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The Rise of Viet Nam's Solar Panel Industry: Inputs, FDI, and Spillovers

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Abstract

When countries subsidize the production and innovation of green goods, does it make it easier for others to join their value chains? We explore this question using Viet Nam's solar panel industry as a case study, using firm-to-firm transaction data to map out its value chain. We find that Viet Nam imports solar parts and components at substantially lower prices from subsidizing countries: about 30% cheaper than from non-subsidizing countries and nearly 50% cheaper from China, where all key inputs are subsidized. We also find that Chinese FDI firms - which account for around 75% of exports and 50% of jobs among all solar producers – export solar panels at around 38% cheaper than other solar panel exporters in Viet Nam. Lastly, we find that local suppliers of solar panel parts and components linked to these firms experience positive productivity gains. Together, the results are consistent with subsidy spillovers that operate through cheaper intermediate inputs, transmission of cost advantage through multinational production networks, and productivity spillovers to local firms.

JEL classification: F14, F23, Q42
Key Words: global value chains, green subsidies, FDI

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1 Introduction

Rapid declines in prices and a global boom in solar panel exports are powering the world's clean energy transition. Industrial policies, including early support for technological innovations and demand expansion by the United States, Japan, Germany, and more recently China, have played a major role in lowering costs and scaling up production. In China for example, local subsidies helped solar panel firms grow by 76% per year during 2004-2013 (Banares-Sanchez et al., 2024). As trade and industrial policies continue to reshape production and trade flows, new manufacturing destinations have entered the industry and begun to specialize within it. These shifts raise a central question for development: when one country subsidizes the production and innovation of green goods, does that make it easier or harder for other countries to also produce those goods or join their global value chains?

We address this question through the case of Viet Nam's solar panel industry. Viet Nam's solar panel exports experienced a meteoric rise between 2018 and 2022, as Viet Nam overtook Malaysia in the US market, accounting for more than a quarter of US solar imports. While this followed increased trade tensions between the US and China,[1] in this paper we focus on how Viet Nam's solar panel industry success can be attributed to attracting FDI and importing parts and components, as well to policy spillovers, particularly from China's green industrial policy.

We use firm-to-firm transaction data from the S&P's Panjiva database - which records trade transactions based on bills of lading - as well as firm-level data from

[1] In 2018, the US imposed 30% tariffs on all cells and panels under Section 201 of the Trade Act of 1974. While Chinese producers faced an extra 25% tariff under Section 301 over concerns related to intellectual property and trade practices, Viet Nam was granted a 24-month exemption from tariffs in 2022. Bollinger et al. (2024) document a sharp decline in Chinese shipments to the US alongside rising shipments from other countries, indicating that US tariffs reshaped sourcing and production patterns.

Viet Nam's Enterprise Surveys to describe Viet Nam's solar panel value chains and document the important role of Chinese firms and inputs in the development of its solar panel industry. We start by compiling a new comprehensive list of all the inputs, whether parts, components, or raw materials, that are part of the solar panel value chain. We do so by combining the list of Rosenow and Mealy (2024), based on the academic literature and industry reports, with that of Fetzer et al. (2024) who used AI to measure input-output relationships in production. We end up with 161 distinct product codes, defined at the 6 digit level using the HS 2017 classification. We then use Panjiva data covering all transactions, both exports and imports, by firms producing solar panels and located in Viet Nam. This data covers transactions with local suppliers as well, as solar panel producers are based in Special Economic Zones (SEZs) that require local inputs to clear customs. This allows us to trace the quasi-entirety of Viet Nam's solar panel value chains, identifying solar panel producers, their exports, and their input transactions over 2018-2022.

First, using firm-level transaction data from Panjiva for Viet Nam, we find that Viet Nam's imports of solar panel parts and components are around 30% cheaper when sourced from countries that provide subsidies compared to those without. Further, we find that Viet Nam's imports of solar panel parts and components are around 50% cheaper when sourced from China - where all solar panel parts and components subsidized - compared to other countries.[2] All solar panel exporters in Viet Nam, whether domestic or foreign-owned use a similarly high share of inputs from China, and stand to benefit from subsidies to solar panel parts and components in China.

Second, we find that solar panels exported by Chinese FDI firms (that account for around 75% of Viet Nam's solar panel exports and 50% of jobs among solar panel producers in Viet Nam) are around 38% cheaper, on average, than those sold by other solar panel exporters in Viet Nam. The difference is more salient for exports to the US;

[2] This is consistent with cross-country results from Rotunno and Ruta (2024a) who find that subsidies lower prices and increase export quantities.

solar panels exported by Chinese FDI firms from Viet Nam to the US were around 54% cheaper than those of other solar panel exporters in Viet Nam. This is indicative of the spillovers of local subsidies across countries through the international networks of firms. Bilir and Morales (2020) shows that research and development (R&D) investments at the headquarters of multinationals raise productivity at their foreign affiliates, highlighting the cross-border transmission of innovation subsidies. At the domestic level, Andrieu and Morrow (2024) find that R&D subsidies targeted at a firm's headquarters in France generate positive spillovers across its branches and connected firms.

Third, we find positive productivity spillovers from Chinese FDI firms to local suppliers of solar panel parts and components in Viet Nam. Although Chinese inputs continue to dominate Viet Nam's solar industry, solar producers are increasingly sourcing domestically. By 2022, the industry had expanded to about 400 firms and 51,000 jobs, with Chinese firms and their suppliers accounting for nearly half of employment. Using synthetic difference-in-differences estimations, we show that establishing a new supplier link with a Chinese FDI solar panel producer increases the labor productivity of a domestic input supplier by 33% in the three years after the link was established. This is consistent with Navarra (2023) who documents spillover effects of subsidies on upstream industries, and Nuriye Melisa et al. (2024), who shows that when downstream firms adopt new technologies, it exerts pressure on upstream suppliers to upgrade their capabilities.

Our results shows the crucial role of foreign investment and foreign inputs in the development of Viet Nam's solar industry, highlighting the benefits of joining global value chains and the potential cross-border effects of subsidies. Not only are Chinese FDI firms contributing to a large share of Viet Nam's exports and employment in the solar panel industry, they also create linkages with domestic suppliers in Viet Nam. What's more, lower-priced inputs from China are widely-used and benefit not only Chinese firms but all solar producers in Viet Nam. Given the number of jobs created in the solar industry in Viet Nam, the diversity of parts and components imported, and the amount of FDI firms and their spillovers, our findings are consistent with Schulze and Xin (2025), who show that Viet Nam's export growth to the US is partly driven by Chinese greenfield FDI and largely reflects trade reallocation rather than significant transshipment of Chinese exports.

Our work contributes to the literature that documents spillovers of green industrial policies. For example, Banares-Sanchez et al. (2024) find that city-level innovation and production subsidies had spillovers on innovation and productivity in other cities. Our study adds to the evidence of cross-country spillovers. It compliments other studies such as Gerarden (2023) which finds that subsidies like the help-to-buy scheme for solar panels in Germany have spillover across countries. Similarly, Barwick et al. (2025) show that consumer subsidies on EVs lead to learning-by-doing in battery production and in turn lower prices, benefiting EV producers in other countries.

We describe the data in section 2 and our results in section 3. We conclude in the last section 4.

2 Data

2.1 Identifying inputs in solar panel supply chains

To identify the inputs that are part of solar panel value chains, we compile a comprehensive list of products based on Rosenow and Mealy (2024) and Fetzer et al. (2024). Rosenow and Mealy (2024) constructs a detailed mapping of the global value chains for solar panels, wind turbines, and electric vehicles by identifying relevant HS 6-digit products through a review of the academic literature as well as industry reports, validating it by industry experts. They identified 107 solar-related inputs. Fetzer et al. (2024) on the other hand builds an AI-generated production network mapping over 5,000 product-level input-output relationships. Their network identifies 70 solar-related inputs. Combining these 2 approaches, we end up with 161 distinct product codes, defined at the 6 digit level using the HS 2017 classification, only 16 of which overlap across the two lists. The list is included in Appendix A.

2.2 Panjiva: Firm-to-firm transactions

We use firm-to-firm transaction data for Viet Nam from 2018 to 2022 from Panjiva, part of S&P Global. Panjiva provides detailed transaction information based on bills of lading and purchase/sale contracts from customs declaration forms. The dataset includes the addresses of suppliers from whom Viet Nam's firms source their inputs, as well as the destination countries to which these firms export their products.

To identify solar panel exporters in the Panjiva data, we selected firms exporting products classified under HS codes 85414021 (unassembled solar cells) and 85414022 (assembled solar cells).[3] We only selected firms when the keywords 'solar', 'photovoltaic', or 'PV' were included in the product description. This allows us to remove a few products that were misclassified as solar panels, such as LED lights. We also focus only on solar panel producers with sales exceeding 5,000 US dollars during 2018-2022. This allows us to focus on Viet Nam's firms that are a robust part of its solar panel industry, while removing firms that are only occasional re-sellers of solar panels.

To identify upstream linkages for each of these solar panel producers, we downloaded all import transactions of products part of solar value chains (Appendix A.) A distinct feature of the Viet Nam Panjiva dataset is its ability to track firm-to-firm transactions within the country in this industry, as solar panel producers are located in SEZs, which require input transactions to clear customs.[4] The combined data includes inputs imported from abroad as well as sourced locally, allowing for a comprehensive

[3] These 8-digit HS codes differ from the corresponding HTSUS codes, where HTSUS classifies 854140.60.20 as "Solar cells assembled into modules or panels" and 854140.60.30 as "Not assembled solar cells". We found no recorded shipments under HTSUS codes 854140.60.20 or 854140.60.30 between January 2018 and December 2022.

[4] Viet Namese customs authorities require firms to declare the contents and value of goods being imported or exported to ensure compliance with regulations and facilitate duty assessments. See Savills (2023) on the concentration of solar panel manufacturers in SEZs.

list of the inputs used by solar panel exporters in Viet Nam.

Table 1 provides descriptive statistics of the Panjiva data. Over the whole sample period (2018-2022), exporters of assembled and unassembled solar panels in Viet Nam recorded 89 transactions (or shipments) on average per month, and 23.4% of those were exports to the US. Over the same period, input suppliers to solar panel producers made 138 shipments on average per month, and 60.4% of those were from China.

Table 1: Summary statistics – Panjiva transaction-level data

	2018–2022		2019	
	Shipments per firm	Share to USA	Shipments per firm	Share to USA
Exports (solar panels)				
Mean	89	0.234	99	0.225
Median	14	0	15	0
SD	219	0.378	221	0.369
Observations	85,768	85,768	15,935	15,935
	2018–2022		2019	
	Shipments per firm	Share from China	Shipments per firm	Share from China
Imports (inputs)				
Mean	138	0.604	136	0.618
Median	18	0.684	23	0.684
SD	491	0.368	478	0.356
Observations	270,345	270,345	60,708	60,708

Note: The table shows firm-level transactions aggregated at the month-year level. The top panel reports exporters of solar panels from Viet Nam. The bottom panel reports input suppliers to Viet Nam. Source: Author's calculation based on Panjiva.

To confirm the coverage of the Panjiva data, in table 2, we compare solar panel total exports in Panjiva to that in CEPII's BACI dataset, a widely used product-level trade dataset. From 2019 onward, Panjiva's export numbers are in line with BACI's, confirming the reliability of Panjiva's data in documenting the extent of Viet Nam's solar panel industry for those years. This is not the case for 2018, hence our focus on 2019-2022 for some of our results.

Table 2: BACI and Panjiva Export Data (HS 854140, Viet Nam to RoW)

Year	**BACI (USD)**	**Panjiva (USD)**	
		Unfiltered	Filtered
2018	1,608,920,241	250,268,861	11,404,156
2019	2,683,797,856	2,426,097,515	2,030,490,839
2020	3,305,991,296	3,906,784,049	3,420,765,603
2021	3,306,209,847	4,397,546,350	3,967,991,338
2022	6,285,099,119	5,286,138,778	4,350,713,201

Note: Panjiva reports total exports from Viet Nam to the rest of the world between 2018 and 2022, based on the filtering approach described in Section 2.2. BACI data represent Viet Nam's total exports to the rest of the world for the same period, aggregated under HS code 854140.

