

# The Impact of IRA 45X Tax Credit on Investment Levels of Solar Industry Firms: An Empirical Study Based on the DID Model

Gongyi Zhang

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Department of Political Economy, School of Politics and Economics Faculty of Social Science and Public Policy, King's College London, London, United Kingdom  
gongyi.zhang@kcl.ac.uk

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## Abstract

In the end of 2022, the U.S. enacted an Inflation Reduction Act, introducing the Section 45X Advanced Manufacturing Production Credit, the credit was imposed to reduce foreign import dependencies and secure domestic clean energy transition. To study Section 45X's causal impact on firm's capital allocation and investment trend, this essay applies a quasi-experimental Difference-in-Differences (DID) framework to a quarterly panel dataset of 20 publicly listed U.S. solar manufacturing firms between the 2016 and 2026 period. Empirical results concluded from the two-way fixed effects model has shown that Section 45X acted as a catalyst, creating a significant supply-side shock. This lift from the policy enlarged quarterly capital investment between eligible solar firms by around 36.8% compared with the controlled firms. Confirmed by parallel trend test, this investment surge truly reveals a direct reaction to a volume-linked subsidy. However, the conclusions also revealed an asymmetrical supply chain unbalance, where downstream module assemblies appear to be more supported than upstream cell production. Therefore, to maintain long-term stability of domestic supply chain before 2029 (phase down stage of the tax credit), policymakers must implement targeted upstream financial support and strategically regulate trade barriers.

## Key words

Difference-in-differences model; Solar Energy; Public Policy; Green Transition Tax Credit.

## 1. Introduction

The global shift to renewable energy has intensified pressure on domestic manufacturing capacity in the U.S. The Electric Vehicle precedent has warned U.S. domestic producers of the consequence of relying on imports, now that the focus is shifted within the solar photovoltaic industry [1]. However, frequent spatial asymmetries occur under this structural preference, as domestic adoption pressure arises yet domestic assembly capabilities are in short, producers then turn to subsidized foreign manufacturers. This is a common issue of discussion that such market failure exacerbates domestic supply chain instability, which also undermines the stability of green transition. Nevertheless, studies have modeled the effect of a tax credit on domestic renewable industry and conclude that it theoretically will create a significant cost advantage for producers [2]. Therefore, for policy makers, determining whether or not a supply-side stimulus can actually incentivize, or restructure firm investment allocation has become a global discussion.

Before 2022, the U.S. solar industry confronted structural weaknesses due to a long period of import dependence. The global solar market data revealed that China accounts for around 80 percent of the primary materials, manufacturing, and installed capacity underlying the photovoltaic supply chain independently, this leaves downstream markets exposed to price instabilities and supply chain volatility. Domestic manufacturers of the U.S. thus are structurally unable to compete with heavily subsidized foreign producers especially on price. Moreover, the import dependency also created national security and supply chain risks, as studies have stated how the COVID-19 pandemic and the Russia-Ukraine war together created disruptions to the global supply chains affecting the green energy transition, exposing the fragility of concentrated manufacturing networks [3,4]. Together, these market failures threatened U.S. climate goals, energy security, employment, and the broader pace of clean energy deployment. In response, the U.S. enacted the Inflation Reduction Act (IRA) in 2022, introducing Section 45X. This study thus examines whether the introduction of Section 45X led to a measurable change in firms' investment trends by employing a quasi-experimental Difference-in-Differences (DID) framework. Specifically, it compares eligible solar manufacturers with a carefully selected group of ineligible

industrial firms, enabling the causal impact of the policy to be distinguished from broader macroeconomic and industry-wide trends.

This analysis serves to ongoing debates over the effectiveness of supply-side policy by examining whether government incentives influence corporate investment levels, or it simply explains activities that firms would have undertaken regardless of intervention [5]. By studying changes in capital expenditure among solar manufacturers before and after the implementation of Section 45X, this study provides firm-level evidence on the investment effects of production-based tax incentives. The conclusion also provides discussions offering policy-relevant perceptions into the effectiveness and long-term sustainability of production subsidies, especially as Section 45X is planning to begin phasing down after 2029.

