient production organization and management experience, and sustained profitability. To supply products meeting international market demands, multinationals must transfer knowledge and technology to domestic firms to ensure quality standards. This can be achieved via equipment and patent transfer, improving process and technical standards for domestic firms. Facing stringent international product standards, domestic firms may passively improve production efficiency by raising R&D investment or innovating in organization capital and management methods.

Empirical studies indicate that customer-supplier relationships significantly transfer and diffuse knowledge, facilitating tacit knowledge flows between firms (Chen & Liu, 2021; Yang, Peng, & Ge, 2022). For instance, Chen and Liu (2021) find that the firm sales revenue increased by approximately 61.35% after a major customer established a national-level high-tech zone, primarily via knowledge spillovers and demand expansion from customer to supplier. Customers also provide suppliers vital knowledge and innovation resources (Li et al., 2022). The relationship intensity enables individual access to external resources, with robust network connections facilitating knowledge transfer (Xu, Yang, & Sun, 2018). Thus, stronger supplier ties with multinational enterprise customers increase FDI technology acquisition through knowledge transfer, promoting firm productivity. This paper proposes:

H2. *Knowledge transfer is one of the channels for FDI technology spillovers in supplier-customer networks.*

The productivity of firms depends on efficient resource allocation. The efficiency of resource allocation is often closely related to the inventory turnover situation (Ding, Guariglia, & Knight, 2013), financial condition (Myers & Majluf, 1984), and resource configuration methods (Wu & Yao, 2023) of the firm.

From the perspective of supply chain inventory configuration efficiency, establishing business relationships with multinationals improve product-market fit in foreign markets and expand the strategic layout to international markets. Such market expansion can increase the scale of firm sales, reduce inventory turnover, improve supply chain efficiency, and consequently enhance firm productivity.

From the perspective of supply chain capital configuration efficiency, FDI, as a financing channel, can ease host country firm financing constraints by bringing scarce capital to the host countries. (Harrison & Rodriguez-Clare, 2010). At the same time, multinationals usually have strong internal financing capabilities and access global markets. Cooperating with such firms can effectively alleviate Chinese suppliers' constraints. Improving financing constraints is more conducive to firms in reducing liquidity risk, promoting investment integration, facilitating technological innovation input, and thus enhancing production efficiency.

Finally, the perspective of supply chain resource configuration methods, of the literature on supply chain concentration show listed firms often rely heavily on key customers for raw materials and business performance. Therefore, firms tend to engage in transactions with a few major customers, establishing long-term cooperative relationships to reduce the uncertainty of market uncertainty. As major customers, multinationals make supplier chains more concentrated when supplier-customer ties form. The supply chain centralization contributes to the formation of stable cooperative relationships, which enhances production cooperation, information sharing, and joint investment along the chain (Kinney & Wempe, 2002). This enables firms to gain a competitive advantage and directly reduce transaction costs from information asymmetry and incomplete contracts. Suppliers can thus secure favorable terms, bolstering efficiency (Bernard, Moxnes, & Saito, 2019). In summary, this paper proposes:

H3. *Optimizing supply chain configuration is one of the channels for FDI technology spillovers in supplier-customer networks.*

3. Research design

3.1. Data

The supply chain-customer data come from Accounting Research Database (CSMAR). For the initial sample, the following criteria were applied for selection: (1) Considering the impact of the 2008 financial crisis, the study period was set from 2009 to 2020. (2) Samples with missing customer information or those unable to identify whether the customer is a foreign-invested firm[3] were excluded. (3) Samples that did not provide complete and detailed information on all five downstream customers in the current year were excluded. (4) ST, *ST, and PT-listed firms were excluded. (5) Samples with missing values for other important variables were excluded. This yields an initial 17,670 observations. After indicator calculation and further screening, the final sample has 2544 observations for empirical analysis.

3.2. Variable

3.2.1. Dependent variable: total factor productivity of firms(TFP)

A standard method for estimating TFP in the current literature is the semi-parametric approach, which effectively addresses endogeneity and sample selection issues inherent in traditional econometric methods. In the regression analyses, this paper employs the LP and OP methods to measure the TFP of firms, denoted as TFP-LP and TFP-OP, respectively.

3.2.2. Independent variable: degree of supply to foreign-invested firms (supply)

In light from Dhyne, Kikkawa, Mogstad, and Tinelnot (2021) and Bao and Liao (2023), we employ eq. (1) to calculate the degree of supply by firms to foreign-invested firms:

$$Supply_{it} = \sum_{c \in I_i} s_{ict} \tag{1}$$

where subscripts c represents the foreign-invested firm customer of listed firm, I_i denotes the customer set of listed firm i, and represents the proportion of sales by listed firm i to foreign-invested firm customer c in year t relative to total sales.

In the above equation, the key factor in the degree of foreign supply is the proportion of sales to foreign invested firms among the listed firm's top five customers. Therefore, identifying the foreign-invested status of these major customers is crucial.

We use the batch import function of the QCC website to upload the cleaned "firm Full Name" of customer companies and conducts the first-round identification based on their registration types. Unidentified firms are imported again after removing location keywords for a second round. Remaining undetermined cases undergo manual identification via firm keywords and former names in a third round. Finally, firms still not meeting the criteria are excluded.