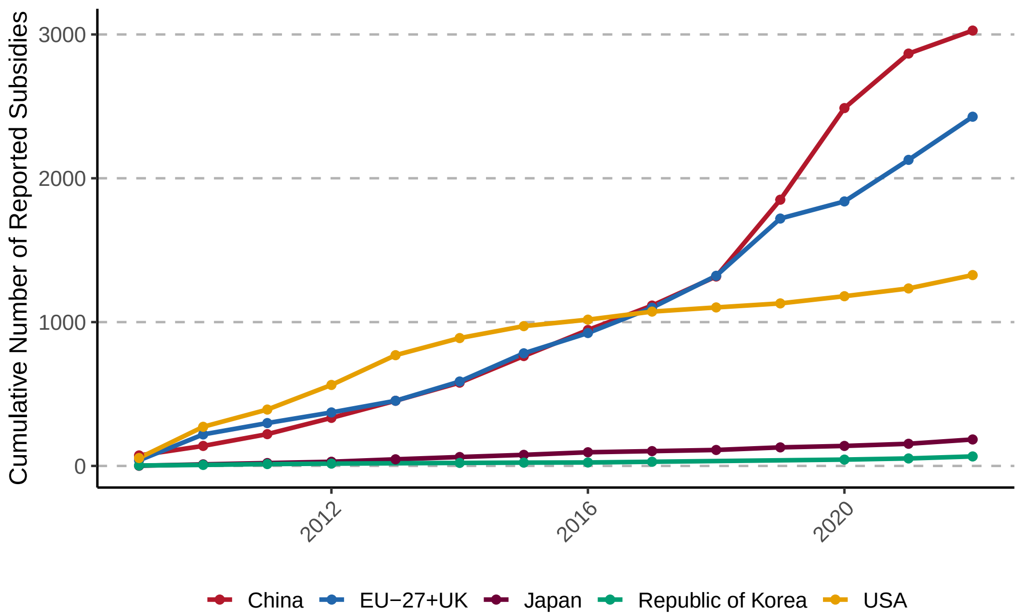
2.3 Viet Nam Enterprise Surveys: Firm-level data

We use firm-level data from the Viet Namese Enterprise Survey (VES). This annual survey is run by the General Statistics Office (GSO) of Viet Nam, and covers all formal firms with a tax ID and that have had some operational income in the previous 2 years. Since 2016, the data is integrated with tax data, and includes information from their balance sheets and income statements. Both the Panjiva dataset and the VES data share a common firm identifier. This enables us to merge the Panjiva data with the Viet Namese Enterprise Survey data, which provides other firm-level variables such as foreign ownership and employment numbers.

2.4 Global Trade Alert: Subsidies across inputs

To measure the extent of the subsidies used along the solar panel value chain, we use data from Global Trade Alert (GTA). GTA is an independent initiative that monitors and provides timely data on government policies impacting global commerce since November 2008. The database encompasses measures affecting trade in goods and services, as well as foreign investment, and migration. It has been used to measure the extent of industrial policies across countries by Juhász et al. (2022), with a focus on subsidies. It's also been used recently by Rotunno and Ruta (2024b) to gauge the effect of subsidies on trade. Figure 1 plots the total cumulative number of reported subsidies on products part of the solar panel value chain. China tops the list with around 3,000 reported cases, covering 92% of the products. The EU (EU27+UK) comes second to China in terms of subsidies for solar input technologies. Viet Nam on the other hand does not have a single notified subsidy in this industry, according to GTA.[5]

Figure 1: Solar Value Chain Reported Cases



Notes: Subsidy data are from the Global Trade Alert (GTA). The list of products is based on the solar industry value chain in Rosenow and Mealy (2024) and Fetzer et al. (2024). Source: Author's calculation based on GTA.

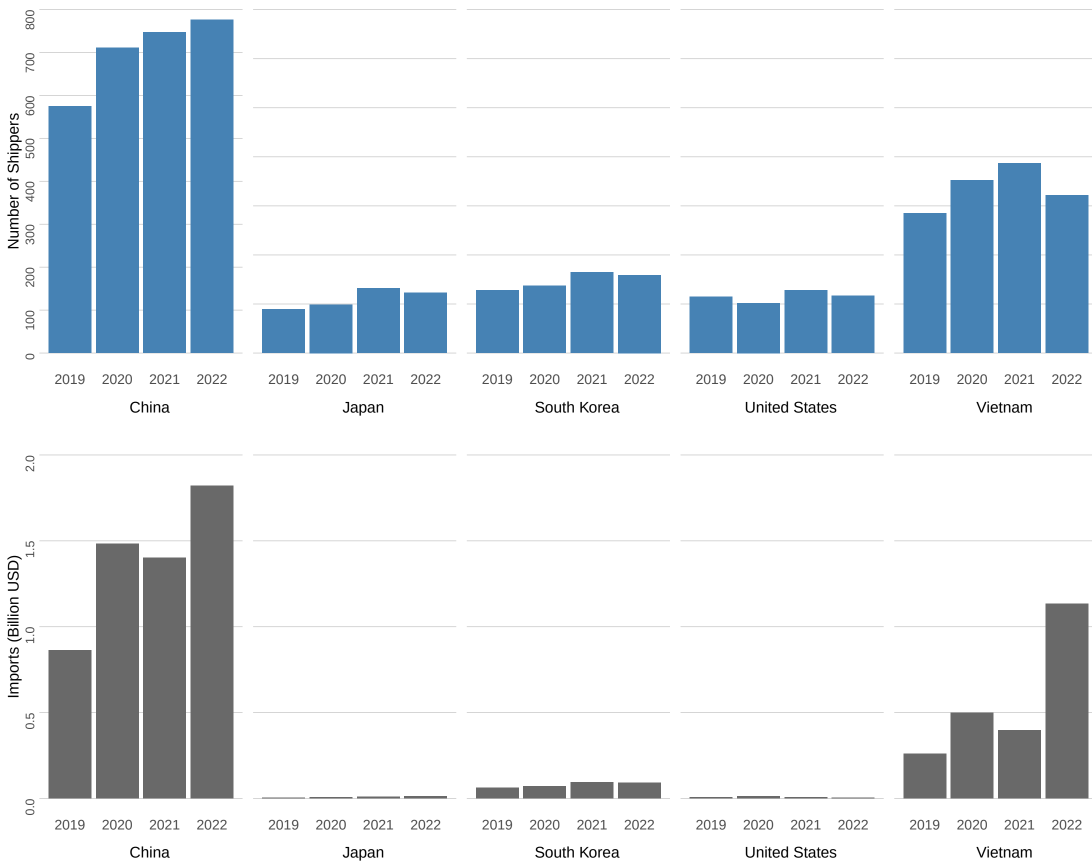
[5]Although the Viet Namese government does not have a direct industrial policy to promote the solar panel industry, it does have a Renewable Energy Development Strategy, which includes feed-in-tariffs on solar power. It also has more than 300 Special Economic Zones (SEZs) where solar firms benefit from preferential tax and customs regimes (Tafese et al., 2025).

3 Results: Inputs, FDI, and spillovers

3.1 Chinese inputs

Chinese inputs dominate Viet Nam's solar supply chains and are cheaper. Figure 2 shows solar panel inputs imports by country of origin and year. It shows how China has been dominating the supply of inputs via imports, while suppliers based in Viet Nam come in second and have seen their share increase over time. This is the case whether we look at the total value of shipments (bottom panel) or at the number of shippers (top panel). In 2022, solar panel producers based in Viet Nam bought inputs from more than 600 different sellers based in China. Other countries supplying inputs, such as the US, Japan, and South Korea, provide only a small fraction of input value relative to China and Viet Nam.

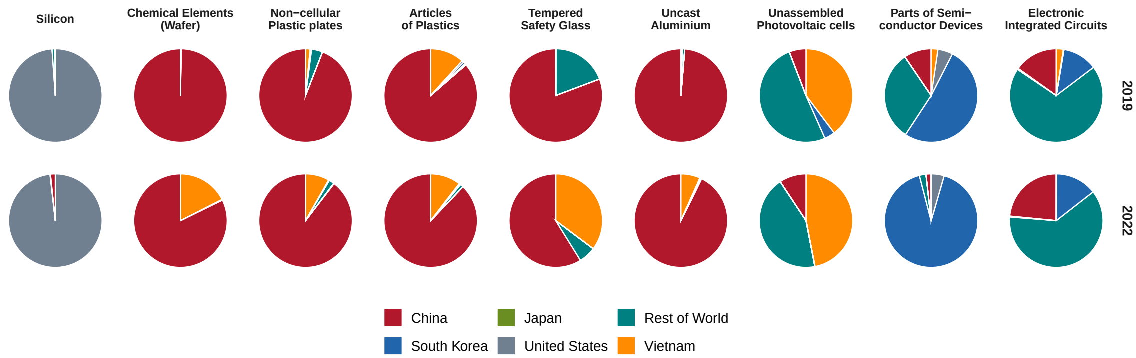
Figure 2: Top input source countries



Notes: The figure reports the number of input shipments (top panel) and total import values in billion USD (bottom panel) for selected source countries of solar panel inputs into Viet Nam, 2019–2022. Source: Author's calculation based on Panjiva.

China is the main supplier for 67 out of 106 products supplied to solar panel producers (see the full list of products solar producers imported and their top source of destination in Appendix A). Figure 3 compares input sourcing patterns for the 9 top inputs that were among the top 12 inputs between 2019 and 2022. China is the main supplier for 5 out of 9 products in both 2019 and 2022, while Viet Nam's share increased in three key inputs, most notably in tempered safety glass. Semiconductor devices on the other hand are mostly from South Korea.

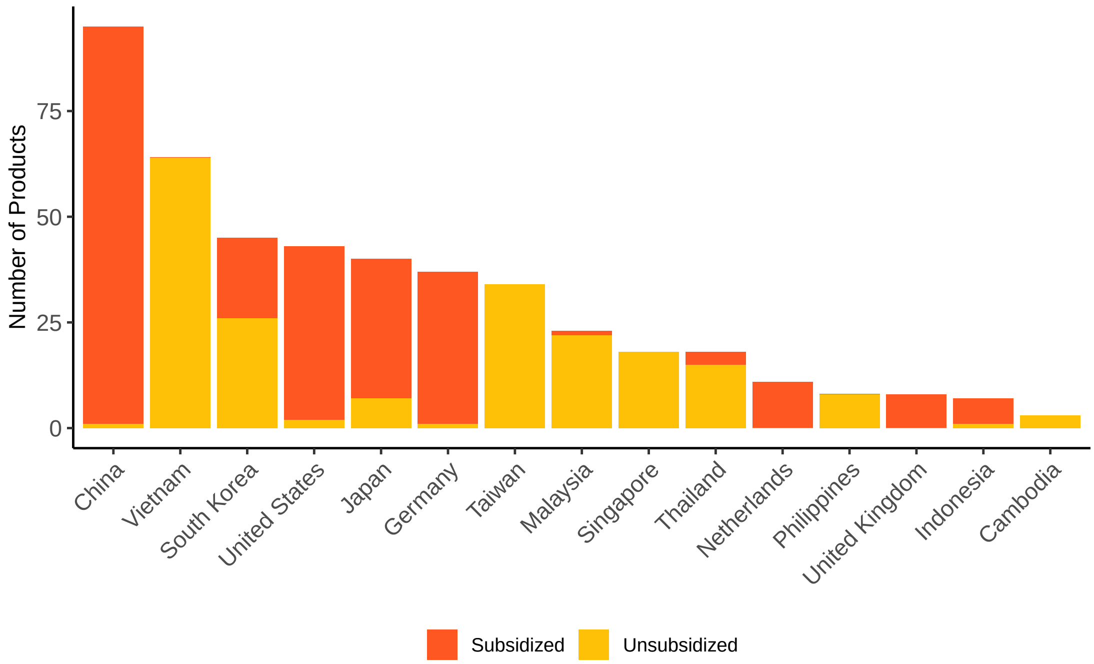
Figure 3: Top 9 Common Inputs Among Top 12 Solar Inputs in 2019 and 2022



Notes: This figure compares the 9 common inputs that appeared in the top 12 inputs used by solar panel firms in Viet Nam in both 2019 and 2022, disaggregated by source of origin. It illustrates the changing composition of input sources over time among Viet Namese firms. Source: Author's calculation based on Panjiva.

