Going Green Like China

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Abstract

China has emerged as the leader in renewable energy innovation, accounting for 83% of global new patents in 2024 (up from 16% in 2009). We attribute this to China's hybrid supply chain. In the downstream electricity sector, state-owned power groups operate under renewable targets set by national planning, and their managers compete for promotion by (over-)fulfilling these targets. This generates large and predictable demand, driving innovation among the private upstream suppliers. Evidence based on global supplier–customer pair data shows that Chinese customers' demand growth strongly stimulates supplier patenting. The effect is absent for non-Chinese customers, stronger for the central power groups, and strongest when CEOs face high promotion incentives. The 2022 clearance of feed-in-tariff arrears as a demand shock confirms causality. Direct subsidies have no effect, but subsidies channeled through fast-growing customers do. This arrangement also leads to upstream overinvestment and overcapacity.

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1 Introduction

Renewable energy has reached a tipping point. The journal *Science* named its 2025 surge as the Breakthrough of the Year, marking the first time renewable sources have surpassed coal as the world's primary source of electricity (Appenzeller, 2025). China has been the central engine of this transformation, supplying approximately 80% of the world's solar cells, 70% of its wind turbines, and 70% of its lithium batteries (Thorp, 2025), and accounting for more than 80% of new patents in the renewable energy industry.

China's position is a striking reversal. Through the 2000s, manufacturing and innovation in green technology were led by the European Union and the United States, while China prioritized economic growth at the expense of environmental protection. Around 2012, China made a strategic shift toward a greener economy. Within roughly a decade, China has gone from a heavily polluted country to the global leader in the manufacturing and innovation of renewable energy technologies central to the global net-zero transition.

What has driven this shift? In this paper, we answer this question by examining renewable energy equipment firms in China and other major countries. Our explanation highlights the uniqueness of China's hybrid economic system and supply chain structure, which combines national planning and political incentive with market competition. This system appears effective in fostering green innovation, although it has inevitably led to overcapacity.

China implements its green-energy commitments through binding quantitative targets in successive Five-Year Plans. Beginning with the 12th Plan (2011–2015), each plan has specified the cumulative gigawatt (GW) capacity of solar and wind power to be installed by the end of the planning period, alongside broader industrial and technological guidance. In 2020, China further reinforced these efforts by announcing its "dual-carbon" goals: peaking carbon emissions by 2030 and achieving carbon neutrality by 2060, in line with the Paris Agreement.

These targets are enforced through the distinctive ownership structure of China's renewable energy supply chain. The chain has two tiers: upstream manufacturers of solar

panels, wind turbines, and energy storage systems supply downstream electricity generators and other end users. What distinguishes the Chinese setting is that the downstream power generators are predominantly state-owned enterprises (SOEs), keeping them closely aligned with national planning. At the core of this segment are eleven central-government-controlled power groups—commonly known as the "five major and six secondary" (5M6S)—which together account for roughly 60% of national electricity generation.

The eleven central groups face direct political incentives: their top executives' performance evaluations are explicitly tied to renewable energy expansion, creating high-powered promotion incentives to meet and exceed national targets. Under this arrangement, Five-Year Plan installation targets have been substantially overfulfilled. For example, under the 13th Plan (2016–2020), the solar power target of 110 GW was overshot with realized capacity of roughly 250 GW; under the 14th Plan (2021–2025), the 650 GW target was met with around 1,200 GW.

The upstream segment, in contrast, is predominantly private and highly competitive: manufacturers compete to supply the state-owned power groups with increasingly advanced technologies at lower prices. Because national planning and managerial promotion incentives together make downstream demand large, credible, and persistent, suppliers face strong incentives to invest in innovation (e.g., Leahy and Neary, 1997; Kamien, Muller and Zang, 1992). Indeed, most new patents in the industry are filed by these private suppliers, not by their state-owned customers.

Our first empirical test asks whether strong demand from Chinese downstream firms effectively stimulates upstream innovation. Using a sample of global suppliers in the renewable energy industry and their major customers, we find that, within supplier–customer relationships, Chinese customers' revenue growth—a proxy for demand—is positively associated with their suppliers' subsequent patenting: a one-standard-deviation increase in three-year average revenue growth corresponds to a 12.0% rise in supplier patent filings the following year. The demand-pull effect is significant for both domestic and foreign suppliers to Chinese

customers but absent for non-Chinese customers. This finding is robust to pair fixed effects, country-by-year fixed effects, and supplier- and customer-side controls.

Second, we trace this distinctive demand-pull to the political incentives facing the executives of the eleven major power groups. Tracking the career outcomes of chief executives and chairpersons across these eleven groups, we find that those overseeing higher renewable energy installation are significantly more likely to be promoted, controlling for financial performance: a one-standard-deviation increase in installation raises the probability of promotion by approximately 13.6 percentage points, more than doubling the sample mean rate of 12.1%. This is consistent with the performance evaluation framework the central government announced in 2021, which formally incorporated the "Dual-Carbon" objectives into executive evaluation.

Third, we link upstream innovation directly to the strength of these career incentives. The demand-pull effect is substantially stronger for customers in the eleven major power groups (5M6S): a one-standard-deviation increase in their revenue growth is associated with approximately 73% more supplier patenting, compared with about 10% for other Chinese customers—a roughly sixfold amplification.