## 2. Research & Policy Background

The section 45X Advanced Manufacturing Production Credit, enacted under the Inflation Reduction Act of 2022 (IRA), is a production-based tax credit targeting domestic green energy manufacturing. Designed intentionally to encourage domestic production, the credit is distinct from traditional investment tax credits like Section 48C, it directly subsidizes the manufacturing of clean energy production; providing direct financial incentives which are directly linked to the physical volume of eligible components produced and sold to unrelated parties.

Specifications of the tax credit are as follows: 1. Thin film photovoltaic cell or crystalline photovoltaic cell (\$ 0.04 per watt), 2. Photovoltaic wafer (\$ 12.00 \$ per square meter), 3. Solar grade polysilicon (\$ 3.00 per kilogram), 4. Polymeric back sheet (\$ 0.40 per square meter), 5. Solar module (\$ 0.07 per watt), 6. Torque tube for solar tracking device (\$ 0.87 per kilogram), 7. Structural fastener for solar tracking device (\$ 2.28 per kilogram) [6].

The nature of section 45X is a structured volume-based production incentive rather than a one-time investment subsidy, it therefore fundamentally reformed the U.S. manufacturing finances. To maximize the financial benefits of these per unit payouts, solar firms were

highly incentivized to rapidly scale up their physical output capabilities. Consequently, the immediate corporate response to the IRA can be measured using planned Capital Expenditure (CapEx). Data has shown that domestic module production has grown from 14.5 GW at the end of 2023 to 42.1 GW at the end of 2024, an increase of 190% [7]. This significant progress could be the result of clean energy firms deploying major capital to expand existing assembly lines and initiate on entirely new manufacture facilities.

However, while aggregate industry data suggest a massive supply-side expansion, assessing the true causal impact of section 45X still remain challenging. The implementation period of the credit clashes with volatile macroeconomic shifts such as post-pandemic supply chain rebalancing and fluctuating national interest rates. To conclusively determine whether this capital deployment was a direct structural response to section 45X or simply a reflection of broader industrial trends, this study moves beyond descriptive forecasting.

### 3. Methodology

#### 3.1 Empirical Strategy and Descriptive Statistics

To fully evaluate the causal impact of the IRA section 45X Advanced Manufacturing Production Credit on domestic solar manufacturing, this study uses a quasi-experimental cross-sector Difference-in-Differences (DID) framework. By comparing subsidized solar manufacturers against a structurally similar but unsubsidized control group, this approach effectively isolates the policy's true expansionary effect from broader macroeconomic volatility, such as post-pandemic supply chain rebalancing and fluctuating national interest rates.

Firm-level quarterly data on capital expenditures/investments ( $\ln\_capex$ ), total assets ( $\ln\_assets$ ), revenues ( $\ln\_sales$ ), and cash holdings ( $\ln\_cash$ ) were obtained from the Compustat–Capital IQ database (S&P Global Market Intelligence) via Wharton Research Data Services (WRDS), forming a balanced quarterly panel from 2016 Q1 to 2026 Q1 [8]. The treatment group consists of 20 publicly listed U.S. manufacturers with active domestic production of eligible components after excluding firms whose CapEx could not be identified and firms

with incomplete reporting histories. The control group was constructed using nearest propensity matching on comparable U.S. industrial automation, sensor, and precision machinery manufacturers, which share similar capital intensity and input costs with the treatment firms but are structurally ineligible for 45X credits, allowing the model to isolate the policy's supply-side effect from broader macroeconomic trends.

The baseline empirical model is specified as follows:

$$\ln\_capex_{it} = \alpha + \beta(Treated_i \times Post_t) + \gamma X_{it} + \mu_i + \nu_t + \epsilon_{it} \quad (1)$$

#### 3.2 Variable Selection

**Dependent Variable ( $\ln\_capex_{it}$ ):** The natural logarithm of quarterly capital expenditures for firm  $i$  in quarter  $t$ . As physical capital investment data often lags due to multi-year factory construction timelines, tracking planned capital deployment cleanly captures the immediate corporate supply-side response to the policy shock.