Figure 4 shows the importance of foreign subsidies for the inputs used by Viet Namese firms. It plots the coverage of subsidies across solar inputs imported in Viet Nam in 2022. China stands out. It supplies the highest number of inputs, at around 100, and every Chinese input imported is subsided. Almost all inputs imported from the US, Germany, the Netherlands, the UK and Japan are subsidized as well, though they account for fewer product lines. And while a large number of inputs are sourced domestically, Viet Nam does not subsidize their production according to GTA. China's role in Viet Nam's solar panel production is thus extremely important, all the more so as inputs typically account for two-thirds of solar panel production costs (Gerarden (2023)).

Figure 4: Number of solar inputs imported in Viet Nam - 2022



Notes: The list of products covered is from Rosenow and Mealy (2024) and Fetzer et al. (2024)'s solar industry value chain. Source: Panjiva and Global Trade Alert data.

To look into the effect of subsidies on input prices, we compare for each input, how different is the unit price if it comes from a country that subsidizes its production or not. More specifically, we estimate the following equation:

$$(1) \quad P_{ijot} = \beta S_{iot} + \eta_{it} + \mu_j + \epsilon_{ijot}$$

where P_{ijot} is the log input price of product i from origin country o, η_{it} is a product-time fixed effect, and S_{iot} is a dummy equal to 1 if the product i is subsidized by country of origin o, and 0 otherwise. We cluster standard errors ϵ_{ijot} two-way, by product and origin country. We thus compare, for each input defined at the 8-digit level, whether they are cheaper if from countries that subsidize them. We also control for firm fixed effects μ_j in some specification to test for the robustness of the relationship.

Since all inputs from China are subsidized, we also estimate the same regression equation but replacing the subsidy dummy with a China dummy to check if the price of inputs is lower on average when sourced from China. We then look at products targeted by China's flagship industrial policy, Made in China 2025 (MiC25), in another specification.[6] Here our aim is to check whether inputs coming from China are even cheaper if the products are targeted by China's main industrial policy. We interact the China dummy with a MiC25 dummy equal to 1 for products targeted by China's MiC25 policy:

$$P_{ijot} = \beta CHN_o + \gamma CHN_o \times MiC_i + \eta_{it} + \mu_j + \epsilon_{ijot} \tag{2}$$

The results are presented in Table 3. Overall, input products from subsidized countries have lower prices compared to those from countries that do not subsidize them. When from subsidy countries, inputs are around 27 to 32% cheaper, and the subsidy discount is statistically significant at the 10% level. When from China, inputs are 50% cheaper. The magnitude of the China discount is not statistically different whether products are covered by its main industrial policy, Made in China 2025, or not. Figure 5 shows the results of the same regression but estimated by year, confirming that China's inputs are cheaper in every year.

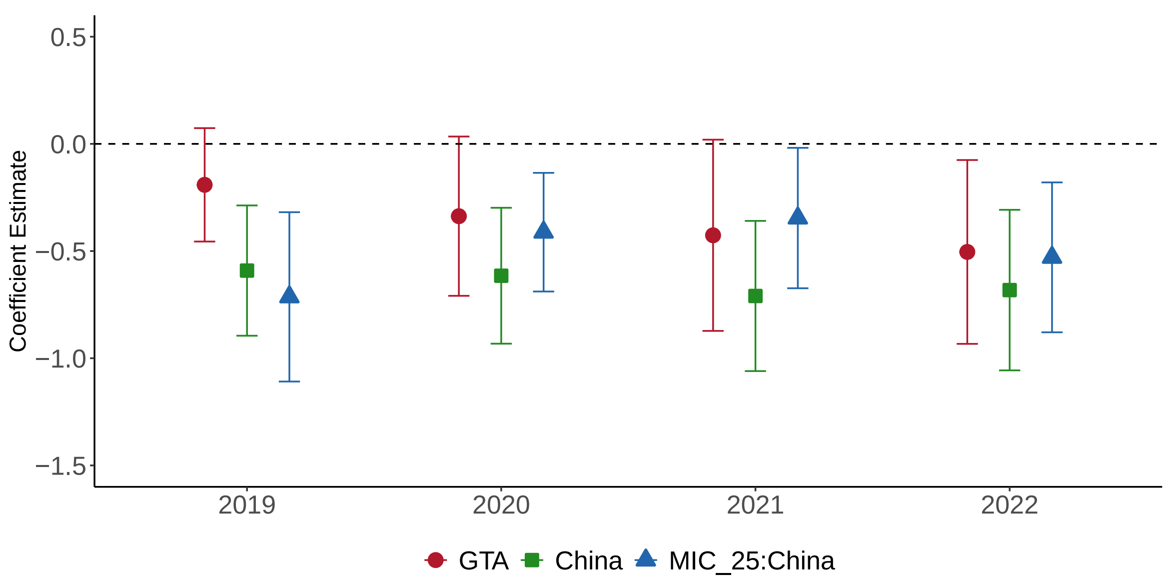
[6] Made in China 2025 is a strategic industrial policy launched in 2015 to upgrade China's manufacturing sector and advance its position in global value chains. It targets key sectors including robotics, aerospace, new energy vehicles, and advanced IT, aiming to foster innovation and reduce reliance on foreign technology. According to Rotunno and Ruta (2024b), who sourced the data from a Chinese State Council press release, the industries covered are defined at the 2-digit level (24, 29, 31, 33, 34, 35), which cover 68% of the products listed as part of solar panel value chains.

Table 3: The role of subsidies in lowering input prices

	Dependent variable: Log price					
	(1)	(2)	(3)	(4)	(5)	(6)
GTA	-0.321*	-0.392*				
	(0.195)	(0.189)				
China			-0.675***	-0.678***	-0.766***	-0.715***
			(0.169)	(0.159)	(0.188)	(0.198)
MIC25:China					0.354	0.159
					(0.346)	(0.230)
Product FE	✓	✓	✓	✓	✓	✓
Month–year FE	✓	✓	✓	✓	✓	✓
Firm FE		✓		✓		✓
Observations	249,659	249,659	249,659	249,659	249,659	249,659
R^2	0.568	0.625	0.575	0.630	0.575	0.631

Notes: Entries are coefficients with two-way clustered standard errors in parentheses (clustered by product and shipment origin). Columns (1)–(2) estimate specifications with the GTA indicator; columns (3)–(4) estimate specifications with the China indicator; columns (5)–(6) include the interaction MIC25:China. All specifications include product and month–year fixed effects; columns (2), (4), and (6) add firm fixed effects. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

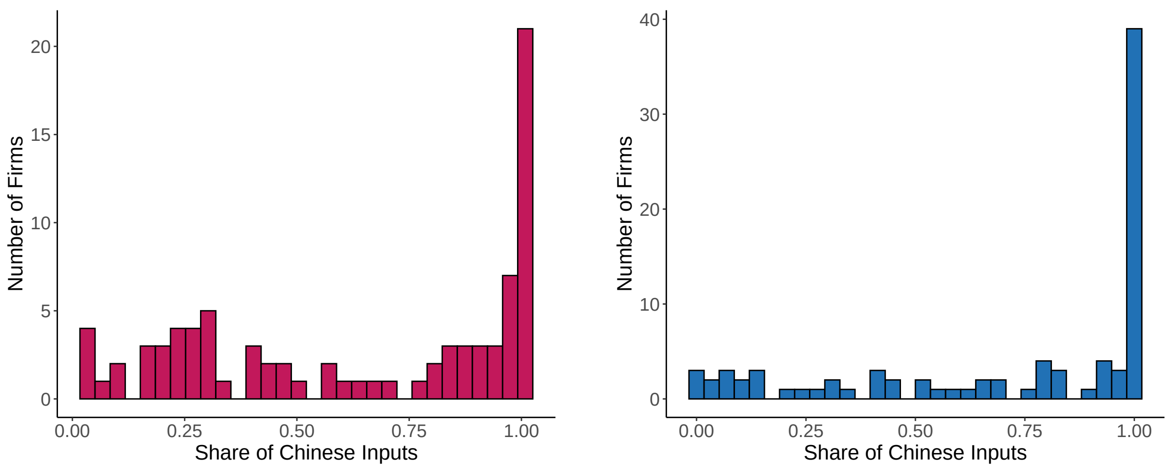
Figure 5: The role of subsidies in lowering input prices, 2019-2022



Notes: The figure show the differences in prices between inputs from countries that subsidize the product vs others, from China vs others, and from China vs. others on MiC25 products. The coefficients are conditional on product (8 digits), year, and firm fixed effects. On average, we have 760 input transactions per month, and 38 per firm. The capped lines are 95% confidence intervals. Standard errors are clustered by origin and product.

Not only does China dominate the supply of solar panel inputs in Viet Nam, its subsidies most likely result in lower prices that benefit solar panel manufacturers in Viet Nam. Figure 6 confirms that all solar firms use a similar share of Chinese inputs, whether these are Chinese FDI firms or not. During 2019-2022, the large majority of Chinese FDI firms as well as all other firms use strictly Chinese inputs. On average, Chinese inputs account for 65% of firms' inputs. This implies all firms having similar access to inexpensive inputs from China may indirectly benefit from Chinese subsidies.[7]

Figure 6: Distribution of the share of Chinese Inputs across firms



(a) Chinese FDI

(b) Other Firms

Notes: The share of Chinese input is calculated as the ratio of Chinese inputs to total inputs used by each firm between 2019 and 2022, based on Panjiva data.

3.2 Chinese FDI

Using Panjiva and VES data, we identify 59 firms selling solar panels in 2019 (assembled or unassembled), and 79 in 2022, in line with the development of Viet Nam's solar panel industry. According to foreign ownership data from the VES, around half of these firms are FDI firms (more than 10% foreign owned). While the VES data identifies

[7]Given the dominant role of Chinese inputs across all firms, and the fact that almost all Chinese inputs are subsidized, it is difficult to isolate the effect of having access to subsidized inputs on the performance of solar exporters.

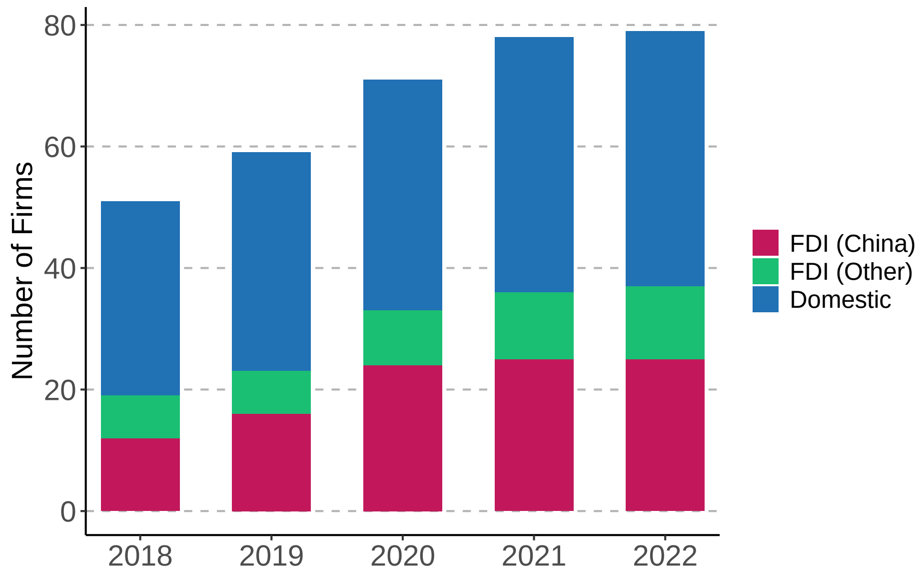
the share of foreign ownership, it does not provide comprehensive information on the country of origin of the firms. To identify Chinese firms, we use the tax IDs in the Panjiva data to look up information on the firms' representatives. FDI firms in Viet Nam are required to appoint a legal representative, who is the legal contact person for government authorities and is most often from the same country of origin as the firm's capital. We manually looked up representatives of all FDI firms online and confirmed that the firms' representative nationality provide the most accurate and systematic measure of firm origin country we can get.[8]

In 2022, around half of the solar panel producers were foreign owned, 25 of which by Chinese owners. This is shown in Figure 7.[9] Although domestic firms account for around half of solar panel producing firms, Chinese FDI firms account for more than 70% of Viet Nam's exports of solar panels (Figure 8). Chinese FDI firms also account for a disproportionately large share of employment among solar panel firms. Figure 9 shows total employment among firms producing solar panels over 2018-2022. Solar panel producers employ around 27,000 workers in 2022, around half of which are employed by Chinese FDI firms.