We further exploit heterogeneity within these eleven groups (5M6S). The demand-pull effect concentrates among groups led by CEOs with longer promotion horizons. Specifically, CEOs younger than 55, who can still serve two full terms in a promoted position before mandatory retirement at age 63, exhibit a total demand-pull effect roughly 17 times that for other Chinese customers. These patterns tie upstream innovation directly to the strength of the political incentive facing the downstream manager.

Together, our findings support the demand channel formalized by Aghion et al. (2025), with national planning mandates and SOE managerial incentives jointly serving as a coordination device that pushes both segments of the supply chain toward a steady state featuring high adoption and innovation in green technologies.

Fourth, we address an endogeneity concern that these results may reflect sorting between

high-growth customers and innovative suppliers rather than a causal demand-pull effect. We exploit the 2022 clearance of accumulated arrears under China's feed-in-tariff (FIT) program for subsidizing renewable installation. The clearance generated a one-time, largely unanticipated cash-flow shock to eligible customers. In a difference-in-differences analysis, suppliers serving treated customers file significantly more patents following the shock, with parallel pre-trends between treatment and control groups.

Fifth, government subsidies are widely believed to be the main driver of China's renewable expansion. We directly test whether they stimulate supplier innovation. For Chinese firms in our sample, subsidies granted directly to suppliers or to their customers are not, on their own, significantly associated with higher supplier patenting, consistent with the literature on information frictions in industrial policy and central planning (see, e.g., Noman and Stiglitz, 2016; Juhász and Lane, 2024, for surveys). However, subsidies allocated to fast-growing downstream customers do stimulate supplier innovation, suggesting that these customers themselves produce information on supplier quality.

Finally, we examine overcapacity, a central concern in discussions of China's renewable energy industry. National guidance and political oversight of the major power groups have not only stimulated strong growth but also reduced demand uncertainty for upstream suppliers; while this encourages innovation, it can also induce excessive investment and production. Consistent with this concern, higher Chinese customer revenue growth is associated with both increased supplier investment in subsequent years—significant for both domestic and foreign suppliers—and rising inventory levels, indicating overproduction.

Related literature and discussion A large body of work establishes that output expansion and demand can effectively drive corporate innovation (Leahy and Neary, 1997; Acemoglu and Linn, 2004; Myers and Pauly, 2019; Clemens and Rogers, 2026; Aghion et al., 2024; Lileeva and Trefler, 2010; Bustos, 2011; Slavtchev and Wiederhold, 2016). Barwick, Xia and Xia (2026) find that China's National Reimbursement Drug List (NRDL) reform

expanded the market size, leading to a surge in pharmaceutical innovation. More recent research highlights the particular role of supply-chain networks in shaping innovation incentives and the diffusion of knowledge (Chu, Tian and Wang, 2019; Liu and Ma, 2021; Dasgupta, Zhang and Zhu, 2021; Palit, Hora and Ghosh, 2022).

Our paper adds to the emerging literature on corporate green innovation (e.g., Bolton, Kacperczyk and Wiedemann, 2023; Choi et al., 2025; Cohen, Gurun and Nguyen, 2026). Among others, this study builds most closely on the theoretical work of Aghion et al. (2025), who develop a dynamic model of green technological transition along a vertical supply chain. A key mechanism in their framework is the demand channel: downstream greenification expands the market for upstream clean technologies, raising innovators' revenues and incentives to invest. We provide large-scale empirical evidence for this mechanism.

They further show that cross-sectoral strategic complementarities can trap economies in low-greenification steady states—even under optimal carbon taxation—making sector-specific industrial policy targeting downstream sectors necessary to overcome the coordination failure.[1] Our results suggest that China's hybrid economy resolves this problem: political incentives at the state-controlled downstream power groups make demand commitments credible and persistent, allowing private upstream suppliers to invest in green innovation without waiting for rivals to act.

A growing body of research examines the effectiveness of industrial policies designed to promote the green transition (e.g., Acemoglu et al., 2016, 2012; Aghion, Hemous and Veugelers, 2025) and has identified several key impediments. Juhász and Lane (2024) and Wang, Wurgler and Zhang (2026) emphasize the challenges arising from the political economy of green industrial policy, including policy uncertainty and time inconsistency. Noman and Stiglitz (2016) highlight the role of information frictions in constraining the effectiveness of policy design and implementation. In the realm of sustainable investment, Hong, Kubik and Shore (2025) document the high return volatility of green assets, while Duchin, Gao and

[1] Bolton and Farrell (1990) highlight similar coordination problems in decentralized economic systems facing urgent choices.

Xu (2025) show that greenwashing further distorts market signals by obscuring firms' true environmental performance.

China's approach to the green transition differs fundamentally from the market-based frameworks prevalent elsewhere. It is driven by top-down national planning and enforced through political incentives to SOE managers, yet it still relies on competition and innovation from the private sector. The long-term planning horizons embedded in successive Five-Year Plans substantially reduce policy uncertainty that might otherwise deter upstream investment. Moreover, managerial incentives tied to green electricity installation create credible demand signals for private upstream firms, help produce information, and leave little room for greenwashing. While China's distinctive approach may not be directly generalizable to other countries, it offers valuable insights into addressing the challenges in green transition.