3.2.3. Control variables

We also control for various firm characteristics, including *Size* (the natural logarithm of the number of employees), *Firm age* (the current year minus the year of establishment), *Foreign ownership ratio* (the proportion of shares held by foreign initiators to the total share capital), *Equity concentration* (the proportion of shares held by the top ten shareholders to the total share capital), *Current ratio* (the sum of current assets divided by current liabilities), *Return on assets* (the net profit divided by the average total assets times 100%, *Return on equity* (the net profit divided by the average equity times 100%), *Inventory turnover ratio* (the cost of goods sold divided by the average inventory), *Industry concentration* (the Herfindahl-Hirschman Index).

Table 1 shows the descriptive statistics of the main variables.

Next, in order to better analyze the characteristic distribution of the supply provided by listed firms to foreign-invested firms, we divided the samples into manufacturing (MFG) and non-manufacturing (NMFG), state-owned enterprises (SOE) and non-state-owned enterprises (NSOE), high-tech enterprises (HTE) and non-high-tech enterprises (NHTE), and used box plots to describe the grouping of core explanatory variables. From Fig. 1, we can see the supply characteristics provided by listed firms to foreign-invested firms under different groups. Overall, manufacturing companies supply foreign-invested firms more than non-manufacturing companies; non-state-owned enterprises supply foreign-invested firms more than state-owned enterprises; high-tech enterprises supply foreign-invested firms more than non-high-tech enterprises. For more detailed features, refer to Fig. 1.

Table 1
Descriptive Statistics of Main Variables.

Variables	Obs	Mean	Std. Dev.	Min	Max
Supply(%)	2544	3.932	9.420	0	82.29
TFP-LP	2544	6.194	1.072	3.839	12.917
TFP-OP	2544	6.614	0.958	2.548	11.418
Size	2544	7.641	1.286	2.197	11.472
Firm age	2544	14.241	6.335	1	28
Foreign ownership ratio	2544	0.007	0.573	0	0.757
Equity concentration	2544	0.495	0.216	0.111	0.964
Current ratio	2544	1.794	2.002	0.529	48.471
Return on assets	2544	0.029	0.089	−2.746	0.336
Return on equity	2544	−0.014	1.095	−41.502	0.667
Inventory turnover ratio	2544	34.797	904.165	0.003	45,256.39
Industry concentration	2544	0.221	0.191	0.399	1

[3] Foreign-invested firms refer to companies established within the territory of China according to Chinese laws, involving joint investments from both Chinese and foreign investors or solely from foreign investors. In general, the foreign capital ratio of a foreign-invested firm should be equal to or greater than 25%. We use registration information from the industrial and commercial administrative authorities to determine whether a company qualifies as a foreign-invested firm.

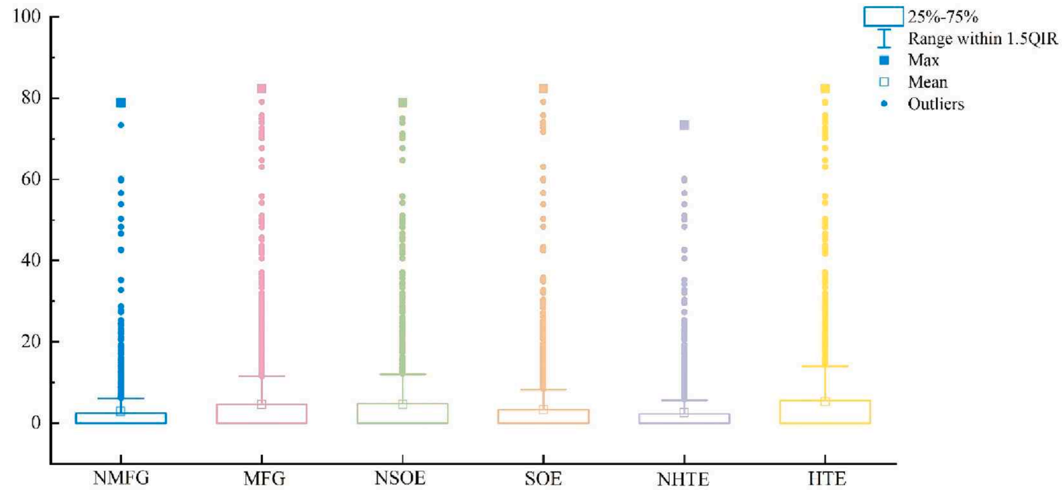

FIG. 1. The Distribution of Grouping Characteristics of Independent Variable.

3.3. Model design

The baseline econometric model for this paper is specified as follows:

$$TFP_{it} = \alpha + \beta Supply_{it} + \sum Controls_{it} + \delta_i + \lambda_t + \varepsilon_{it} \quad (2)$$

where subscripts *i* and *t* denote the firm and year, respectively. TFP_{it} is the dependent variable representing the total factor productivity of firm *i* in year *t*. $Supply_{it}$ is the key explanatory variable of interest, indicating the extent to which firm *i* supplies to foreign-invested firms in year *t*. $\sum Controls_{it}$ represents a series of firm-year level control variables. Additionally, the model controls for unobservable firm fixed effects δ_i and year fixed effects λ_t with ε_{it} being the error term.

4. Empirical results

4.1. Baseline results

The baseline regression analysis is conducted by progressively introducing fixed effects, and the results are presented in Table 2. Columns 1, 3, and 5 employ TFP-LP as the dependent variable, while Columns 2, 4, and 6 use TFP-OP. Columns 1 and 2 only include firm fixed effects, Columns 3 and 4 add year fixed effects, and Columns 5 and 6 further incorporate industry fixed effects. The coefficient of the core explanatory variable remains consistently and significantly positive at the 1% level, suggesting the robustness of the baseline regression results. The results indicate that FDI can generate technology spillovers through direct supplier-customer relationships, improving the productivity of upstream suppliers.