[8] We looked up firms in these two online directories: https://thuvienphapluat.vn/ma-so-thue/cong-ty-tnhh-vina-union-mst-2500517544.html and https://masothue.com/2500517544-cong-ty-tnhh-vina-union.

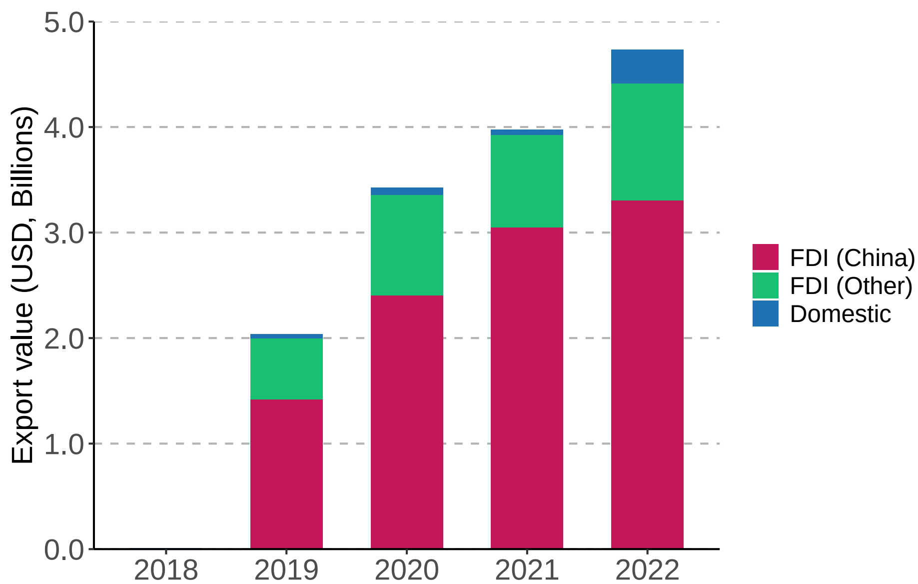
[9] Among the Chinese firms, 7 were on the US antidumping list in 2012. Montti (2024) suggest that antidumping duties imposed in 2012 propelled Chinese FDI to third countries, using these locations as 'export platforms.' See: https://www.federalregister.gov/documents/2012/12/07/2012-29668/crystalline-silicon-photovoltaic-cells-whether-or-not-assembled-into-modules-from-the-peoples.

Figure 7: Number of firms: FDI vs. domestic



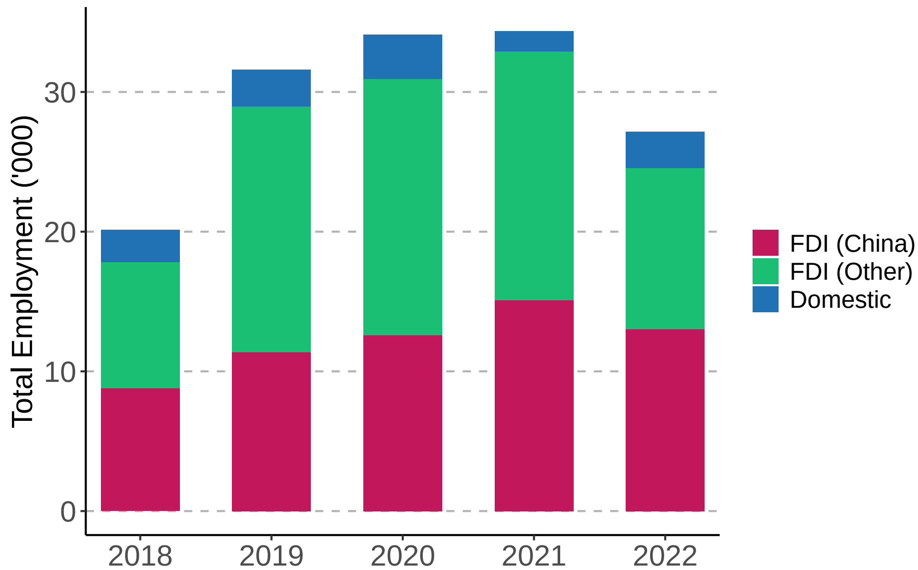
Notes: Solar panel producers in Viet Nam. Source: Panjiva and VES.

Figure 8: Exports by firm ownership



Notes: Viet Nam's exports of solar panels by firm ownership. Source: Panjiva and VES.

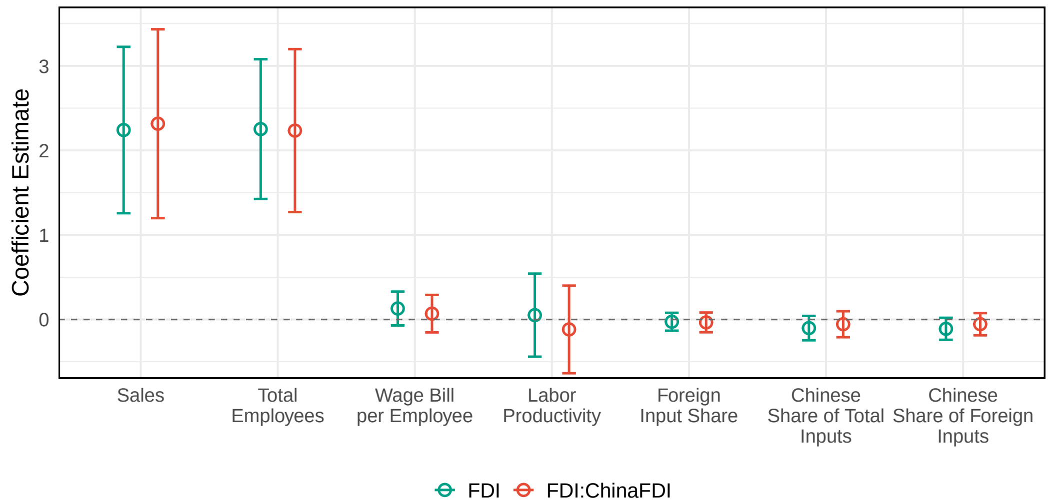
Figure 9: Employment in solar panel firms in Viet Nam



Notes: Viet Nam's employment in solar panel producing firms. Source: Panjiva and VES.

Figure 10 compares Chinese FDI and domestic solar panel firms, as well as FDI firms from any country, along various dimensions. It plots the differences in characteristics such as sales and labor productivity after absorbing year fixed effect. On average, Chinese FDI firms have higher sales and employment compared to domestic firms. The coefficients suggests they are 8 times larger in terms of sales and employees. However, there are no statistically significant differences in wages or labor productivity, nor in the share of foreign or Chinese inputs used, confirming that all firms have access to inexpensive Chinese inputs.

Figure 10: Comparing FDI and Domestic Solar Exporters in Viet Nam



Notes: Sales, Total Employees, Wage Bill per Employee, and Labor Productivity are in logarithmic form. Labor productivity is defined as value added per employee. These four variables are from the VES data. The data on the Foreign Input Share (the ratio of foreign inputs to total inputs), Chinese Share of Total Inputs (Chinese inputs over total inputs), and Chinese Share of Foreign Inputs (Chinese inputs over foreign inputs), is from Panjiva. The coefficients represent estimates from regressions of firm characteristics on FDI and Chinese FDI dummies, controlling for year fixed effects. The capped lines are 95% confidence intervals, with standard errors clustered at the firm level.

We compare the export prices of Chinese FDI firms with those of other solar panel exporters in Viet Nam. The premise is that Chinese firms benefit from home-country subsidies as part of China's industrial policy, and thus their export prices should remain lower even when production occurs abroad. Prior research shows that such headquarters-level support can spill over internationally; Bilir and Morales (2020) shows that innovation originating at headquarters diffuses to foreign affiliates, and Andrieu and Morrow (2024) find that R&D subsidies targeted at French headquarters generate positive effects across the firm's global network. Building on this literature, we test whether Chinese subsidies similarly translate into lower export prices for their affiliates in Viet Nam by estimating the following specification across export transactions (with each firm reporting an average of 132 transactions per year):

$$P_{ijdt} = \alpha_i + \mu_d + \gamma_t + \beta CHN_j + \epsilon_{ijdt} \quad (3)$$

where P_{ijdt} is the log of the export price of product i (assembled and non-assembled solar cells: 85414021 or 85414022) sold by firm j to destination country d, in month t. α_i and μ_d are product and destination fixed effects, γ_t is a month-year fixed effect, and CHN_j is a dummy equal to one if firm j is a Chinese FDI firm, and zero otherwise. We cluster standard errors two way, by firm and destination.

We find that solar panels sold by Chinese firms are indeed cheaper on average than those sold by other firms. This is shown in the regression table in the top panel of Figure 11. The coefficient in column (6) (-.701) suggests that assembled solar panels exported by Chinese FDI firms to the US were around 54% cheaper than those of other firms. We find solar panels sold by Chinese firms to any destination to be cheaper as well, but the price difference is smaller. The coefficient in column (5), (-.473), suggests that panels exported by Chinese firms were 37.7% cheaper. In the bottom panel of Figure 11, we plot the differences in export prices (in logs) between Chinese FDI and other firms, for each year between 2019 and 2022. We look at export prices to the US, to the EU and UK, and to the world as a whole (overall) separately. The most robust pattern that emerges is that Chinese FDI export prices are lower than the export prices charged by other firms when the destination is the US. This is in line with Chinese subsidies allowing Chinese firms to sell at lower prices (or with lower quality solar panels).[10]