The literature on the Chinese economy has long emphasized competition among local government officials as a key driver of economic growth (e.g., Qian and Xu, 1993; Maskin, Qian and Xu, 2000; Li and Zhou, 2005; Song, Storesletten and Zilibotti, 2011; Jia, Kudamatsu and Seim, 2015; Song and Xiong, 2023), with evidence suggesting that such tournament-style incentives can partially substitute for weak formal institutions. Groves et al. (1995) document similar competitive dynamics among SOE managers. We extend this line of research by showing that the central government has harnessed these tournament mechanisms to effectively advance its "dual-carbon" objectives, leveraging political control over personnel appointments in major electricity firms to sustain credible and persistent downstream demand for renewable energy equipment.

2 Background and Stylized Fact

2.1 China's green transition

Strategic turn to sustainability Since initiating economic reforms in the 1980s, China long prioritized rapid economic growth over environmental protection. As it became the

"world's factory," the resulting air and water pollution, public-health concerns, and rising carbon emissions drew increasing domestic and international scrutiny. The strategic shift began around 2012, when the leadership articulated a broader vision of *ecological civilization*—encompassing not only decarbonization but also environmental protection and sustainability across all dimensions—and emphasized that economic growth should no longer come at the expense of environmental sustainability.[2] This shift was institutionalized in 2013 through a revised performance evaluation framework for local government officials, which replaced the prior GDP-only emphasis with balanced criteria covering environmental protection and energy efficiency.

The progress is visible in environmental outcomes: Figure 1 plots the trends in several indicators. Panels A and B show steady improvement in water and air quality over time, with the lake water quality attainment rate rising from 42.3% in 2011 to 77.1% in 2024 and the national average PM2.5 concentration falling from 85 to 29 over the same period. Panel C shows that electric vehicles accounted for over 40% of new vehicle sales in 2024, and Panel D shows that the share of electricity generated from renewable sources rose from 2% in 2011 to over 18% in 2024.

In September 2020, China further announced its "dual-carbon" goals at the 75th UN General Assembly—peaking carbon emissions before 2030 and achieving carbon neutrality before 2060, in line with its Paris Agreement commitments.

National planning As with many of its other national strategic objectives, China relies on its series of Five-Year Plans to implement goals related to environmental protection and renewable energy development. Each plan is first formulated and approved at the national level, after which local governments, sectoral ministries, and major SOEs develop more specific targets, actions, and policies in alignment with national priorities. These plans not only offer broad policy and technological guidance for industrial development but also specify

[2]In his 2012 report to the 18th National Congress of the CPC, then-President Hu Jintao formally elevated "ecological civilization" to one of the nation's five overarching development objectives; see Online Appendix A.2 for further details.

concrete, quantitative targets to be achieved by the end of each planning period.

The Five-Year Plans also set clear expectations for private sectors and markets, reducing policy uncertainty and guiding long-term investment decisions. In practice, many private enterprises formulate their own strategic plans in alignment with the targets articulated in the government's plans. In this sense, the Five-Year Plans serve as a coordination device that aligns the long-term economic decisions of public and private actors.

Starting with the 12th Five-Year Plan (2011–2015), the renewable energy industry has been an important focus. The plan established quantitative objectives for key indicators such as carbon intensity, energy efficiency, and the share of non-fossil fuels in primary energy consumption, and the next two Five-Year Plans continued this practice. Table 1 lists the key targets: the cumulative installed solar PV target rose from 21 GW to 110 GW under the 13th Plan (2016–2020) and 650 GW under the 14th (2021–2025), and the targeted share of non-fossil energy in primary consumption climbed from 11.4% by 2015 to 15% by 2020 and 20% by 2025.

These targets are binding, and most have not only been met but typically substantially exceeded. Actual installed solar capacity reached approximately 250 GW by 2020 and 1,200 GW by 2025, well above the planned 110 GW and 650 GW; wind installations followed a similar pattern, reaching 280 GW by 2020 and 600 GW by 2025 against targets of 210 GW and 450 GW. The realized share of non-fossil energy in primary consumption reached 12.0% in 2015, 15.8% in 2020, and 19.8% in 2025, closely tracking or surpassing the official targets.

Other policy initiatives A range of supporting policies, all aligned with the Five-Year Plans, has facilitated this transition. The most prominent are the feed-in-tariff (FIT) system for renewable generation, state-directed green loans channeled through the major commercial banks, and large-scale investment in ultra-high-voltage (UHV) transmission infrastructure to integrate western renewable capacity with eastern consumption centers. These initiatives—particularly UHV, given its scale and long horizon—signal the central government's strong

commitment to the green transition. We summarize these policies and provide additional institutional detail in Online Appendix A.2.

Progress and stylized facts China's decarbonization progress has been broadly comparable to, if not faster than, that of other major economies, despite starting from a relatively high baseline in the early 2010s. Figure 2 shows that the carbon intensity of both GDP (Panel A) and power generation (Panel B) have declined markedly in China since 2010, substantially narrowing the gap with other countries. Figure 3 shows annual additions of solar and wind generation capacity by country: in recent years, China's new installations have exceeded the combined total of all other countries. While this partly reflects China's position as the world's largest electricity consumer, the pace of expansion is striking—a decade ago, most new renewable capacity was concentrated in the European Union and the United States, but China has since surpassed both regions, marking a significant realignment in global renewable energy investment and manufacturing.