**Treatment Group ( $Treated_i = 1$ ):** Publicly traded, U.S.-listed manufacturing corporations whose core operations involve the domestic assembly of 45X-eligible clean energy hardware. They include sub-sectors, photovoltaic thin-film and crystalline modules, solar cells, microinverters, central inverters, and structural solar tracker components (torque tubes, structural fasteners, and longitudinal purlins). These firms also receive a direct, volume-based, dollar-per-unit tax credit upon the sale of their physical hardware. Therefore, their quarterly capital expenditure ( $capex$ ) profiles are directly linked to the operational optimization of domestic manufacturing capacity additions.

**Control Group ( $Treated_i = 0$ ):** A strictly matched group of US-listed manufacturing corporations operating within the parallel industry such as advanced manufacturing, heavy machinery, or automation component industries, which face identical macroeconomic conditions but have zero structural eligibility for volume-based subsidies. Sub-sectors included factory automation robotics, industrial sensor vision equipment, traditional electric utility transformers/fuses, commercial building control systems, and precision fluid-handling apparatuses. These companies share identical structural constraints with the treated group, such as changes in US production wages, fluctuations in international steel/aluminum prices, do-

mestic industrial electricity costs, and broad logistics/supply chain bottlenecks.

Temporal Boundary ( $Post_i$ ): A binary indicator set to 1 for the post-treatment window (2023 Q1 to 2026 Q1) following the activation of the Section 45X credits, and 0 for the pre-treatment baseline (2016 Q1 to 2022 Q4). This extended pre-treatment window is vital for verifying the parallel trends assumption.

Control Variables ( $X_{it}$ ): A vector of firm-level fi-

nancial controls designed to prevent omitted variable bias. This includes firm scale ( $\ln\_assets$ ), product market demand pulls ( $\ln\_sales$ ), and internal liquidity ( $\ln\_cash$ )

Fixed Effects:  $\mu_i$  absorbs time-invariant, unobserved firm characteristics, while  $v_t$  captures time-specific macroeconomic shocks affecting all industries simultaneously. Table 1 presents the descriptive statistics of variables:

Table 1 Summary Statistics

| Variables         | N (quarters) | Mean  | Sd    | Min    | Max    |
|-------------------|--------------|-------|-------|--------|--------|
| <b>ln(capex)</b>  | 639          | 2.818 | 1.770 | -3.576 | 6.587  |
| <b>Treated</b>    | 639          | 404   | 491   | 0      | 1      |
| <b>Post</b>       | 639          | 376   | 485   | 0      | 1      |
| <b>ln(assets)</b> | 639          | 7.756 | 1.420 | 4.282  | 10.746 |
| <b>ln(sales)</b>  | 639          | 6.047 | 1.424 | 2.316  | 8.958  |
| <b>ln(cash)</b>   | 639          | 5.880 | 1.507 | 630    | 9.344  |

### 3.3 Hypothesis

$H_0$  (Null Hypothesis): The enactment of Section 45X had no statistically significant effect on the capital expenditure of eligible domestic solar manufacturing firms relative to the matched control group. Formally,  $\beta = 0$ , indicating that any observed post-2022 CapEx growth among treated firms reflects broader macroeconomic trends rather than a policy-specific response.

$H_1$  (Alternative Hypothesis): The Section 45X Advanced Manufacturing Production Credit had a statistically significant, positive effect on the capital expenditure of eligible solar manufacturing firms relative to the control group. Formally,  $\beta > 0$ , indicating that the interaction term ( $Treated_i \times Post_i$ ) is positive and significant, meaning treated firms exhibited a differential increase in  $\ln\_capex$  beyond what is explained by firm-level controls and time fixed effects. This would suggest that the volume-linked, per-unit structure of 45X directly incen-

tivized treated firms to accelerate capacity-expanding capital deployment, consistent with the theoretical logic that a production-based (rather than investment-based) subsidy rewards output scale and therefore induces a stronger CapEx response than a comparably sized but structurally different incentive.

## 4. Results

### 4.1 Results Analysis

Table 2 presents the regression results evaluating the causal impact of the IRA Section 45X Advanced Manufacturing Production Credit on the capital expenditures of domestic solar manufacturing firms. To systematically isolate the policy's effect from confounding variables, the analysis progresses through a robustness hierarchy of four distinct empirical models.