4.2. Robustness tests

4.2.1. Excluding the influence of customers from listed firms

Foreign-invested customers concurrently being publicly listed firms may confound impacts. We address potential bias by re-estimating the model excluding cases where a supplier's top five customers are both foreign-invested and listed firms. From Columns 1 and 2 of Table 3, it can be observed that the results remain robust.

4.2.2. Excluding the influence of suppliers from foreign-invested firms

The inspection of this part mainly considers two aspects: first, when the supplier is a foreign-invested firm, whether from the impact of managerial decisions or relationship networks, it is more likely to establish business relationships with foreign-invested firm customers. This phenomenon may affect our baseline regression analysis. Second, a substantial body of literature indicates that multinational enterprises

Table 3
Results of Excluding the Influence of Customers from Listed firms.

	(1)	(2)
	TFP-LP	TFP-OP
Supply	0.005***	0.004**
	[0.002]	[0.002]
Control variables	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	2400	2400
Adjusted R^2	0.871	0.838

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

Table 2
Results of Basic Regression.

	(1)	(2)	(3)	(4)	(5)	(6)
	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP
Supply	0.005***	0.004***	0.005***	0.004***	0.005***	0.004***
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	No	No	Yes	Yes	Yes	Yes
Industry fixed effects	No	No	No	No	Yes	Yes
Observations	2544	2544	2544	2544	2544	2544
Adjusted R^2	0.870	0.837	0.873	0.842	0.877	0.846

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

have higher productivity than domestic firms(Amiti et al., 2023; Keller & Wolfgang, 2021). Therefore, suppliers that are also foreign-invested firms may inherently possess higher productivity. Thus, after excluding the samples of suppliers that are foreign-invested firms, we find the results remain robust as shown in Table 4.

4.2.3. Excluding the impact caused by newly hired executives with overseas backgrounds and work experience

Companies may experience unobservable shocks influencing their supply relationships with foreign-invested firms and overall productivity. While these shocks might not be evident in all new employees, it is crucial to consider the impact of recruiting influential personnel (Alfaro-Urena et al., 2022). Our primary focus is on the impact of hiring directors with overseas backgrounds and work experience. Initially, we excluded samples where the number of directors with overseas backgrounds increased from the previous year. The regression results are reported in Columns 1 and 2 of Table 5. Additionally, concerns arise with the recruitment of directors with overseas work experience, as they are likely to leverage their previous relationships with foreign employers to secure new contracts for their current employers with multinationals and transfer knowledge gained from prior employment, thereby enhancing the productivity of the new employer (Alfaro-Urena et al., 2022). Hence, we also exclude samples where the number of directors with overseas work experience increases from the previous year, and the regression results are reported in Columns 3 and 4 of Table 5. *Re*-estimation confirms the robustness of our findings.

4.2.4. Alternative measures

Firstly, for the dependent variable, we employ OLS and GMM methods to calculate the total factor productivity of publicly listed firms and conduct robustness tests on the dependent variable. Secondly, we measure the degree of supply to foreign-invested firms by assigning values based on a specific rule:, assign 5 points if the top-ranking customer is a foreign-invested firm; 4 points for the second-ranking customer, and so on. Finally, the scores are summed to obtain the alternative indicator "$Supply_{ASS}$". Building on the original measurement approach, this paper predicts the degree of supply to foreign-invested firms by considering the proportion of sales to the top five customers relative to the total sales by listed firms, yielding the alternative indicator "$Supply_{Tot}$". The results, as reported in Table 6, remain consistent.

4.2.5. Change the model specification

To address potential variations in fixed effects, we augment the baseline regression model—controling for individual fixed effects—by successively adding industry-year fixed effects and province-year fixed effects. In addition, we also consider the robust standard error of clustering. Recognizing the impact of random errors, this paper clusters standard errors at the firm and province levels. The results, as reported in Table 7, remain consistent.

Table 4
Results of Excluding the Influence of Suppliers from Foreign-invested firms.

	(1)	(2)
	TFP-LP	TFP-OP
Supply	0.005***	0.004**
	[0.002]	[0.002]
Control variables	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	2508	2508
Adjusted R^2	0.874	0.842

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

Table 5
Results of Excluding Listed firms and Newly Hired Executives with Overseas Backgrounds and Work Experience.

	Newly hired directors with overseas backgrounds		Newly hired directors with overseas work experience	
	(1)	(2)	(3)	(4)
	TFP-LP	TFP-OP	TFP-LP	TFP-OP
Supply	0.004**	0.004*	0.004**	0.004*
	[0.002]	[0.002]	[0.002]	[0.002]
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	1759	1759	1829	1829
Adjusted R^2	0.884	0.853	0.880	0.848

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

4.2.6. Endogeneity tests

4.2.6.1. Sample-selection bias based on Heckman's two-step method. In reality, China has never mandated listed firms to disclose the names of their top 5 customers and suppliers. However, guidelines encouraging firms to separately disclose the names of their top 5 customers (suppliers) were released in different years, potentially introducing sample selection bias to the baseline model. To mitigate this interference, Heckman's two-step method is employed for estimation. In the first step, using the complete panel data of all listed firms, a Probit model estimates a binary variable indicating whether a listed firm fully reports the names of its top 5 customers. The resulting Inverse Mills Ratio (IMR) is then computed. In the second step, IMR is incorporated into the baseline regression model, and the estimation is re-conducted. Table 8 displays that the coefficient of IMR is not significant. The core explanatory variable remains significantly positive even after the inclusion of IMR, with no significant differences observed in the estimated coefficients compared to the baseline regression.