Similar trends are present for innovation. Figure 4 (Panels A and B) reports the annual number of patents applied for and granted, respectively. In 2024, Chinese suppliers accounted for more than 83% of patent filings in the renewable energy sector, up from less than 20% in the 2000s, when innovation in this field was dominated by firms from the European Union and the United States.

2.2 Hybrid supply-chain structure

The renewable energy industry generally exhibits a two-tier supply chain structure. The upstream segment mainly consists of three industries—solar panels, wind turbines, and energy storage systems; see Panel A of Figure 5.

The downstream segment comprises end users across multiple industries that utilize these technologies. Panel B of Figure 5 presents the industry composition of customer companies. The largest customers are concentrated in the utility, energy, transportation, and electrical

equipment sectors. Among them, electricity generation companies operating power plants (classified under utilities) account for a substantial share of total demand.

Customers' political incentive In our sample of Chinese customers, the asset-weighted state ownership share is above 80%, ensuring that national planning objectives are effectively transmitted through the supply chain. Most of these state-owned customers are electricity generation firms, which divide into two categories.

The first comprises the eleven "five major and six secondary" power groups (hereafter, 5M6S), which are pure-play generators centrally administered by the State-owned Assets Supervision and Administration Commission (SASAC). The 5M6S together account for roughly 60% of China's total electricity generation, making them the central force in the country's power supply; their incentives are therefore most directly aligned with central-government priorities.

What most distinguishes the 5M6S is the SASAC-administered executive performance evaluation system, which has progressively strengthened the role of sustainable development over the last fifteen years. A 2008 directive on corporate social responsibility placed environmental performance among the evaluation criteria, and a 2019 framework on high-quality development emphasized the green transition. The landmark is the 2021 policy that explicitly incorporated the "dual-carbon" goals into the executive performance evaluation framework, with specific rewards for outstanding performance and penalties for missing targets. Managers of the 5M6S thus face career incentives directly tied to renewable energy expansion: they compete with their peers for promotions conditioned on meeting or exceeding green-installation targets. Online Appendix A.2 provides additional institutional detail on the 5M6S and the relevant SASAC policy documents.

The remaining 40% of generation is supplied by provincial-level state-owned firms, central SOEs whose primary business lies outside power generation (e.g., China Coal), private generators, and small-scale producers. Together with downstream customers in other indus-

tries (transportation, industrial equipment, materials, and so on), these firms make up the non-5M6S portion of our Chinese-customer sample. While they face much weaker managerial incentives than the 5M6S, most are still politically aligned with or strongly guided by the central plans.

Together, the state ownership of downstream customers and the binding nature of Five-Year Plan targets make demand for green technology stronger and more predictable among Chinese customers as a whole than among their non-Chinese counterparts. Within China, however, the 5M6S face the most direct and explicit managerial incentives—a distinction we exploit empirically in Sections 4.2 and 4.3. These incentive structures not only reinforce strong and predictable demand for renewable energy equipment but also generate valuable information about high-quality and innovative equipment suppliers. This parallels the role of political incentives among local-government officials in shaping informative regional economic policies and driving growth (e.g., Maskin, Qian and Xu, 2000; Li and Zhou, 2005; Song and Xiong, 2023).

Suppliers In contrast, the suppliers in the upstream segment—the renewable energy equipment manufacturers—are predominantly private firms. The asset-weighted state ownership share of Chinese supplier companies is only around 10%. These companies compete intensely to provide equipment to the 5M6S and other downstream generators, offering increasingly advanced technologies at lower prices. As a result, the upstream renewable equipment market is highly competitive, and it is also the sector that files the new patents advancing renewable energy technology.

In sum, China's hybrid supply chain can be characterized by state-owned customers with strong and predictable demand, combined with a private and highly competitive supplier sector that drives innovation.

3 Data and Sample Construction

3.1 Sample construction

We focus on firms that produce renewable energy equipment, identified using the Bloomberg Industry Classification System (BICS). Specifically, we select all firms classified under the Level 4 sub-industry *Renewable Energy Equipment* within the *Energy* sector, which covers manufacturers of solar, wind, and energy storage equipment.[3] This yields a global universe of 8,040 firms, of which 1,182 are publicly listed.

Patent information is from Orbis Intellectual Property, which covers records from patent offices worldwide. We match 6,030 of the 8,040 identified firms to Orbis using ISINs, LEIs, and firm names, and find 1,261 with at least one patent. We identify environment-related patents using two complementary criteria: CPC codes within the Y02 categories (Hege, Li and Zhang, 2024) and IPC codes listed in the IPC Green Inventory (Bolton, Kacperczyk and Wiedemann, 2023).

Supply chain relationships are obtained from FactSet Revere, which compiles supplier–customer links from firms' financial statement disclosures and public news sources. We focus on pairs in which a renewable energy equipment firm serves as supplier. A total of 731 such firms participate in at least one supply chain relationship during 2009–2024, of which 632 maintain relationships lasting longer than one year. Coverage is inherently limited to publicly listed firms subject to mandatory supply chain disclosure requirements.[4]

Finally, we collect financial data for all firms in our sample for 2009–2024 from Compustat (U.S. firms), Compustat Global (non-U.S. listed firms), and BvD Orbis Global Financials. Control variables for both the customer and supplier sides are defined in Table 2.

[3]The sub-industry comprises three Level 5 segments: *Solar Energy Equipment* (polysilicon, photovoltaic cells and modules, thin-film modules), *Wind Energy Equipment* (turbines and components such as bearings, blades, and towers), and *Other Renewable Energy Equipment* (fuel cells, energy storage systems, and related technologies). Leading firms in each segment are listed in Online Appendix Table A1.