Table 2: Regression Results

| Variables                 | (1)<br>ln_capex | (2)<br>ln_capex | (3)<br>ln_capex | (4)<br>ln_capex |
|---------------------------|-----------------|-----------------|-----------------|-----------------|
| <b>treated*post</b>       | -0.067          | 0.330***        | 0.313***        | 0.313           |
|                           | (0.139)         | (0.105)         | (0.109)         | (0.246)         |
| <b>treatment</b>          | 0.030           |                 |                 |                 |
|                           | (0.092)         |                 |                 |                 |
| <b>post</b>               | -0.287***       | -0.148**        |                 |                 |
|                           | (0.093)         | (0.071)         |                 |                 |
| <b>ln_assets</b>          | 1.083***        | 0.584***        | 0.603***        | 0.603***        |
|                           | (0.086)         | (0.116)         | (0.135)         | (0.205)         |
| <b>ln_sales</b>           | -0.216***       | 0.463***        | 0.499***        | 0.499**         |
|                           | (0.075)         | (0.092)         | (0.098)         | (0.182)         |
| <b>ln_cash</b>            | 0.250***        | -0.021          | -0.025          | -0.025          |
|                           | (0.040)         | (0.055)         | (0.059)         | (0.102)         |
| <b>Constant</b>           | -5.639***       | -4.392***       | -4.548***       | -4.548***       |
|                           | (0.217)         | (0.476)         | (0.613)         | (1.118)         |
| <i>N</i>                  | 639             | 639             | 639             | 639             |
| <b>Time fixed effects</b> | No              | No              | Yes             | Yes             |
| <b>Firm fixed effects</b> | No              | Yes             | Yes             | Yes             |
| <b>R-squared</b>          | 0.781           | 0.397           | 0.429           | 0.429           |

Standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ 

Column (1) shows the OLS baseline, where the interaction term's coefficient is negative and statistically insignificant (-0.067). This result mainly reflects omitted variable bias, as the model fails to account for time-invariant differences across firms between solar manufacturers and the control group. As firm fixed effects are introduced in Column (2), the DID coefficient shifts to a positive 0.330 and becomes significant at the 1% level, indicating that within-firm comparisons reveal a substantial investment reaction following the Section 45X credit. Column (3) is the study's primary specification, which adds quarterly time fixed effects (TWFE) to absorb shared macroeconomic shocks across the 2016–2026 period. The DID coefficient remains stable at 0.313 ( $p < 0.01$ ), translating to an approximate 36.8% ( $e^{0.3134} - 1$ ) increase in quarterly investment among eligible so-

lar manufacturers relative to the control group.

Column (4) applies firm-level standard errors to address serial correlation over time. While the coefficient magnitude is unchanged (0.3134), the standard error widens to 0.2464, a common consequence of the small number of firm clusters ( $N=20$ ) rather than evidence against the underlying effect. Taken together, the consistent and significant results in Columns (2) and (3) provide strong support for the core hypothesis that Section 45X served as an immediate, powerful supply-side catalyst for domestic manufacturing investment.

## 4.2 Parallel Trend Test Results

The validity of the Difference-in-Differences (DID) framework relies strictly on the parallel trends assumption, which display that in the absence of the policy

shock, the capital investment ( $\ln\_capex$ ) of the treated solar manufacturers and matched control industrial firms must follow a synchronic trajectory over time. To verify

this, this study executes a parallel trend test mapping the pre and post coefficients of CapEx around the 2022 Inflation Reduction Act (IRA) enactment.

Table 3 Parallel Trend Test Result

| Variables                             |                   |
|---------------------------------------|-------------------|
|                                       | (1) $\ln\_capex$  |
| pre 5 (2021Q4)                        | -0.136 (0.314)    |
| pre 4 (2022Q1)                        | -0.274 (0.304)    |
| pre 3 (2022Q2)                        | -0.096 (0.306)    |
| pre 2 (2022Q3)                        | -0.306 (0.390)    |
| 45X                                   | -0.273 (0.389)    |
| post 1 (2023Q2)                       | 0.492 (0.317)     |
| post 2 (2023Q3)                       | 0.017 (0.334)     |
| post 3 (2023Q4)                       | 0.146 (0.259)     |
| post 4 (2024Q1)                       | 0.247 (0.244)     |
| post 5 (2024Q2)                       | 0.461* (0.266)    |
| Log(Total Assets - Firm Size Control) | 0.670*** (0.218)  |
| Log(Quarterly Corporate Revenues)     | 0.477** (0.192)   |
| Log(Liquidity Cash Holdings)          | -0.021 (0.106)    |
| Constant                              | -4.904*** (1.297) |
| Observations                          | 639               |
| Time fixed effects                    | Yes               |
| Firm fixed effects                    | Yes               |
| R-squared                             | 0.431             |