4.2.6.2. Instrumental variable regression. Considering potential endogeneity issues like reverse causality, we conducted a two-stage least squares (2SLS) estimation using instrumental variables (IVs). We select the following IVs: (1) We employ the lagged one-period values of SupplyAss and SupplyTot as IV1 and IV2. The lagged values exhibit some correlation with the endogenous explanatory variable in the current period but are unrelated to the outcome variable, satisfying the exclusion restriction. (2) We use the mean degree of supply from same-year same-industry suppliers to foreign-invested firms as IV3. In terms of correlation, companies within the same industry experience similar external environments and sharing similar characteristics, causing the industry average to correlate with firm-level measures. Since the industry mean is aggregated, it is unlikely to directly impact the dependent variable in this paper, meeting the homogeneity principle. IV regression results are presented in Table 9. The under-identification tests reject the null hypothesis, indicating a correlation between the instrumental and endogenous variables. Simultaneously, these instrumental variables also reject the weak instrument hypothesis. Our conclusions remain valid after addressing endogeneity using IVs.

5. Further analysis

5.1. Channel analysis

5.1.1. Knowledge transmission channel

This paper delineates the knowledge transfer channels of FDI technology spillovers in supplier-customer networks in terms of innovation input, innovation output, and the innovation boundary.

Firstly, we draw on the approach by Triguero and Córcoles (2013) to

Table 6
Results of Alternative Measures.

	(1)	(2)	(3)	(4)	(5)	(6)
	TFP-OLS	TFP-GMM	TFP-LP	TFP-OP	TFP-LP	TFP-OP
Supply	0.003**	0.005***				
	[0.001]	[0.002]				
$Supply_{ASS}$			0.011**	0.011**		
			[0.005]	[0.005]		
$Supply_{Tot}$					0.002***	0.002***
					[0.001]	[0.001]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2544	2544	2544	2544	2544	2544
Adjusted R^2	0.908	0.829	0.873	0.841	0.873	0.842

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

Table 7
Results of Change the Model Specification.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP
Supply	0.005***	0.004**	0.005***	0.004**	0.005***	0.004**	0.005**	0.004**
	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	No	No	No	No	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	No	No	No	No
Province-year fixed effects	No	No	Yes	Yes	No	No	No	No
Observations	2544	2544	2544	2544	2544	2544	2544	2544
Adjusted R^2	0.882	0.851	0.888	0.860	0.873	0.842	0.873	0.842

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; The values in parentheses in columns 1 to 4 represent the standard errors of the regression coefficients. The values in parentheses in columns 5 to 6 represent the robust standard errors of the regression coefficients clustered at the provincial level. The values in parentheses in columns 7 to 8 represent the robust standard errors of the regression coefficients clustered at the enterprise level.

Table 8
Results of Heckman's Two-step Method.

	(1)	(2)
	TFP-LP	TFP-OP
Supply	0.005**	0.005**
	[0.002]	[0.002]
IMR	−0.016	−0.056
	[0.159]	[0.159]
Control variables	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Observations	1899	1899
Adjusted R^2	0.868	0.832

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

measure the supplier's innovation capability through the sustainability of innovation inputs (IIP). Specifically, IIP is assessed by comparing the supplier's research and development (R&D) expenditures before and after receiving FDI. The formula to calculate IIP is as follows:

$$IIP_t = \frac{IIN_t + IIN_{t-1}}{IIN_{t-1} + IIN_{t-2}} \times (IIN_t + IIN_{t-1}) \tag{3}$$

where IIP_t represents the sustainability of innovation input for the firm in the t-th year, and IIN_t, IIN_{t-1}, $IIN_{t-2}$are the R&D expenditures for the firm in the t-th, (t-1), and (t-2) years, respectively.

Next, following Dang and Motohashi (2015), we measure the innovation capability of the supplier from two perspectives: encompassing exploitative innovation (Exploi) and exploratory innovation (Explor). Exploitative innovation is quantified as the natural logarithm of one plus the sum of utility model and design patent applications filed by the supplier. Exploratory innovation is calculated as the natural logarithm of one plus the sum of invention patent applications.

Lastly, inspired by Byun, Oh, and Xia (2021), based on the primary classification of patents applied by listed firms, we assess the breadth of a supplier's knowledge base using the distribution of their patent applications across technology fields, which serves as an indicator for measuring the innovation boundary of the firm. Similar to the Herfindahl index, this metric reflects whether the distribution of a firm's technological fields is "concentrated" or "dispersed," indicating changes in the innovation boundary. A higher value suggests a more dispersed distribution of technological fields, widening the innovation boundary. The formula to calculate this knowledge breadth measure is as follows:

$$Inn\_hhi_{it} = 1 - \sum \left(\frac{Z_{imt}}{Z_{it}} \right)^2 \tag{4}$$

where Z_{imt} represents the cumulative number of invention and utility model patents applied for by firm i up to year t in major group m, and Z_{it} represents the cumulative number of patents applied for by firm i up to year t across all major groups. A higher value for Inn_hhi_{it} indicates a broader knowledge breadth in patent applications for a firm, signifying a wider innovation boundary.

Columns 1 and 2 of Table 10 show that the interaction term $IIP \times Supply$ is significant at the 10% and 5% levels, indicating that the FDI technology spillovers between firms are more pronounced when suppliers have stronger sustainable innovation input capability. This suggests that FDI can enhance the sustainable innovation input capability of upstream suppliers through direct supply relationships, thereby improving their productivity.