[4]In China, listed firms must disclose the revenue share of their top five customers and suppliers, but may report trading partners anonymously. In the United States, the SEC requires disclosure of customers representing at least 10% of total revenue, but does not mandate supplier disclosure.

For Chinese A-share listed firms, firm-level subsidy data are obtained from CSMAR based on mandatory disclosures in their annual financial statements. We match CSMAR records to our main sample using ISINs and firm names. To our knowledge, comparable firm-level subsidy data are not available for firms listed in other markets.

One caveat for the 5M6S power groups (Section 2.2): the parent groups are typically unlisted and appear in our supply chain data only through their listed subsidiaries.[5] We therefore use Tianyancha to manually identify whether each Chinese customer belongs to one of the 5M6S.

3.2 Summary Statistics

After restricting the sample to observations with non-missing financial data for both parties, customer total assets above USD 100 million,[6] relationships lasting more than one year, and at least one supplier patent during the relationship, we obtain 8,998 customer–supplier–year observations covering 198 renewable energy equipment firms in 23 countries.

Table 2 reports summary statistics. Suppliers file an average of 207 patents per year (median 40), nearly all environment-related. Customers' three-year average revenue growth is 13.1% per year, and suppliers' is 20.7%. Figure 5 shows the industry composition of suppliers (Panel A) and customers (Panel B). The largest customer industries are Utilities (23%) and Energy (19%), followed by Electrical Components and Transportation Equipment under the Industrial sector (14% and 12%, respectively). Among supplier firms with available BICS Level 5 segment information, Solar Energy Equipment firms account for 35%, Wind Energy Equipment firms for 20%, and Energy Storage Systems firms for 31%, with the remainder in other renewable equipment categories.

[5] For example, the China Three Gorges Corporation is represented in our customer data by three China-listed subsidiaries: Hubei Energy Group, China Yangtze Power, and China Three Gorges Renewables.

[6] We do not require disclosure of transaction values, which would sharply reduce sample size. The asset threshold ensures that retained customers are economically meaningful to their suppliers.

4 Empirical Result

4.1 Demand-pull Innovation among Suppliers

Section 2.2 argued that two features of China's hybrid system should make its downstream customers distinctively effective at pulling upstream innovation. First, the central government's Five-Year Plans set national renewable energy targets that translate into a large and predictable expansion path for downstream demand. Second, the downstream electricity sector is dominated by a small group of centrally administered state-owned power firms whose senior executives have direct career stakes in fulfilling those targets. Together, these features generate downstream demand that is large, credible, and persistent—conditions that strengthen upstream suppliers' incentives to invest in innovation.

We start by testing this prediction in our global sample by comparing innovation responses among suppliers of Chinese versus non-Chinese customers. Specifically, we estimate the following model:

$$Patent^{S}_{s,t+1} = \beta_1 \, \Delta Revenue^{C}_{s,c,t-2\to t} + \gamma \, Controls^{S}_{s,t} + \gamma_2 \, Controls^{C}_{c,t} + \epsilon_{s,c,t+1} \tag{1}$$

where S refers to the supplier firm and C to the customer firm. The dependent variable, $Patent$, is the count of patents filed by the supplier in year $t+1$. We estimate the model as a Poisson regression with high-dimensional fixed effects, following Cohn, Liu and Wardlaw (2022).

We proxy customer demand by the customer's three-year average revenue growth, $\Delta Revenue^{C}_{t-2\to t}$.[7] Because firm-level supplier-to-customer transaction values are not publicly disclosed, total revenue growth is the most direct demand proxy available in the data, although it can in part reflect changes in product prices rather than quantities. As a robustness check, we replace this measure with newly installed renewable electricity generation capacity for the

[7] If the supply chain relationship has existed for less than three years, the average is taken from the start of the relationship.

subsample of power-firm customers.

We control for firm characteristics on both sides of the pair. Supplier-side controls include $\Delta Revenue^{S}_{t-2\to t}$ (three-year average revenue growth), $R\&D^{S}$ (R&D expenditure scaled by revenue), $\ln(Asset^{S})$, ROA^{S}, $CapEx^{S}$ (capital expenditure scaled by total assets), and $Tangibility^{S}$ (PP&E scaled by total assets). Customer-side controls include $\ln(Asset^{C})$, ROA^{C}, $CapEx^{C}$, and $Tangibility^{C}$, as well as the customer's current-year innovation, $\ln(Patent^{C})$.[8] Pair fixed effects absorb time-invariant matching between high-growth customers and innovative suppliers, alleviating concerns about endogenous sorting. The $Country^{C}_{s,c} \times Year_t$ and $Country^{S}_{s,c} \times Year_t$ fixed effects further rule out country-by-year shocks, such as renewable-policy reforms in either the customer's or the supplier's country.