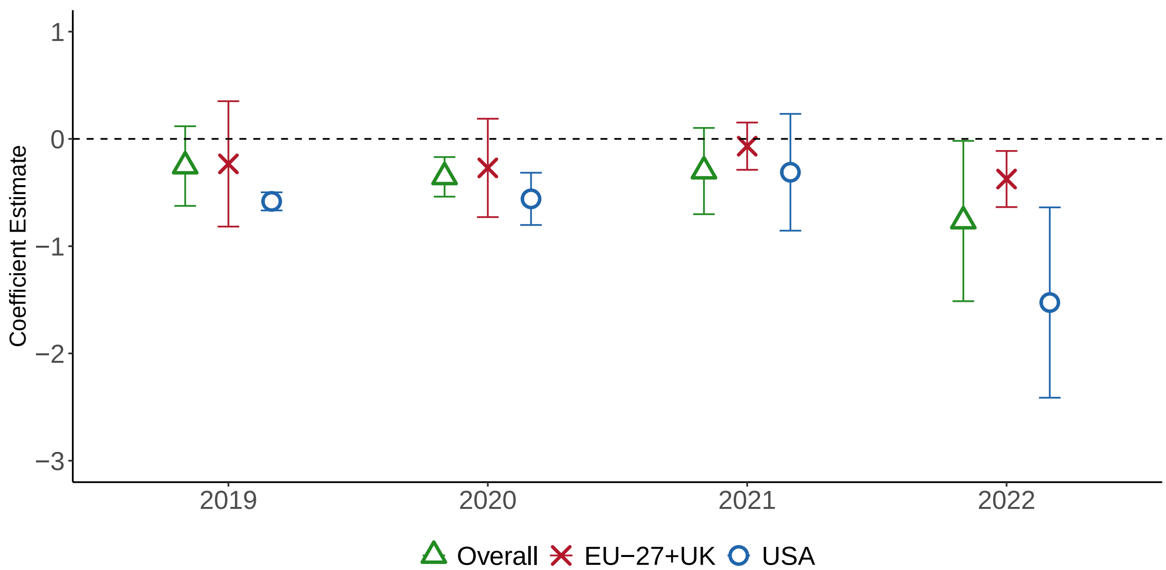
[10] We also explore whether export prices are even lower for the Chinese firms headquartered in cities identified by Banares-Sanchez et al. (2024) as benefiting from local solar subsidies, but find no statistical price difference across headquarter locations in China. Banares-Sanchez et al. (2024) gathered data on city-level solar panel subsidies in China, either in production, innovation, or consumption, using text analysis of all laws and regulations implemented since 1949. Among firms with Chinese representatives, we find that 8 are headquartered in cities that received local subsidies. The cities that received local subsidies for their solar panel industry are Beijing, Jinzhou, Shenyang, Guangzhou, Dougguan, Foshan, Guilin, Changsha, Pingxiang, Xinyu, Gaoan, Yichang, Haidong, Xi'an, Luoyang, Zhengzhou, Jincheng, Anyang, Handan, Taiyuan, Heze, Huaibei, Bozhou, Hefei, Yangzhou, Huai'an, Suqian, Shanghai, Suzhou, Hangzhou, Huzhou, Jiaxing, Shaoxing, Ningbo, Taizhou, Jinhua, Lishui, Quzhou, Sanya. Major Chinese cities not covered by local subsidies include Chongqing, Tianjin, Wuhan, Chengdu, Shenzhen for example.

Figure 11: Export prices

(a) Average price differences over 2019-2022

	Dependent Variable: Log Price					
	Unassembled & Assembled			Assembled		
	Overall (1)	Overall (2)	USA (3)	Overall (4)	Overall (5)	USA (6)
Chinese FDI	-0.272*	-0.346**	-0.700***	-0.277*	-0.473***	-0.701***
	(0.155)	(0.163)	(0.207)	(0.154)	(0.171)	(0.206)
Product FE	✓	✓	✓	✓	✓	✓
Month-year FE	✓	✓	✓	✓	✓	✓
Destination FE		✓			✓	
Observations	85176	85176	40975	67786	67786	40320
R^2	0.842	0.850	0.409	0.097	0.154	0.187

(b) Price difference in assembled solar panels, by year



Notes: Coefficient estimates with 95% confidence intervals from regressing the price of solar panels on a Chinese FDI dummy, as specified in equation 3. . Standard errors are clustered two-way, at the destination and firm levels: * p < 0.1, ** p < 0.05, *** p < 0.01.

To sum up, Chinese FDI firms have been increasing their presence in Viet Nam, they contribute to the majority of exports and employment in the industry, and they sell at lower prices than local firms.

3.3 Chinese FDI spillovers to suppliers

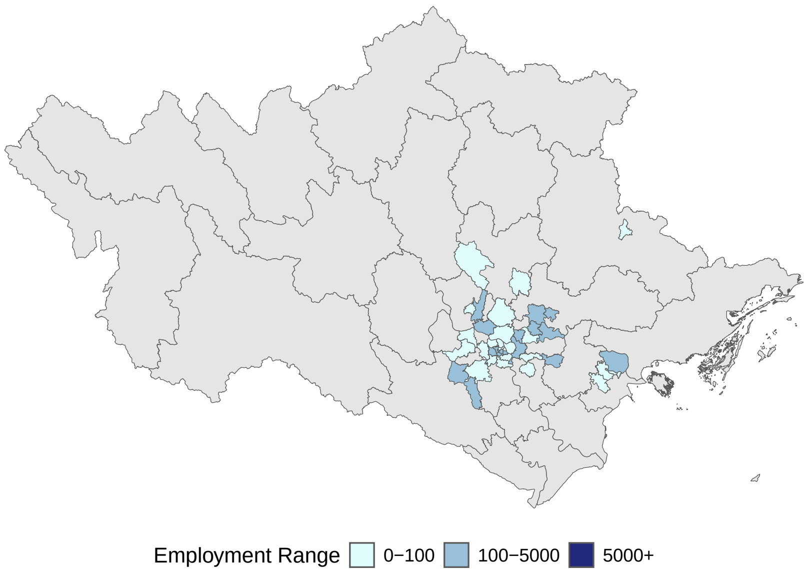
Finally, we look at the spillover effects of FDI firms on upstream suppliers. As Alfaro-Ureña et al. (2022) and Amiti et al. (2024) have documented, supplying inputs to FDI firms is usually associated with employment and productivity gains.

The data suggests that solar firms have indeed increasingly sourced from suppliers based in Viet Nam. These input suppliers are largely clustered around solar panel firms near Hanoi. [11] Figure 12 illustrates the development of this cluster, where most of the solar panel value chain is located. It shows the geographical expansion of the industry - both solar panel manufacturers and input suppliers - and their employment levels from 2016 to 2021.

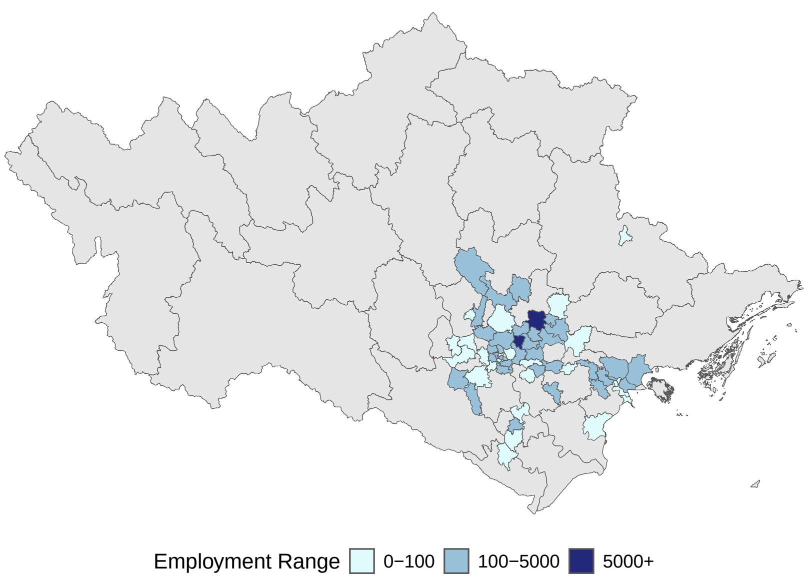
[11]We consider both manufacturing and wholesale firms as input suppliers.

Figure 12: Expansion of the Northern solar cluster

(a) 2016



(b) 2022

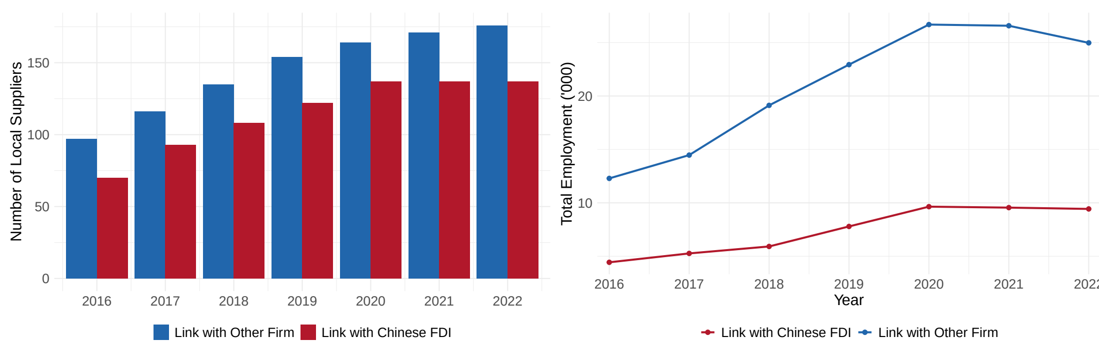


Note: The map shows aggregated employment from both solar producers and firms supplying to solar producers at the district level. In the 2022 map, the dark blue area at the top represents the city center of Bac Giang Province. Since VES data reports location of the firm headquarters and not necessarily where production is, we cross-checked the locations of solar manufacturers with https://ultralowcarbonsolar.org/global-solar-manufacturing/, and found them consistent with the VES data.

Figure 13 (Panel a) shows the growing number of firms supplying inputs to both Chinese and other solar firms: 209 of these input suppliers already existed in 2017, and around 30 firms entered per year in the following years. By 2022, there are 318 local suppliers, around 125 of which have links to Chinese FDI firms. In total, these firms employ around 25,000 workers in 2022, 10,000 of which are employed by firms supplying inputs to Chinese FDI firms (Panel b). The high employment share of suppliers to Chinese FDI firms again highlight the important role of Chinese firms in the development of Viet Nam's solar panel industry.

Figure 13: Employment in firms supplying inputs to solar panel exporters

(a) Firms (b) Jobs



Note: Local Suppliers were identified in Panjiva data, and employment numbers are from the VES data.

To document the spillovers from FDI to local suppliers, we estimate the effect of being a first-time supplier to an FDI solar panel producer on firm performance. We use the diff-in-diff approach of Amiti et al. (2024) and the estimators of Callaway and Sant'Anna (2021), Sun and Abraham (2021) and Arkhangelsky et al. (2021) to address the heterogeneity of treatment effects. Specifically, we estimate the following equation:

$$(4) \qquad y_{i,t} = \sum_{\ell=-4}^{3} \beta_{\ell-1} FdiLink_{i,\ell} + \delta_i + \gamma_t + \epsilon_{i,t}$$

where $y_{i,t}$ is an outcome such as employment, sales, labor productivity, or average wage in firm i in year t, $FdiLink_{i,\ell}$ indicates the first local supplier link to FDI solar producers between 2019 and 2022 (the data cover the years 2018 to 2022, so we focus on links created after 2018), δ_i are firm fixed effects and γ_t are year fixed effects.

We focus only on domestic solar suppliers and compare those supplying to FDI firms to those that supply to domestic firms only during 2018–2022. Firms are included if they existed in the VES data at least one year before they appear in the Panjiva data as solar input suppliers. The *never treated* group includes solar input suppliers that never supply to FDI firms. The *treated* group includes firms that start supplying to FDI firms in 2019, 2020, 2021 or 2022. The *not yet treated* firms are those that exist in the VES data but haven't started supplying inputs to FDI firms yet but will in the following years. We assume that input suppliers *not yet supplying* to FDI firms and those that *never* do are a valid counterfactual for firms starting supplying FDI firms.

Since becoming a supplier is not a random event, the validity of our estimations relies on the assumption that firms' outcomes would have evolved similarly in the absence of forming such a linkage. We test for the presence of pre-trends following Callaway and Sant'Anna (2021) and Sun and Abraham (2021) and use the Synthetic Difference-in-Differences (SDiD) method (Arkhangelsky et al., 2021), which controls for pre-trends by construction.[12]

The estimated treatment effects are summarized in Table 4 and the results over time illustrated in Figure 14. Across estimators, we find no statistically significant effects on sales, employment, wages or productivity from establishing a new link with an FDI solar producer. The coefficients are positive for sales and employees, but not

[12]SDiD combines features of synthetic control and difference-in-differences by constructing a weighted average of control units to create a synthetic counterpart for each treated unit. It applies time weights to ensure that treated and control units exhibit parallel pre-treatment trends. One limitation of SDiD in this context is that supplier relationships with solar producers develop in a staggered manner, meaning the method does not produce a conventional event study. Following Arkhangelsky et al. (2021), we address this by using randomization inference. We compare the estimated effects for firms supplying to FDI solar firms against a distribution of placebo effects generated by randomly assigning ("fake") treatment status across firms. We implement this using the Stata package `sdid_event` developed by Ciccia (2024), which requires a balanced panel and accommodates staggered treatment. Standard errors are estimated using the placebo method with 4 randomly assigned treatment replications.

statistically significant, and there are indication of possible pre-trends. Overall there does not appear to be positive spillovers from supplying FDI firms.