Columns 3 and 4 of Table 10 demonstrate that the interaction term $Exploi \times Supply$ is significant at the 5% level, indicating that FDI technology spillovers between firms are more pronounced when suppliers have higher exploitative innovation capability. Thus, FDI may improve

Table 9
Results of instrumental variable regression.

	First phase		Second phase					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Supply	Supply	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP
IV1	0.675*** [0.074]							
IV2	0.124*** [0.011]							
IV3		−0.320*** [0.091]						
Supply			0.021*** [0.007]	0.019*** [0.007]	0.014*** [0.005]	0.012** [0.005]	0.042** [0.020]	0.037* [0.020]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1872	2544	1872	1872	1872	1872	2544	2544
Adjusted R^2	/	/	0.895	0.868	0.998	0.998	0.998	0.997
F test	/	/	83.20	83.20	134.89	134.89	12.37	12.37

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

Table 10
Results of mechanism verification of knowledge transfer.

	Sustainability of innovation investment		Dual innovation				Innovation boundariy	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP
Exploi×Supply	2.210* [1.060]	2.310** [1.060]						
Explor×Supply			0.002** [0.001]	0.003** [0.001]				
IIP × Supply					0.001 [0.001]	0.001 [0.001]		
Inn_hhi × Supply							0.007** [0.003]	0.009*** [0.003]
Supply	0.003* [0.002]	0.002 [0.002]	0.004** [0.002]	0.003 [0.002]	0.005*** [0.002]	0.004** [0.002]	0.003* [0.001]	0.002 [0.001]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1490	1490	2538	2538	2538	2538	1833	1833
Adjusted R^2	0.920	0.892	0.873	0.842	0.873	0.842	0.915	0.890

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

the exploitative innovation capability of upstream suppliers through direct supply relationships, thereby promoting productivity. However, Columns 5 and 6 of Table 10 show that the interaction term *Explor×Supply* is insignificant, suggesting that FDI has a less pronounced impact on the enhancement of suppliers' exploratory innovation. The possible reason lies in the fact that emerging economy firms, represented by China, often focus more on imitation over pioneering innovation (Di, Zhang, & Gammeltoft, 2012); their technology typically involves localizing technologies from the developed countries (Elango & Pattnaik, 2007), lacking impacts on exploratory innovation. Therefore, although FDI can bring new knowledge to Chinese firms through direct supply relationships, such influence is mainly reflected in exploitative innovation rather than exploratory innovation, highlighting the limitations of FDI technology spillovers on firm innovation.

Columns 7 and 8 of Table 10 indicate that the interaction term *Inn_hhi×Supply* is significant at the 5% and 1% levels, suggesting that the FDI technology spillovers are more pronounced for firms with wider innovation boundaries. This indicates that FDI can broaden the innovation boundary of upstream suppliers through direct supply relationships, enhancing their productivity. In summary, knowledge transfer is one of the channels for FDI technology spillovers in supplier-customer networks.

5.1.2. Optimizing supply chain configuration channel

By integrating factors influencing supply chain configuration efficiency, the paper examines the channels of FDI technology spillovers between firms through the optimization of supply chain configuration across three dimensions: supply chain inventory configuration efficiency (Inv), supply chain capital configuration efficiency (Cap), and supply chain resource configuration methods (Met). Firstly, following Zhang and Duan (2023), we measure supply chain inventory configuration efficiency using the natural log of 365 divided by inventory turnover ratio, calculated as ln(365/inventory turnover ratio); lower values indicate higher efficiency of supply chains. Secondly, following Ju, Lu, and Yu (2013), Using the SA index to measure the financing constraints of supplier enterprises, this study evaluates the supply chain capital configuration efficiency of firms based on their financing constraint conditions. Thirdly, inspired by Wu and Yao (2023), the degree of supply chain concentration is used to measure the supply chain resource configuration method of enterprises. Supply concentration is measured by the mean ratio of purchasing from the top five suppliers and sales to the top five customers; a higher value implies greater supply chain concentration.

Table 11 shows the results verifying the supply chain optimization mechanism. Column 1 examines the impact of the supply to foreign-invested firm customers on suppliers' inventory configuration

Table 11
Results of mechanism verification for optimizing supply chain configuration.

	Inventory configuration efficiency	Capital configuration efficiency	Resource configuration methods
	(1)	(2)	(3)
	Inv	Cap	Met
Supply	−0.009*** [0.003]	−0.003* [0.000]	0.252*** [0.043]
Control variables	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	2544	2544	2544
Adjusted R^2	0.789	0.972	0.737

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

efficiency. The core explanatory variable is statistically significantly negative at the 1% level, indicating that supplying foreign-invested firm customers can enhance the inventory configuration efficiency of suppliers' supply chains. The speed at which a company sells inventory is a crucial indicator influencing its operational performance. Improvement in supply chain inventory configuration efficiency implies enhancement in the operational capabilities and inventory management efficiency of the firm, thereby boosting its market value and subsequently enhancing its productivity levels.

Column 2 tests the effect of supplier's degree of supplying to foreign-invested firm customers on the capital configuration efficiency of supply chains. The core explanatory variable is significantly negative at the 10% level, suggesting that supplying foreign-invested firm customers can effectively alleviate financing constraints. Undoubtedly, the allocation of resources by firms within the supply chain network relies heavily on financial support. Financing constraints often result in firms not being able to obtain timely and adequate funding, thus reducing overall investment efficiency (Myers & Majluf, 1984). Therefore, by enhancing the efficiency of supply chain capital configuration, it is possible to optimize the financing environment for firms further, improve investment efficiency, and promote productivity levels.