Panel A of Table 3 reports estimates of Equation (1) separately for Chinese customers (Columns (1)–(4)) and non-Chinese customers (Columns (5)–(7)). Columns (1) and (2) show that Chinese customers' revenue growth has a positive and statistically significant effect on suppliers' subsequent patenting. The magnitude is economically meaningful: under the most stringent specification, a one-standard-deviation increase in customer revenue growth is associated with a 12.0% rise in supplier patents the following year.[9]

Columns (3) and (4) further split the Chinese-customer sample by supplier nationality. The effect persists even for foreign suppliers to Chinese customers (Column (4)), with a coefficient that is both economically and statistically significant. In contrast, for non-Chinese customers, the coefficient on $\Delta Revenue^{C}_{t-2\to t}$ is negative and statistically insignificant across all specifications (Columns (5)–(7)). Suppliers' own revenue growth has little explanatory power in any column.

To formally test whether the coefficient on $\Delta Revenue^{C}_{t-2\to t}$ differs between Chinese and non-Chinese customers, we estimate Equation (2) on the full sample, augmenting the baseline with an interaction between $\Delta Revenue^{C}_{t-2\to t}$ and $isCN^{C}$, a dummy equal to one if the

[8] The dependent variable $Patent^{S}$ enters as a count to match the Poisson specification; $Patent^{C}$ enters as a log control to address its skewness.

[9] Calculated as $e^{0.376\times 0.302} - 1 \approx 0.120$.

customer is Chinese.

$$\begin{aligned} Patent^{S}_{s,t+1} = \beta_1 \, \Delta Revenue^{C}_{s,c,t-2\to t} + \beta_2 \, \Delta Revenue^{C}_{s,c,t-2\to t} \times isCN^{C}_{s,c} \\ + \gamma_1 \, Controls^{S}_{s,t} + \gamma_2 \, Controls^{C}_{c,t} + \epsilon_{s,c,t+1} \end{aligned} \tag{2}$$

Panel B of Table 3 reports these results. The coefficient on $isCN^{C} \times \Delta Revenue^{C}_{t-2\to t}$ is positive and significant across all fixed-effect specifications, confirming that the demand-pull effect is materially stronger for Chinese customers.

Chinese customers' demand is also more *predictable*: estimating an AR(1) model of $\Delta Revenue^{C}$ yields a substantially higher autoregressive coefficient for Chinese than for non-Chinese customers; see Online Appendix Table A2. This finding further supports our claim that national planning makes downstream demand more credible and persistent in China.

Robustness First, we construct a more direct proxy for solar- and wind-related equipment demand using customers' newly installed renewable electricity generation capacity.[10] We re-estimate Equations (1) and (2), replacing $\Delta Revenue^{C}_{t-2\to t}$ with customers' three-year cumulative newly installed capacity scaled by total assets ($RenewAdp_{t-2\to t}$). Consistent with the baseline, Table 4 shows that the coefficient on $RenewAdp_{t-2\to t}$ is significant for Chinese customers but not for non-Chinese ones, and the interaction $RenewAdp_{t-2\to t} \times isCN^{C}$ is significantly positive.

The findings are also robust to alternative specification choices: (i) using a one-year rather than three-year revenue growth window, which captures more recent demand (Online Appendix Table A3); (ii) restricting the dependent variable to environment-related patents, *EnvPatent* (Online Appendix Table A4); (iii) extending the innovation-measurement horizon to three years (Online Appendix Table A5); and (iv) including Supplier- or Customer-Industry × Year fixed effects, which absorb industry-level shocks to supplier innovation

[10] Installed capacity is measured using plant-level data from the Global Energy Monitor (GEM) database, which provides owner, establishment year, installed capacity, and location for individual power plants. We match these records to our customer firms by plant-owner name. Newly installed capacity in a given year is the capacity of solar and wind plants newly established by the customer in that year.

(Online Appendix Table A6).

Falsification Test To rule out broad country-level confounders, we conduct a falsification test in which each actual customer is replaced with a fictitious one drawn from our sample, matched on country and on closest firm size in the relationship's starting year and held fixed throughout. Re-estimating Equation (1) on this fictitious sample yields a statistically insignificant coefficient on $\Delta Revenue^{C}_{t-2\to t}$ for Chinese fictitious customers (Online Appendix Table A7). Since fictitious and actual customers face similar macroeconomic and renewable-policy environments by construction, this null confirms that the demand-pull effect operates through the supplier–customer relationship itself rather than through broad country-level factors.

4.2 Managerial Incentive of Customers

The preceding section showed that Chinese customers exert a distinctively strong demand-pull on upstream innovation, consistent with two features of China's hybrid system: national renewable energy planning and the political incentives facing executives of the "five major and six secondary" (5M6S) power groups described in Section 2.2. We now zoom into the second mechanism. We document the incentive structure empirically by testing whether renewable energy adoption has become a meaningful criterion in SOE executive promotion, reflecting SASAC's progressive tightening of green performance targets in its evaluation framework. The analysis focuses on the eleven 5M6S power groups, which together account for roughly 60% of China's electricity generation. We hand-collect career movements of their chairpersons and CEOs from annual reports and public sources; the sample begins in 2015, as earlier records are incomplete.