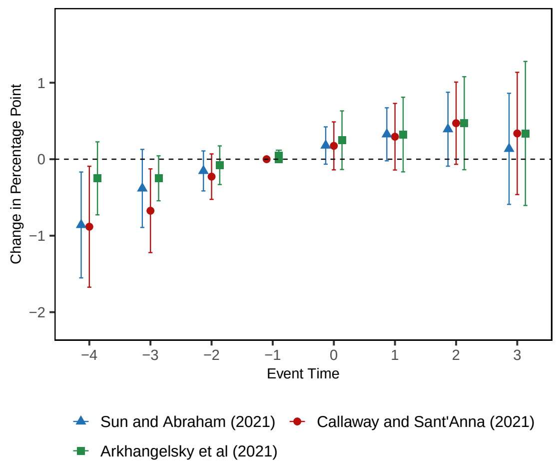
Table 4: The Effects of Supplying to FDI vs. Other Solar Producers

	Sales	**Employees**	**Average Wages**	**Labor Productivity**
Sun and Abraham (2021)				
FdiLink	0.258	0.255	0.074	0.042
	(0.215)	(0.184)	(0.113)	(0.206)
Observations	692	692	692	692
Adjusted R^2	0.841	0.774	0.282	0.628
Callaway and Sant'Anna (2021)				
FdiLink	0.301	0.351	0.151	0.047
	(0.226)	(0.229)	(0.106)	(0.209)
Observations	400	400	400	400
Arkhangelsky et al. (2021)				
FdiLink	0.334	0.362	0.125	0.042
	(0.266)	(0.227)	(0.112)	(0.244)
Observations	400	400	400	400
Firm FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

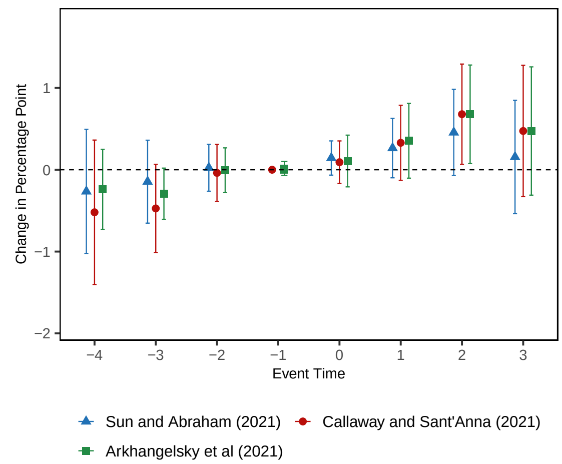
Notes: The table shows the average treatment effects on the treated (ATT) for domestic suppliers starting a relationship with FDI producers. The estimates are derived from Equation 4, controlling for firm and year fixed effects. The results are based on Sun and Abraham (2021), Callaway and Sant'Anna (2021), and Arkhangelsky et al. (2021). Sales, Employees, Average Wages, and Labor Productivity (Value Added / Total Employment) are all transformed using the natural logarithm. Standard errors are clustered at the firm level. Statistical significance is denoted as follows: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Figure 14: The Effects of Supplying to FDI vs. Other Solar Producers

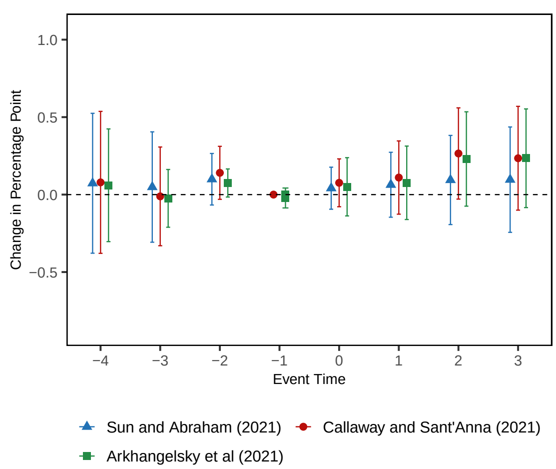
(a) Sales



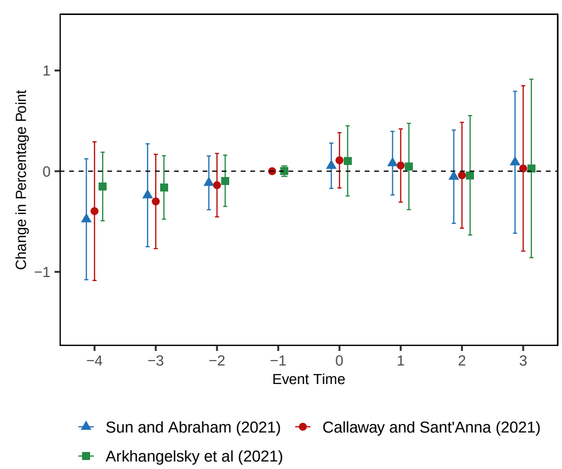
(b) Employees



(c) Wages Per Person



(d) Labor Productivity



Notes: The capped bars are 95% confidence intervals. Firm and year fixed effects are included, and standard errors are clustered at the firm level.

We examine the effect of supplying specifically to Chinese FDI firms in Table 5 and Figure 15. Across estimators, we find that supplying Chinese FDI solar firms increases labor productivity among domestic suppliers. According to the SDiD estimator, we find that a new link with a Chinese FDI solar producer increases labor productivity by 33% in the three years after treatment, and the coefficient is statistically significant at the 10% level. What's more, there is no indication of any pre-trends in labor productivity, suggesting that the effect may be causal. The effects on labor productivity are consistent with Alfaro-Ureña et al. (2022) and Amiti et al. (2024) and corroborate that firms integrated into global value chains may experience positive spillovers. We find indications of corresponding positive effects on average wages 3 years after starting supplying, which increase by 10%. The coefficients on sales are also large and positive yet not statistically significant. We find no statistically significant effect on employment numbers.

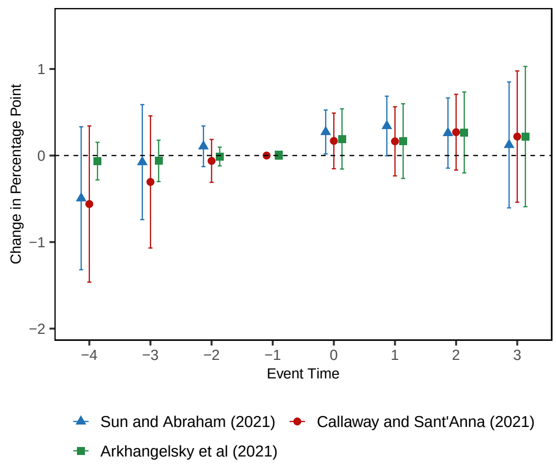
Table 5: The Effects of Supplying to Chinese FDI vs. Other Solar Producers

	Sales	**Employees**	**Average Wages**	**Labor Productivity**
Sun and Abraham (2021)				
ChnFdiLink	0.249	0.010	0.150**	0.280**
	(0.203)	(0.151)	(0.066)	(0.132)
Observations	692	692	692	692
Adjusted R^2	0.881	0.829	0.479	0.711
Callaway and Sant'Anna (2021)				
ChnFdiLink	0.200	0.032	0.123	0.275*
	(0.212)	(0.157)	(0.076)	(0.151)
Observations	400	400	400	400
Arkhangelsky et al. (2021)				
ChnFdiLink	0.208	0.030	0.098	0.287*
	(0.229)	(0.161)	(0.093)	(0.172)
Observations	400	400	400	400
Firm FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

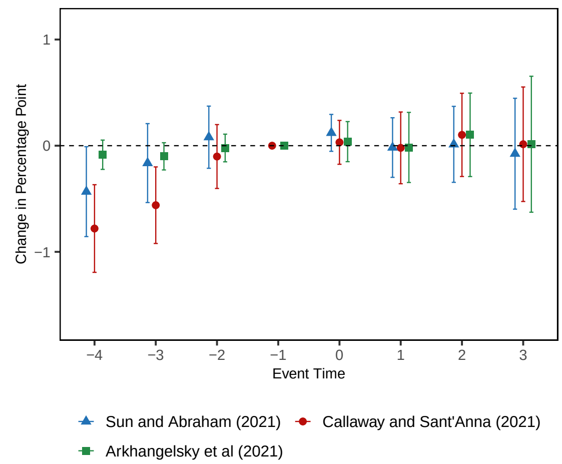
Notes: The table shows the average treatment effects on the treated (ATT) for domestic suppliers starting a relationship with Chinese FDI producers. The estimates are derived from Equation 4, controlling for firm and year fixed effects. The results are based on Sun and Abraham (2021), Callaway and Sant'Anna (2021) and Arkhangelsky et al. (2021). Sales, Employees, Average Wages, and Labor Productivity (Value Added/ Total Employment), are all transformed using the natural logarithm. Standard errors are clustered at the firm level. Statistical significance is denoted as follows: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Figure 15: The Effects of Supplying to Chinese FDI vs. Other Solar Producers

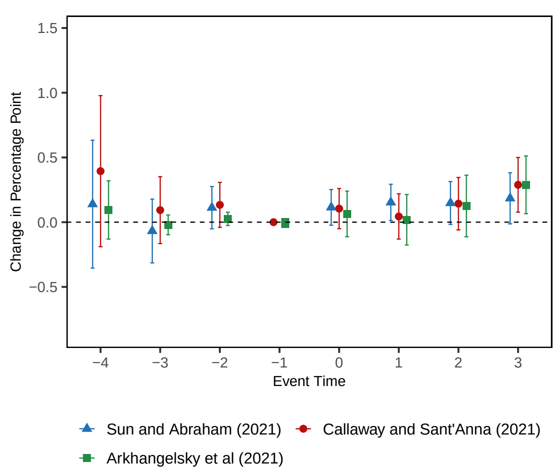
(a) Sales



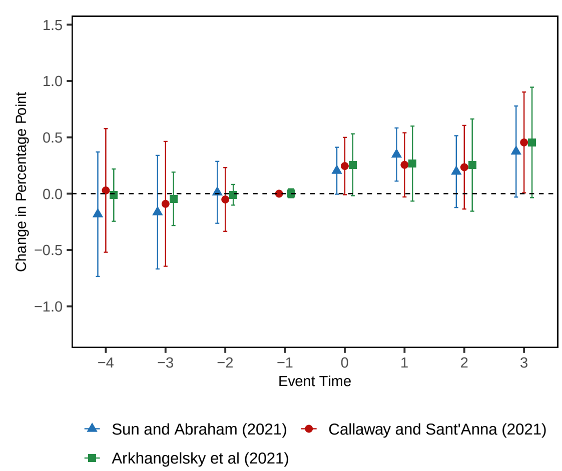
(b) Employees



(c) Wages Per Person



(d) Labor Productivity



Notes: The capped bars are 95% confidence intervals. Firm and year fixed effects are included, and standard errors are clustered at the firm level.

To test the robustness of the effect of supplying to Chinese FDI on labor productivity among suppliers, we extend the sample of supplying firms to all suppliers based in Viet Nam, including those that are foreign-owned. The results in Table 6 and Figure 16 confirm the positive effects of supplying to Chinese FDI on labor productivity.