Standard errors in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

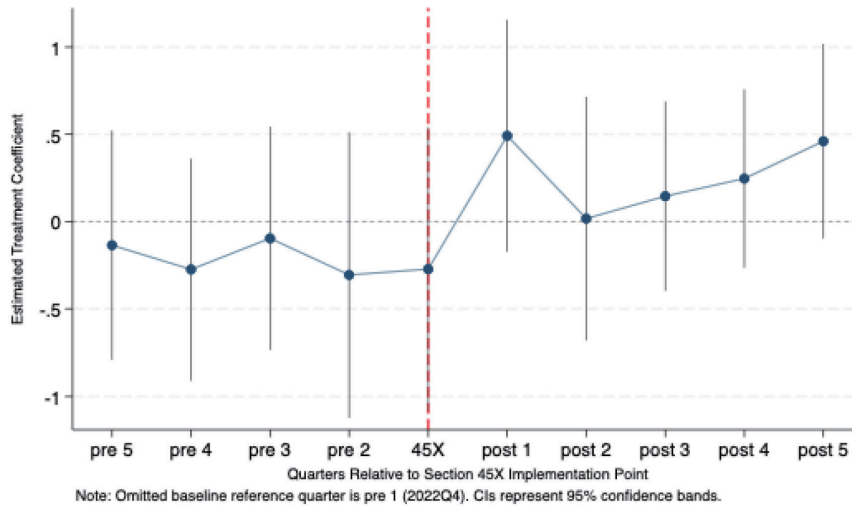


**Figure 1 Parallel Trend Test Plot**

As shown in Table 3, the coefficients for the pre-treatment periods from pre 5 (2021Q4) through pre 2 (2022Q3) remain statistically insignificant with the values slight less than zero. This indicates that there are no general effects or baseline variances between the two associates before the implementation of the subsidy. A sharp structural rise is then visible right after the post-treatment area, with the estimate coefficient climbing significantly to 0.461 ( $p < 0.10$  by post 5 (2024Q2)). Visually in Figure 1, the dynamic coefficients persisted flat and below zero during the pre-policy area but transformed into significant positive values post-enactment. This confirms that the Section 45X production tax credit successfully passed the parallel trend test, serving as a distinct catalyst for capital expansion.

## 5. Discussion

### 5.1 Analysis of Causal Mechanisms

The empirical result of this study confirms the alternative hypothesis: the implementation of the Section 45X Tax Credit generated a significant, positive supply-side shock, expanding quarterly capital expenditures between eligible domestic solar manufacturers by approximately 36.8% relative to control industries. This outcome aligns with the theories of green industrial policy arguing that while demand-side subsidies (like the Investment Tax Credit) stimulate consumer deployment, direct, volume-based production incentives can protect domestic supply chains from international products. The

divergence observed in the TWFE model post-2022 suggests that Section 45X successfully lowered the long-term marginal cost curve of domestic assembly.

### 5.2 Policy Recommendations

Despite the policy's success in presenting the growing investment of firms domestically, there are still remaining issues. Currently, the US solar supply chain is experiencing asymmetrical expansion; now that downstream module assembly quantity has surged, upstream production of solar cells and silicon wafers remains severely underdeveloped [9]. Therefore, the necessity of guaranteeing long-term operating status of these newly build factories is crucial, leading to concerns in the methods of adjusting target goals. First, the U.S. government should consider expanding the financial premium of Section 45X explicitly for upstream components to incentivize vertical integration. Preceding research suggests that well-designed supply-side subsidies can improve domestic production incentives and strengthen supply chain competitiveness, particularly when upstream and downstream sectors are developed simultaneously [10]. Second, as Section 45X is planned to begin its phase-down process after 2029, policymakers must provide a long-term guidance on trade barriers to prevent subsidized foreign producers immediately oversupplying domestic factories the moment the tax credits expire.