We define the following career movements as promotions: transfers to government agencies at the same administrative ranks (e.g., the National Energy Administration), promotions from CEO to chairperson within the same group, and appointments as chairperson of a larger

SOE group. We then estimate a logit model at the group level with year fixed effects to examine whether renewable energy adoption increases the probability of executive promotion, conditional on financial performance:

$$Promotion_{c,t+1\to t+K} = \beta_1 RenewAdp_{c,t} + \gamma\, Controls_{c,t} + \epsilon_{s,c,t} \tag{3}$$

$Promotion_{c,t+1\to t+K}$ is a dummy variable that equals one if the group c's CEO or chairman experiences a promotion in year $t+1$ to $t+K$ and zero otherwise, where $K \in \{1,2,3\}$. $RenewAdp_{c,t}$ is measured as the group level total newly installed renewable energy capacity in year t, scaled by total assets (Watts per USD assets).[11] For ease of interpretation, we standardized $RenewAdp$. Control variables include the firm size ($\ln(Asset)$), return on equity (ROE), revenue growth ($\Delta Revenue$), and gross margin ($GrossMargin$), all obtained from Tianyancha. Year fixed effects are included. The sample period is from 2015 to 2024.

Further, as the central government has placed increasing emphasis on the "Dual-Carbon" objectives and gradually incorporated them into the executive evaluation framework, we expect the effect of $RenewAdp$ on $Promotion$ to strengthen over time. To test this, we augment the specification with an interaction between $RenewAdp$ and a time trend t:

$$Promotion_{c,t+1\to t+K} = \beta_1 RenewAdp_{c,t} + \beta_2 RenewAdp_{c,t} \times t_t + \gamma\, Controls_{c,t} + \epsilon_{s,c,t} \tag{4}$$

Table 5 shows that the results are significant and consistent with our conjecture. For example, results in Column (5) show that a one-standard-deviation increase in $RenewAdp$ raises the probability of promotion by approximately 13.6 percentage points ($1.278 \times 0.121 \times (1-0.121) \approx 0.136$, with a z-statistic of 4.5, evaluated at the sample mean promotion rate of 12.1%). The positive coefficients on $RenewAdp \times t$ in columns (2) and (4) further suggest that this relationship has strengthened over time, consistent with SASAC's progressive tightening

[11] Installed capacity is collected from the Global Energy Monitor (GEM) database, which provides owner, establishment year, installed capacity, and location for individual power plants. We match the names of plant owners to the 5M6S power groups and their listed subsidiaries.

of green performance targets.[12]

Renewable energy adoption has thus become a high-powered career incentive for SOE executives, making the major power groups credible and predictable customers for upstream suppliers and providing the persistent downstream demand that pulls innovation along the supply chain.

Our findings are closely related to the broader tournament literature on Chinese local government officials. Li and Zhou (2005) and Maskin, Qian and Xu (2000) show that regional officials with stronger economic performance are significantly more likely to be promoted, creating powerful career incentives that drive local economic activity. We extend this finding to SOE managers, documenting that green energy adoption has become an increasingly important criterion in executive evaluation. Our results also relate to Shleifer and Vishny (1994), who argue that political objectives can distort managerial incentives away from value maximization; in our setting, however, this political incentive is channeled productively toward renewable energy expansion, aligning managerial career concerns with national sustainability goals.

4.3 Heterogeneity in Political Incentive

Sections 4.1 and 4.2 together establish two facts: Chinese customers pull innovation more strongly than non-Chinese ones, and 5M6S executives' careers are tied to renewable energy expansion. We now link the two more directly by testing whether the demand-pull effect itself strengthens with the intensity of customers' political incentives. Within the sample of Chinese supplier–customer pairs, we exploit two sources of cross-sectional variation: (i) whether the customer belongs to the 5M6S, which face the strongest political incentives to fulfill national renewable-installation targets; and (ii) among the 5M6S, the CEO's remaining promotion horizon.

[12] In the conditional logit model with year fixed effects, years with no within-year variation in $Promotion_{t+1}$ are dropped, leading to a smaller number of observations in Columns (1).

5M6S versus other Chinese customers We augment the baseline with an interaction between $\Delta Revenue^{C}_{t-2\to t}$ and $5M6S^{C}$, a dummy equal to one if the customer belongs to one of the eleven 5M6S power groups described in Section 2.2. The comparison group, which we refer to throughout as *other Chinese customers*, consists of all Chinese customers outside the 5M6S; it includes both Chinese electricity generators not in the 5M6S (provincial utilities, private generators, and central SOEs whose primary business is not power generation) and Chinese customers in other downstream industries.

$$\begin{aligned} Patent^{S}_{s,t+1} = \beta_1 \, \Delta Revenue^{C}_{s,c,t-2\to t} + \beta_2 \, \Delta Revenue^{C}_{s,c,t-2\to t} \times 5M6S^{C}_{s,c} \\ + \gamma_1 \, Controls^{S}_{s,t} + \gamma_2 \, Controls^{C}_{c,t} + \epsilon_{s,c,t+1} \end{aligned} \tag{5}$$

Panel A of Table 6 reports the results. The interaction $\Delta Revenue^{C}_{t-2\to t} \times 5M6S^{C}$ is positive and statistically significant in Columns (1) and (2). The effect remains robust in Columns (3) and (4), which additionally control for interactions between $\Delta Revenue^{C}_{t-2\to t}$ and other customer characteristics ($\ln(Asset^{C})$, ROA^{C}, $CapEx^{C}$, $Tangibility^{C}$, and $\ln(1 + Patent^{C})$). The amplification is therefore specifically driven by the 5M6S political-incentive channel, rather than by general firm attributes such as size. The magnitudes are sizable: in Column (1), the demand-pull coefficient for the 5M6S is roughly six times larger than for other Chinese customers ($0.304 + 1.511 = 1.815$ vs. 0.304). Equivalently, a one-standard-deviation increase in customer revenue growth is associated with roughly a 73% increase in supplier patenting for 5M6S customers, compared with about 10% for other Chinese customers.