Column 3 examines the impact of the supplier's degree of supplying to foreign-invested firm customers on the supplier's resource configuration methods. The result reveals a positively significant association at 1%, implying connections with foreign-invested firms can increase suppliers' supply chain concentration. Centralized supply chain resource configuration methods help firms establish stable upstream and downstream cooperation, enhance production collaboration, information sharing, and joint investments between supply chain partners (Kinney & Wempe, 2002). This enhances the competitive advantage of firms and promotes productivity levels.

In conclusion, optimizing supply chain configuration is one of the channels for FDI technology spillovers in supplier-customer networks.

5.2. Heterogeneous effects

5.2.1. The heterogeneous effect of supplier ownership

To analyze how supplier ownership affects FDI spillovers, we divided the sample into state-owned and non-state-owned suppliers. Regression results are reported in Columns 1 to 4 of Table 12. It can be observed that the core variable is significantly positive for state-owned suppliers but insignificant for non-state-owned suppliers. The ownership nature of firms influences supply chain resource and technology allocation, and firms with different ownership natures have differences in their functional roles in the industry supply chain (Yang et al., 2022). State-owned firms often have more stable production and product supply capabilities than non-state-owned firms (Tao, Wang, Xu, & Zhu, 2023). The direct or indirect connections between state-owned firms and the government facilitate their access to more scarce resources and information (Chen, Li, Shapiro, & Zhang, 2014). Therefore, state-owned suppliers may more rapidly respond to foreign customer needs. Thus state-owned suppliers may capture FDI technology spillovers more easily.

Table 12
Results of Ownership of Suppliers Hypothesis Test.

	State-owned supplier		Non-state-owned supplier	
	(1)	(2)	(3)	(4)
	TFP-LP	TFP-OP	TFP-LP	TFP-OP
Supply	0.004** [0.002]	0.003* [0.002]	0.002 [0.003]	0.001 [0.003]
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	1456	1456	1088	1088
Adjusted R^2	0.906	0.880	0.877	0.852

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

5.2.2. The heterogeneous effect of supplier industry characteristics

To analyze the differentiated impacts of industry characteristics on the FDI technology spillovers, we analyze two dimensions: the suppliers' sector and the technological attributes. In order to more precisely identify the contributions of the heterogeneous effects in terms of suppliers' sector and technological attributes, we divided suppliers into the following four sub-group: in the following four sub-groups: 1) Manufacturing & High-tech, 2) Manufacturing & Non-High-tech, 3) Non-Manufacturing & Non-High-tech, 4) Non-Manufacturing & High-tech.

Due to the small sample size from Non Manufacturing & High tech, reliable regression analysis cannot be performed. Therefore, we have only reported the analysis results for the other three scenarios. Table 13 shows that the core variable is significant for high-tech manufacturing firms but insignificant otherwise. The main reason is that compared to non-high-tech firms, high-tech firms face more intense competition (Kim & Steensma, 2017). Thus, high-tech firms are more likely to prioritize acquiring resources through various spillovers to spur innovation and boost their competitive advantage (Yang et al., 2022). Meanwhile, the manufacturing industry typically has stronger technological demands and innovative vitality. Therefore, FDI, as an essential channel for firms to acquire knowledge and technology, is thus more crucial for high-tech manufacturing firms to improve their productivity.

5.2.3. The heterogeneous effect of risk bearing level

Multinational enterprises serve as important channels for transmitting supply shocks (Biermann & Huber, 2022), with external risks such as financial crises exerting long-term effects on multinational enterprises and impacting the performance of both their parent and subsidiary companies (Basco, Felice, Merlevede, & Mestieri, 2023). In recent years, with the increase in uncertainty within global supply networks, the issue of risk interaction with multinational corporations has become increasingly prominent.

To better explore FDI technology spillovers in supplier-customer networks from a risk perspective, we start from the characteristic of firms' risk-bearing level, adopting the approach of He, Yu, and Yang (2019) and others, using the volatility of Roa during the observation period to measure the firm's risk-bearing level. The higher the value, the higher the firm's risk-bearing level. At the same time, we define firms with a risk-bearing level above the median in the sample as high-risk-bearing firms, and other firms as low-risk-bearing firms, to analyze whether different levels of risk-bearing have a differentiated impact on firms' ability to capture technology spillovers from FDI in supplier-

Table 13
Results of Supplier Industry Characteristics Hypothesis Test.

	Manufacturing & High-tech		Manufacturing & Non-High-tech		Non-Manufacturing & Non-High-tech	
	(1)	(2)	(3)	(4)	(5)	(6)
	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP
Supply	0.006***	0.004**	0.007	0.006	0.000	−0.000
	[0.002]	[0.002]	[0.005]	[0.005]	[0.003]	[0.003]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1213	1213	339	339	930	930
Adjusted R^2	0.885	0.847	0.938	0.909	0.882	0.865

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

customer networks.

From Table 14, it can be seen that the core explanatory variable for firms with a high level of risk-bearing is significant at the 1% level, while it is not significant for firms with a low level of risk-bearing. This indicates that firms with a high level of risk-bearing are more likely to capture technology spillovers from FDI in supplier-customer networks. The main reason may be that FDI itself can be considered a risk factor in corporate investment decisions. With the influence of external risk uncertainty, the firm's level of risk-bearing becomes crucial in the process of capturing FDI technology spillovers. A higher level of risk-bearing is usually manifested as firms having higher capital expenditures (Bargeron, Lehn, & Zutter, 2010) and a greater propensity for innovation (Hilary & Hui, 2006), reflecting that firms are more fully utilizing investment opportunities, more likely to capture technology spillovers from FDI among firms, and enhance their productivity.