### 5.3 Limitations and Future Research

The most crucial limitation is related with the

dataset, constrained by a relatively short post-treatment temporal window (2023–2026) and a limited number of publicly traded US solar manufacturers available in the database (N=20). Moreover, depending on the survival rate of these newly capitalized factories, it is difficult to evaluate their long-term performance until they begin active production and the subsidy phase-down initiates. Future research should aim to incorporate private corporate financial data or extend the study period beyond 2026 to evaluate whether this massive capital deployment successfully translates into sustained, globally competitive physical output.

## 6. Conclusion

This research delivers strong empirical evidence on how the IRA Section 45X tax credit created causal impacts on U.S. solar manufacturing firms' investment levels. The conclusion made under the quasi-experimental (DID) framework is that the volume-based production benefit successfully initiated a supply side shock. Firms eligible for the credit increased their quarterly capital investments compared the controlled group by a significant level of 36.8%. The parallel trends test reinforced these results, confirming that there was a direct structural relationship between the policy and the investment surge rather than just showing a macro level trend. However, despite the effective mobilization of firm investments created by Section 45X, it revealed an unhealthy growth of the solar industry supply chain, where downstream assemblies are favored over upstream cell and wafer production. Even though this research is constrained by a relatively small sample of 20 solar manufacturing firms and a short post 45X study period, it created a baseline framework for future studies. Thus, possible approaches for further research could focus on extending the timeline of evaluation and the sample size; this will allow researchers to clarify whether this incentive converts into a global competition or rather reflecting a temporary reaction to a fiscal stimulus.

## References

- [1] Bown, C. P. (2023). Industrial policy for electric vehicle supply chains and the US-EU fight over the Inflation Reduction Act. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4449020>
- [2] Min, Y., Brinkerink, M., Jenkins, J., & Mayfield, E. (2025). Effects of the Inflation Reduction Act on renewable energy manufacturing and development costs and deployment. *Environmental Research Energy*, 2(4), 045008. <https://doi.org/10.1088/2753-3751/ae17d1>
- [3] Allam, Z., Bibri, S. E., & Sharpe, S. A. (2022). The rising impacts of the COVID-19 pandemic and the Russia–Ukraine war: energy transition, climate justice, global inequality, and supply chain disruption. *Resources*, 11(11), 99. <https://doi.org/10.3390/resources11110099>
- [4] Robinson, Q., & Featherston, R. (2024, October 18). *Assessing the United States' Solar Power Play*. Center for Strategic and International Studies. <https://www.csis.org/analysis/assessing-united-states-solar-power-play>
- [5] Karatzas, A., Ancarani, A., Fratocchi, L., Di Stefano, C., & Godsell, J. (2022). When does the manufacturing reshoring strategy create value?. *Journal of Purchasing and Supply Management*, 28(3), 100771. <https://doi.org/10.1016/j.pursup.2022.100771>
- [6] Internal Revenue Service. (2023). *Advanced Manufacturing Production Credit*. IRS. <https://www.irs.gov/credits-deductions/advanced-manufacturing-production-credit>
- [7] Solar Energy Industries Association. (2025, March 11). *Solar Market Insight Report 2024 Year in Review*. SEIA. <https://seia.org/research-resources/solar-market-insight-report-2024-year-in-review/>
- [8] Wharton Research Data Services. (2026). *S&P Global Market Intelligence*. WRDS. <https://wrds-www.wharton.upenn.edu/pages/about/data-vendors/sp-global-market-intelligence/>
- [9] Helveston, J. P., He, G., & Davidson, M. R. (2022). Quantifying the cost savings of global solar photovoltaic supply chains. *Nature*, 612(7938), 83–87. <https://doi.org/10.1038/s41586-022-05316-6>
- [10] Manouchehrabadi, M. K., & Yaghoubi, S. (2022). Comparing supply-side and demand-side policies in the solar cell supply chain under competitive circumstances: a case study. *Environmental Science and Pollution Research*, 30(1), 477–500. <https://doi.org/10.1007/s11356-022-21946-9>