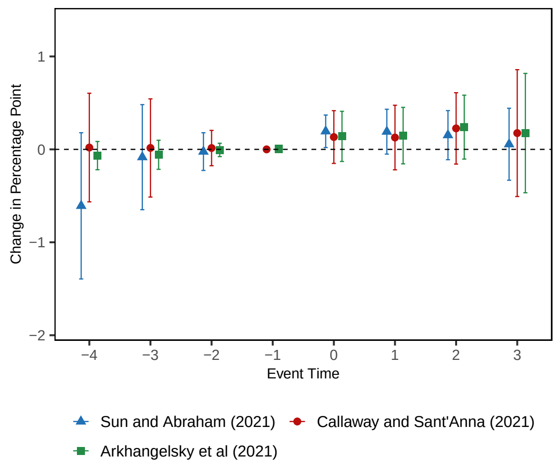
Table 6: The Effects of Supplying to Chinese FDI vs other Solar Producers - Extended sample

	Sales	**Employees**	**Average Wages**	**Labor Productivity**
Sun and Abraham (2021)				
ChnFdiLink	0.148	0.039	0.036	0.276*
	(0.122)	(0.108)	(0.061)	(0.097)
Observations	1232	1232	1232	1232
Adjusted R^2	0.929	0.918	0.539	0.691
Callaway and Sant'Anna (2021)				
ChnFdiLink	0.154	0.033	0.054	0.176**
	(0.111)	(0.092)	(0.055)	(0.088)
Observations	1,177	1,177	1,177	1,177
Arkhangelsky et al. (2021)				
ChnFdiLink	0.147	0.030	0.002	0.209*
	(0.132)	(0.104)	(0.070)	(0.115)
Observations	1,177	1,177	1,177	1,177
Firm FE	✓	✓	✓	✓
Year FE	✓	✓	✓	✓

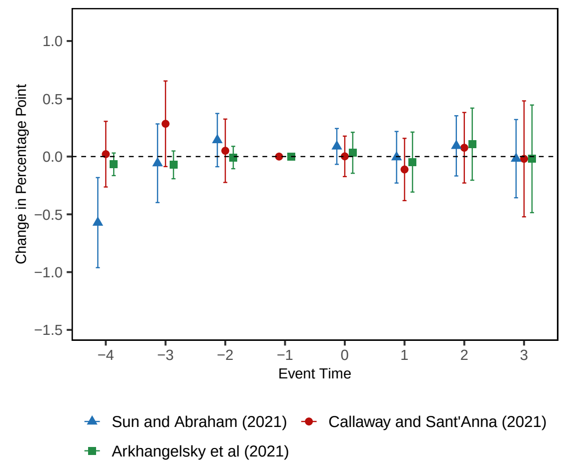
Notes: The table shows the average treatment effects on the treated (ATT) for local suppliers after starting a relationship with Chinese FDI producers. The extended sample include suppliers that are foreign-owned. The estimates are derived using Equation 4, controlling for firm and year fixed effects. The results are based on Sun and Abraham (2021), Callaway and Sant'Anna (2021) and Arkhangelsky et al. (2021). Sales, Employees, Average Wages, and Labor Productivity (Value Added/ Total Employment), all transformed using the natural logarithm. Standard errors are clustered at the firm level. Statistical significance is denoted as follows: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Figure 16: The Effects of Supplying to Chinese FDI vs. Other Solar Producers - Extended Sample

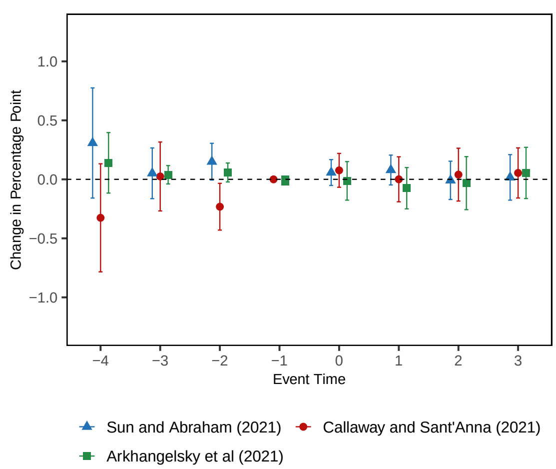
(a) Sales



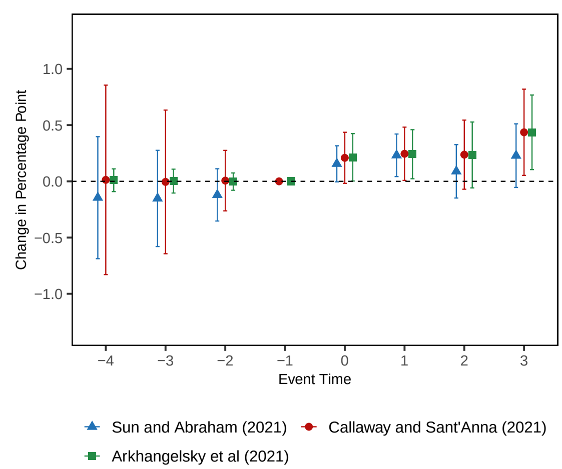
(b) Employees



(c) Wages Per Person



(d) Labor Productivity



Notes: The capped bars are 95% confidence intervals. Firm and year fixed effects are included, and standard errors are clustered at the firm level. The extended sample includes suppliers that are foreign-owned.

4 Conclusion

Using the development of Viet Nam's solar panel industry as a case study, this paper seeks to understand the role of foreign investment, foreign inputs, and foreign subsidies in value chain participation. We showed that most of the inputs used by solar producers in Viet Nam are imported, the majority of which are from China and are subsidized. These inputs are cheaper than those from other countries on average and are used to similar extent by both foreign and domestic solar products. We then showed that Chinese FDI firms account for a large share of Viet Nam's solar panel exports and employment. This corroborates the findings of Garred and Yuan (2025) regarding the Chinese characteristics of Viet Nam's solar panel industry. We also estimated that local firms that start supplying Chinese FDI firms see increases in labor productivity when compared to firms supplying to other solar panel manufacturers, highlighting spillovers from Chinese FDI to upstream sectors. Overall, our paper adds to growing body of evidence on the role of China and its industrial policy in driving development across countries. It also contributes to the debate about cross-border effects of subsidies for green goods. Given the global public good nature of green technologies, understanding the spillover effects of government trade and industrial policies on their production and diffusion is crucial. Our results show evidence of positive spillovers on the supply side and speak to the need for global coordination on subsidies for green goods.

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Appendix A List of inputs of the solar panel supply chain

Table 7: Solar Panel Inputs

HS 6-digit	Description	Total (USD)	Top Origin	Subsidized	Source
854140	Electrical apparatus; photosensitive, including photovoltaic cells, whether or not assembled in modules or made up into panels, light-emitting diodes (LED)	1114730631.0	Viet Nam	1	Rosenow and Mealy (2024)
381800	Chemical elements; doped for use in electronics, in the form of discs, wafers or similar forms; chemical compounds doped for use in electronics	1011717032.2	China	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
700719	Glass; safety glass, toughened (tempered), (not of a size and shape suitable for incorporation in vehicles, aircraft, spacecraft or vessels)	325383196.4	China	1	Rosenow and Mealy (2024)
761699	Aluminium; articles n.e.c. in heading 7616	298251144.8	China	1	Rosenow and Mealy (2024)
280461	Silicon; containing by weight not less than 99.99% of silicon	282799864.5	United States	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
854239	Electronic integrated circuits; n.e.c. in heading no. 8542	235386364.5	Taiwan	1	Fetzer et al. (2024)
392099	Plastics; plates, sheets, film, foil and strip (not self-adhesive), of plastics n.e.c. in heading no. 3920, non-cellular and not reinforced, laminated, supported or similarly combined with other materials	146109827.6	China	1	Rosenow and Mealy (2024)
848620	Machines and apparatus of a kind used solely or principally for the manufacture of semiconductor devices or of electronic integrated circuits	131588649.4	China	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
392010	Plastics; plates, sheets, film, foil and strip (not self-adhesive), of polymers of ethylene, non-cellular and not reinforced, laminated, supported or similarly combined with other materials	63894589.2	China	1	Rosenow and Mealy (2024)

HS 6-digit	Description	Total (USD)	Top origin	Subsidized	Source
392690	Plastics; other articles n.e.c. in chapter 39	58506562.5	China	1	Rosenow and Mealy (2024)
853690	Electrical apparatus; n.e.c. in heading no. 8536, for switching or protecting electrical circuits, for a voltage not exceeding 1000 volts	58225403.6	China	1	Rosenow and Mealy (2024)
853400	Circuits; printed	51538455.0	China	1	Fetzer et al. (2024)
850440	Electrical static converters	32217473.9	China	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
700510	Glass; float glass and surface ground or polished glass, in sheets, non-wired, having an absorbent reflecting or non-reflecting layer	24377326.6	Viet Nam	1	Rosenow and Mealy (2024)
854442	Insulated electric conductors; for a voltage not exceeding 1000 volts, fitted with connectors	19350419.4	China	1	Fetzer et al. (2024)
903033	Instruments and apparatus; for measuring or checking voltage, current, resistance or power, without a recording device (excluding multimeters)	17685385.5	China	1	Fetzer et al. (2024)
392062	Plastics; plates, sheets, film, foil and strip (not self-adhesive), of poly(ethylene terephthalate), non-cellular and not reinforced, laminated, supported or similarly combined with other materials	12726304.9	China	1	Rosenow and Mealy (2024)
760421	Aluminium; alloys, hollow profiles	8834705.9	China	1	Rosenow and Mealy (2024)
847950	Machinery and mechanical appliances; industrial robots, n.e.c. or included	8203166.8	China	1	Rosenow and Mealy (2024)
853229	Electrical capacitors; fixed, n.e.c. in heading no. 8532	8147824.2	China	1	Fetzer et al. (2024)
847990	Machines and mechanical appliances; parts, of those having individual functions	6663674.3	Malaysia	1	Rosenow and Mealy (2024)
853710	Boards, panels, consoles, desks and other bases; for electric control or the distribution of electricity, (other than switching apparatus of heading no. 8517), for a voltage not exceeding 1000 volts	6502740.6	China	1	Fetzer et al. (2024)

HS 6-digit	Description	Total (USD)	Top origin	Subsidized	Source
901380	Optical devices, appliances and instruments; n.e.c. in heading no. 9013 (including liquid crystal devices)	6121599.0	China	1	Rosenow and Mealy (2024)
854449	Insulated electric conductors; for a voltage not exceeding 1000 volts, not fitted with connectors	5575690.2	China	1	Fetzer et al. (2024)
392190	Plastics; plates, sheets, film, foil and strip, other than cellular	5356273.5	China	1	Rosenow and Mealy (2024)
854150	Electrical apparatus; photosensitive semiconductor devices n.e.c. in heading no. 8541, including photovoltaic cells, whether or not assembled in modules or made up into panels	4801238.3	China	1	Fetzer et al. (2024)
854460	Insulated electric conductors; for a voltage exceeding 1000 volts	4665236.6	China	1	Fetzer et al. (2024)
847989	Machines and mechanical appliances; having individual functions, n.e.c. or included in this chapter	4465034.8	China	1	Rosenow and Mealy (2024)
321410	Mastics; painters' fillings	3776834.3	United States	1	Rosenow and Mealy (2024)
848690	Machines and apparatus of heading 8486; parts and accessories	3619858.9	Germany	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
284329	Silver compounds; excluding silver nitrates	3593592.9	Japan	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
391000	Silicones; in primary forms	2918303.4	Japan	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
853650	Electrical apparatus; switches n.e.c. in heading no. 8536, for a voltage not exceeding 1000 volts	2557104.1	China	1	Rosenow and Mealy (2024)
854411	Insulated electric conductors; winding wire, of copper	2255040.1	Taiwan	1	Fetzer et al. (2024)
740931	Copper; strip, of a thickness exceeding 0.15mm, of copper-tin base alloys (bronze), in coils	2222208.9	China	1	Rosenow and Mealy (2024)
730890	Iron or steel; structures and parts thereof, n.e.c. in heading 7308	2092558.7	China	1	Rosenow and Mealy (2024)