5.3. Sources of FDI driving technology spillovers in supplier-customer networks

Which source of FDI is more effective in improving domestic firm productivity through supplier-customer networks? Chinese scholars have particularly focused on FDI from Hong Kong, Macao, and Taiwan (HMT) compared to non-HMT FDI. Meng and Xu (2005) find at an aggregate level that FDI from HMT exhibits significant technology spillovers but not for non-HMT. However, Lin et al. (2009) reveals that non-HMT investments have positive horizontal, forward, and backward spillovers. In contrast, HMT investments have negative horizontal and backward spillovers and positive forward spillovers. This highlight that the source of FDI is a crucial factor influencing technology spillovers.

As opposed to the existing studies that mainly distinguish between HMT and non-HMT regions, we not only differentiate HMT foreign investments from non-HMT foreign investments but also further categorize non-HMT foreign investments into developed country investments,[4] developing country investments, and investments from the British Virgin Islands, the Cayman Islands, and Bermuda. The primary reason for this categorization is that, due to differences in technological levels between developed and developing countries, FDI from advanced countries tends to have greater spillovers (Griffith et al., 2004).

Table 14
Results of Risk Bearing Level Hypothesis Test.

	High risk bearing firms		Low risk bearing firms	
	(1)	(2)	(3)	(4)
	TFP-LP	TFP-OP	TFP-LP	TFP-OP
Supply	0.008***	0.007***	0.002	0.001
	[0.002]	[0.002]	[0.002]	[0.002]
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	1183	1183	1207	1207
Adjusted R^2	0.857	0.825	0.935	0.917

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

On the other hand, firms often register in regions such as the British Virgin Islands (VGB), Bermuda (BMU), and the Cayman Islands (CYM) for tax avoidance purposes, leading to unclear identification of their actual capital sources and the emergence of a considerable amount of "round-trip" foreign capital, raising concerns about the quality of foreign investment (Xiao, Xu, & Fan, 2022). Moreover, we observed various sample suppliers serve foreign-invested firm from these "tax havens."[5] Hence, it is necessary to separate and analyze investments from these regions.

Fig. 2 depicts the distribution of China's FDI sources. Evidently, the HMT region consistently stands as the primary source of China's FDI, comprising 63.51% of investment in 2011 rising to 77.75% in 2021. Developed countries represent the second-largest source of China's FDI with 20.81% share in 2011 falling to 16.37% by 2021 The British Virgin Islands, the Cayman Islands, and Bermuda collectively constitute the third-largest source, comprising 11.00% of the total investment in 2011, declining to 4.53% in 2021. FDI from developing countries has a relatively low share, accounting for 4.68% of the total investment in 2011 and decreasing to 1.35% in 2021.

Next, we primarily explore the differentiated impacts of FDI sources on its technology spillovers in supplier-customer networks. We identify the origins of FDI in foreign-invested firms using equity structure data from the Qichacha website with the following principles: (1) When there is only one overseas shareholder in the equity structure information of a foreign-invested firm, the origin of this overseas shareholder is considered as the source of foreign investment for that firm. (2) When there are two or more overseas shareholders from different regions, and their shareholding ratios are different, the overseas shareholder ranked the first is considered the source of foreign investment for that firm. (3) When there are two or more overseas shareholders from different regions but with the same shareholding ratios, the foreign-invested firm is assigned as multiple identities. (4) When there are two or more overseas

[4] The developed-country foreign investment, as classified in our paper, refers to excluing foreign investment from developed countries originating in tax havens such as the British Virgin Islands, the Cayman Islands, and Bermuda.

[5] Internationally recognized offshore centers are numerous, among which the British Virgin Islands, the Cayman Islands, and Bermuda outside China are particularly noteworthy. Meanwhile, by observing China's foreign direct investment data, it can be observed that foreign direct investment from these three regions constitutes a significant proportion. Therefore, in this context, the term "tax haven regions" primarily refers to the British Virgin Islands, the Cayman Islands, and Bermuda.

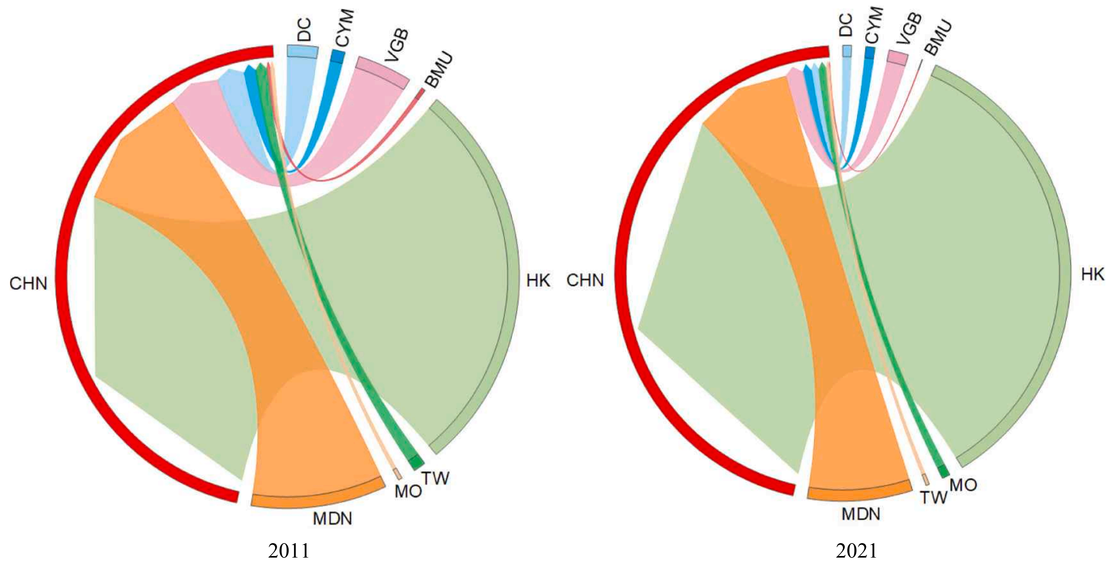

Fig. 2. Distribution of FDI Sources in China in 2011 and 2021.