HS 6-digit	Description	Total (USD)	Top origin	Subsidized	Source
848610	Machines and apparatus of a kind used solely or principally for the manufacture of semiconductor boules or wafers	1887844.3	Japan	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
280469	Silicon; containing by weight less than 99.99% of silicon	1869000.0	China	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
381010	Pickling preparations for metal surfaces; soldering, brazing or welding powders and pastes consisting of metal and other materials	1746771.0	Singapore	1	Rosenow and Mealy (2024)
903090	Instruments, apparatus for measuring, checking electrical quantities, not meters of heading no. 9028; parts and accessories, for measuring or detecting alpha, beta, gamma, x-ray, cosmic and other radiations	1653120.0	Malaysia	1	Fetzer et al. (2024)
280421	Gases, rare; argon	1545638.6	Viet Nam	1	Fetzer et al. (2024)
845611	Machine-tools; for working any material by removal of material; operated by laser	1296901.4	Germany	1	Rosenow and Mealy (2024)
841950	Heat exchange units; not used for domestic purposes	968298.0	China	1	Rosenow and Mealy (2024)
848640	Machines and apparatus of a kind used solely or principally for the manufacture or repair of masks and reticles, assembling semiconductor devices or electronic integrated circuits, or for lifting, handling, loading or unloading items of heading 8486	549029.7	China	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
730431	Iron or non-alloy steel (excluding cast iron); seamless, cold-drawn or cold-rolled, tubes, pipes and hollow profiles of circular cross-section	410829.1	Viet Nam	0	Rosenow and Mealy (2024)
741011	Copper; foil, not backed, of a thickness not exceeding 0.15mm, of refined copper	341230.7	United States	0	Fetzer et al. (2024)
900290	Optical elements; n.e.c. in heading no. 9002 (e.g. prisms and mirrors), mounted, being parts or fittings for instruments or apparatus, of any material (excluding elements of glass not optically worked)	328128.8	China	1	Rosenow and Mealy (2024)

HS 6-digit	Description	Total (USD)	Top origin	Subsidized	Source
811299	Gallium, germanium, hafnium, indium, niobium (columbium), rhenium and vanadium; articles thereof, other than unwrought including waste and scrap and powders	254580.0	China	1	Fetzer et al. (2024)
854420	Insulated electric conductors; co-axial cable and other co-axial electric conductors	243902.9	Viet Nam	1	Fetzer et al. (2024)
900190	Optical elements; lenses n.e.c. in heading no. 9001, prisms, mirrors and other optical elements, unmounted, of any material (excluding elements of glass not optically worked)	185554.0	China	1	Rosenow and Mealy (2024)
903082	Instruments and apparatus; for measuring or checking semiconductor wafers or devices	159396.7	Netherlands	1	Fetzer et al. (2024)
730830	Iron or steel; structures and parts thereof, doors, windows and their frames and thresholds for doors	107488.1	China	1	Rosenow and Mealy (2024)
853610	Electrical apparatus; fuses, for a voltage not exceeding 1000 volts	80017.0	China	1	Rosenow and Mealy (2024)
841989	Machinery, plant and laboratory equipment; for treating materials by change of temperature, other than for making hot drinks or cooking or heating food	67448.7	China	1	Rosenow and Mealy (2024)
850870	Parts of vacuum cleaners	63611.5	Hungary	1	Rosenow and Mealy (2024)
903039	Instruments and apparatus; for measuring or checking voltage, current, resistance or power, with a recording device (excluding multimeters)	58406.8	China	1	Fetzer et al. (2024)
850131	Electric motors and generators; DC, of an output not exceeding 750W	53153.8	Switzerland	1	Rosenow and Mealy (2024)
841990	Machinery, plant and laboratory equipment; parts of equipment for treating materials by a process involving a change of temperature	50423.6	China	1	Rosenow and Mealy (2024)
854620	Electrical insulators; of ceramics	45743.1	China	1	Fetzer et al. (2024)

HS 6-digit	Description	Total (USD)	Top origin	Subsidized	Source
761610	Aluminium; nails, tacks, staples (other than those of heading no. 8305), screws, bolts, nuts, screw hooks, rivets, cotters, cotter-pins, washers and similar articles	43289.8	China	1	Rosenow and Mealy (2024)
392061	Plastics; plates, sheets, film, foil and strip (not self-adhesive), of polycarbonates, non-cellular and not reinforced, laminated, supported or similarly combined with other materials	33485.0	China	1	Rosenow and Mealy (2024)
841280	Engines; pneumatic power engines and motors, n.e.c. in heading no. 8412	29535.7	Japan	1	Rosenow and Mealy (2024)
721090	Iron or non-alloy steel; flat-rolled, width 600mm or more, plated or coated with materials n.e.c. in heading no. 7210	28591.3	Viet Nam	0	Rosenow and Mealy (2024)
760612	Aluminium; plates, sheets and strip, thickness exceeding 0.2mm, alloys, rectangular (including square)	26692.7	China	1	Rosenow and Mealy (2024)
854470	Insulated electric conductors; optical fibre cables	26248.0	China	1	Fetzer et al. (2024)
850490	Electrical transformers, static converters and inductors; parts thereof	23234.9	China	1	Rosenow and Mealy (2024) and Fetzer et al. (2024)
392520	Plastics; builders' ware, doors, windows and their frames and thresholds for doors	22750.0	Thailand	1	Rosenow and Mealy (2024)
711590	Metal; precious or metal clad with precious metal, other than that of item no. 7115.10	21485.0	South Korea	0	Rosenow and Mealy (2024)
847960	Machinery and mechanical appliances; evaporative air coolers	20396.2	China	1	Rosenow and Mealy (2024)
850819	Vacuum cleaners, with self-contained electric motor, n.e.c. in item no. 8508.1	17095.1	China	1	Rosenow and Mealy (2024)
761691	Aluminium; cloth, grill, netting and fencing, of aluminium wire	15200.0	Japan	0	Rosenow and Mealy (2024)
700992	Glass mirrors; framed, excluding rear-view mirrors for vehicles	14164.8	China	1	Rosenow and Mealy (2024)
850860	Vacuum cleaners, other than with a self-contained electric motor	11932.6	Italy	1	Rosenow and Mealy (2024)

HS 6-digit	Description	Total (USD)	Top origin	Subsidized	Source
903031	Multimeters; for measuring or checking voltage, current, resistance or power, without a recording device	11452.2	China	1	Fetzer et al. (2024)
903290	Regulating or controlling instruments and apparatus; automatic, parts and accessories	9548.4	China	1	Fetzer et al. (2024)
741022	Copper; foil, backed with paper, paperboard, plastics or similar backing material, of a thickness (excluding any backing) not exceeding 0.15mm, of copper alloys	9504.9	China	1	Fetzer et al. (2024)
853641	Electrical apparatus; relays, (for a voltage not exceeding 60 volts)	9404.2	China	1	Rosenow and Mealy (2024)
730441	Steel, stainless; cold-drawn or cold-rolled (cold-reduced), tubes and pipes of circular cross-section	9378.3	China	1	Rosenow and Mealy (2024)
284920	Carbides; of silicon, whether or not chemically defined	7879.5	China	1	Fetzer et al. (2024)
901390	Optical appliances and instruments; parts and accessories for articles of heading no. 9013	7138.7	Germany	1	Rosenow and Mealy (2024)
830630	Photograph, picture or similar frames, mirrors; of base metal	6180.8	Viet Nam	0	Rosenow and Mealy (2024)
854419	Insulated electric conductors; winding wire, (of other than copper)	5860.0	Viet Nam	1	Fetzer et al. (2024)
903032	Multimeters; for measuring or checking voltage, current, resistance or power, with a recording device	4448.8	Germany	1	Fetzer et al. (2024)
700991	Glass mirrors; unframed, excluding rear-view mirrors for vehicles	3311.8	Viet Nam	0	Rosenow and Mealy (2024)
853390	Resistors; parts of the resistors of heading no. 8533	3000.0	China	1	Fetzer et al. (2024)
854690	Electrical insulators; other than of glass and ceramics	2393.6	South Korea	0	Fetzer et al. (2024)
854290	Parts of electronic integrated circuits	2118.1	United States	1	Fetzer et al. (2024)
730451	Steel, alloy (not stainless steel); seamless, cold-drawn or cold-rolled (cold-reduced), tubes, pipes and hollow profiles of circular cross-section	1929.0	Viet Nam	0	Rosenow and Mealy (2024)

HS 6-digit	Description	Total (USD)	Top origin	Subsidized	Source
854233	Electronic integrated circuits; amplifiers	1884.4	Viet Nam	1	Fetzer et al. (2024)
392051	Plastics; of acrylic polymers, polymethyl methacrylate, plates, sheets, film, foil and strip (not self-adhesive), non-cellular and not reinforced, laminated, supported or similarly combined with other materials	1642.8	Viet Nam	1	Rosenow and Mealy (2024)
853222	Electrical capacitors; fixed, aluminium electrolytic	1610.9	China	1	Fetzer et al. (2024)
760611	Aluminium; plates, sheets and strip, thickness exceeding 0.2mm, (not alloyed), rectangular (including square)	1580.0	China	1	Rosenow and Mealy (2024)
902750	Instruments and apparatus; using optical radiations (UV, visible, IR), (other than spectrometers, spectrophotometers and spectrographs)	1280.0	China	1	Fetzer et al. (2024)
760120	Aluminium; unwrought, alloys	939.1	Viet Nam	0	Rosenow and Mealy (2024)
853670	Connectors for optical fibres, optical fibre bundles or cables	660.2	China	1	Rosenow and Mealy (2024)
853225	Electrical capacitors; fixed, dielectric of paper or plastics	440.3	China	1	Fetzer et al. (2024)
854232	Electronic integrated circuits; memories	371.7	China	1	Fetzer et al. (2024)
392030	Plastics; of polymers of styrene, plates, sheets, film, foil and strip (not self-adhesive), non-cellular and not reinforced, laminated, supported or similarly combined with other materials	223.1	China	1	Rosenow and Mealy (2024)
853661	Electrical apparatus; lamp-holders, for a voltage not exceeding 1000 volts	130.8	Japan	1	Fetzer et al. (2024)
392094	Plastics; plates, sheets, film, foil and strip (not self-adhesive), of phenolic resins, non-cellular and not reinforced, laminated, supported or similarly combined with other materials	120.0	China	1	Rosenow and Mealy (2024)

HS 6-digit	Description	Total (USD)	Top origin	Subsidized	Source
741021	Copper; foil, backed with paper, paperboard, plastics or similar backing material, of a thickness (excluding any backing) not exceeding 0.15mm, of refined copper	81.6	China	1	Fetzer et al. (2024)
845640	Machine tools; for working any material by removal of material; operated by plasma arc processes;	60.5	China	1	Rosenow and Mealy (2024)
284310	Colloidal precious metals; whether or not chemically defined	60.0	China	1	Fetzer et al. (2024)
850132	Electric motors and generators; DC, of an output exceeding 750W but not exceeding 75kW	30.0	China	1	Rosenow and Mealy (2024)
722611	Steel, alloy; flat-rolled, width less than 600mm, of silicon-electrical steel, grain-oriented	24.4	China	1	Rosenow and Mealy (2024)
392059	Plastics; of acrylic polymers (excluding polymethyl methacrylate), plates, sheets, film, foil and strip (not self-adhesive), non-cellular and not reinforced, laminated, supported or similarly combined with other materials	17.7	China	1	Rosenow and Mealy (2024)

Notes: The solar value chain was constructed by harmonising the item lists from Rosenow and Mealy (2024) and Fetzer et al. (2024), resulting in a final set of 161 items. According to Panjiva, Viet Namese firms used 106 of these in production. 'Origin' refers to the primary source of input used by Viet Namese solar producers. 'Method' explains how the input was identified. 'GTA' indicates whether the product received any form of subsidy based on GTA. We do not account for input shares—if any portion originated from a subsidized source, it is marked as 1; otherwise, 0. Total (USD) refers to the total value of the input used by Viet Namese firms, aggregated across all source origins.