shareholders from different regions with different shareholding ratios, and two or more overseas shareholders have shareholding ratios exceeding 25%, the foreign-invested firm is assigned multiple identities based on the source of the overseas shareholder with a shareholding ratio exceeding 25%. Finally, based on the FDI source, they are categorized into regions such as HMT, developed countries, developing countries, and tax havens such as the British Virgin Islands, the Cayman Islands, and Bermuda. The supply degree to foreign-invested firms from different FDI sources is measured according to the measurement method of the core explanatory variables.

Table 15 presents the regression results of the differentiated impacts of FDI sources. In Columns 1 and 2, the coefficients of $Supply^{MDN}$ are both significantly positive at the 1% level, and the magnitude of the regression coefficients is approximately twice as big as that of the baseline regression. This indicates that FDI from developed countries exhibits inter-firm technology spillovers through supplier-customer networks.

Columns 3 and 4 show that the coefficients of $Supply^{HMT}$ are significantly positive at the 5% level and insignificant, respectively. This indicates that we do not have sufficient evidence to establish a significant impact of FDI from HMT on Chinese firms. The main reasons could be that foreign-invested firms from developed countries often possess more advanced technology, a global value chain, and more renowned brands than those from HMT (Tong, 2010). Additionally, there may be a considerable presence of "pseudo-investments" among firms from HMT. However, given HMT's sizable FDI share including some high-quality capital and cultural proximity, conditions could enable major industry/region-specific spillovers (Xiao, Xiao, & Yang, 2020).

Columns 5 and 6 show that the coefficients of $Supply^{DC}$ are positive but not statistically significant, indicating limited developing country FDI spillovers via direct supply relationships. Reasons could be small overall FDI volume concentrated in labor-intensive sectors and a smaller technology gap impeding advanced knowledge transfers to Chinese firms.

Columns 7 and 8 show that the coefficients of $Supply^{TAX}$ are negative but not statistically significant, indicating that the technology spillovers of FDI from tax havens is insignificant. Unlike other regions, although the results are not statistically significant, the coefficients are negative. It is important to note that offshore financial centers typically do not engage in actual "productive activities" and lack legal entities conducting real business operations (Xiao et al., 2022). Many of them involve domestic funds using the FDI channel to re-enter China. Such FDI may not be technologically more advanced than domestic firms, creating unfair competition conditions in the market. Therefore, caution is needed when dealing with FDI from tax havens.

Table 15
Results of the Differentiated Impact of FDI Source on Its Technology Spillovers.

	MDN		HMT		DC		TAX	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP	TFP-LP	TFP-OP
$Supply^{MDN}$	0.008***	0.008***						
	[0.003]	[0.003]						
$Supply^{HMT}$			0.004**	0.003				
			[0.002]	[0.002]				
$Supply^{DC}$					0.010	0.007		
					[0.009]	[0.009]		
$Supply^{TAX}$							−0.006	−0.006
							[0.006]	[0.006]
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2544	2544	2544	2544	2544	2544	2544	2544
Adjusted R^2	0.874	0.843	0.874	0.842	0.873	0.842	0.873	0.842

Note: ***,**,*denote the significance at 1%, 5%, and 10% levels, respectively; Standard errors in parentheses.

6. Concluding remarks

FDI technology spillovers have long drawn academic and government attention. Diverging from existing research, we adopt a business relationship perspective to focus on FDI technology spillovers in supplier-customer networks. Our study offers micro-level evidence that expands the scope of previous work and provides noval insights into how domestic firms in supply networks can benefit from FDI technology diffusion.

Using 2009–2020 Chinese listed firm supplier-customer data, this paper investigates the mechanisms behind FDI technology spillovers in supplier-customer networks. The key findings are as follows: First, in the Chinese market, FDI technology spillovers can directly occur through connections between supplier-customer networks, demonstrating the inter-firm technology spillover effects of FDI. This primarily occurs via two channels: knowledge transfer and optimization of supply chain configuration. Second, FDI technology spillovers significantly benefit state-owned firms and high-tech manufacturing firms, while the higher the level of risk undertaken by a company, the more likely it is to obtain FDI technology spillovers from the supplier-customer networks. Lastly, FDI from developed countries tends to generate technology spillovers within supplier-customer networks, whereas FDI from HMT, developing countries, and regions considered "tax havens," such as the British Virgin Islands and the Cayman Islands, does not.

Furthermore, while this paper reveals the backward associational effects of FDI technology spillovers in supplier-customer networks, existing research generally suggests differences between the forward and backward associational effects of FDI technology spillovers. Future research could investigate the forward associational effects of FDI technology spillovers. Additionally, the measurement methods employed in this paper could verify if other prominent domestic firms generate technology spillovers via direct supply chain links. This can expand research on technology spillovers along supply chains.

Data availability

Data will be made available on request.

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