Managers' promotion horizon We next exploit heterogeneity in career incentives among the 5M6S, using CEO age. SOE managers face mandatory retirement at approximately age 63; those close to this cutoff have little remaining promotion horizon, while younger CEOs face strong incentives to compete for advancement. This identification strategy has been widely used in studies of tournament effects among Chinese local officials (e.g., Chen, He

and Liu, 2020). We estimate:

$$\begin{aligned} Patent^{S}_{s,t+1} = \beta_1 \, \Delta Revenue^{C}_{s,c,t-2\to t} + \beta_2 \, \Delta Revenue^{C}_{s,c,t-2\to t} \times Years_to_Retire^{C}_{s,c,t} \\ + \beta_3 \, Years_to_Retire^{C}_{s,c,t} + \gamma_1 \, Controls^{S}_{s,t} + \gamma_2 \, Controls^{C}_{c,t} + \epsilon_{s,c,t+1} \end{aligned} \tag{6}$$

where $Years_to_Retire^{C}_{s,c,t}$ is the CEO's remaining years to age 63.[13]

We first restrict the sample to suppliers serving the 5M6S. Panel B Column (1) shows that the coefficient on $\Delta Revenue^{C} \times Years_to_Retire^{C}$ is positive and significant, confirming that the demand-pull effect strengthens with the CEO's remaining promotion horizon. Column (2) replaces the continuous measure with $YoungCEO$, a dummy equal to one if the CEO is younger than 55. The age-55 cutoff identifies the threshold above which further promotion is much less realistic: an executive promoted after 55 cannot serve two full terms in the new senior position before reaching mandatory retirement.[14] The coefficient on $\Delta Revenue^{C} \times YoungCEO^{C}$ is positive and significant.

Finally, we extend the analysis to the full sample of suppliers to Chinese customers, setting $Years_to_Retire$ to zero for customers outside the 5M6S, since their managers' promotions are not subject to SASAC's green-installation KPI. Panel B Column (3) shows that the coefficient on $\Delta Revenue^{C} \times Years_to_Retire^{C}$ remains positive and significant.

Column (4) splits 5M6S customers into those managed by young CEOs ($YoungCEO$) and those managed by older CEOs ($OldCEO$), with other Chinese customers as the omitted

[13] We focus on the political incentives of CEOs rather than chairmen because CEOs are the ones managing daily operations and are typically younger with greater promotion prospects. Most chairmen in the 5M6S are approaching retirement. While the statutory retirement age in China is 60, senior executives in central SOEs often have their tenure extended to around 63.

[14] Senior executives in China's central SOEs face a retirement age of 63, extended from the statutory age of 60. A standard term in a senior position is usually four years, so two full terms span eight years. A CEO must therefore be promoted before age 55 ($63 - 2 \times 4 = 55$) to complete both terms; beyond this age, the prospect of further meaningful promotion effectively disappears.

category:

$$
\begin{aligned}
Patent^{S}_{s,t+1} = {} & \beta_1 \, \Delta Revenue^{C}_{s,c,t-2\to t} + \beta_2 \, \Delta Revenue^{C}_{s,c,t-2\to t} \times YoungCEO^{C}_{s,c,t} \\
& + \beta_3 \, \Delta Revenue^{C}_{s,c,t-2\to t} \times OldCEO^{C}_{s,c,t} + \beta_4 \, YoungCEO^{C}_{s,c,t} \\
& + \gamma_1 \, Controls^{S}_{s,t} + \gamma_2 \, Controls^{C}_{c,t} + \epsilon_{s,c,t}
\end{aligned}
\tag{7}
$$

The baseline coefficient on $\Delta Revenue^{C}$ (0.307, significant at 1%) captures the effect among other Chinese customers and likely reflects national planning's influence on typical downstream firms, independent of the 5M6S political-incentive channel. The interaction with $OldCEO^{C}$ (1.448, significant at 5%) indicates that, for 5M6S managed by CEOs close to retirement, the incremental demand-pull is roughly five times the baseline. The interaction with $YoungCEO^{C}$ (4.812) is substantially larger still—about 3.3 times the $OldCEO^{C}$ coefficient. Combining the baseline and the $YoungCEO^{C}$ interaction, the total demand-pull coefficient for young-CEO 5M6S is $0.307 + 4.812 = 5.119$, roughly 17 times the baseline for other Chinese customers.

Together, these patterns show that the political-incentive channel operates incrementally on top of the baseline influence of national planning: stronger career incentives among SOE managers translate into more credible demand signals and a sharper innovation response among their suppliers.

These results are consistent with the framework of Aghion et al. (2025): non-Chinese firms lack the downstream coordination mechanism necessary to escape the low-greenification equilibrium, which explains why the demand channel remains inactive outside China. Under China's hybrid system, national planning combined with the political incentives of SOE managers serves as a coordination device that steers the economy toward a high-greenification equilibrium.

4.4 Quasi-natural Policy Experiment

We complement the cross-sectional results in Sections 4.1–4.3 with quasi-experimental evidence to identify the causal effect of downstream demand on upstream innovation. A natural concern with the baseline is sorting: high-growth Chinese customers may match with more innovative suppliers for reasons unrelated to the demand-pull mechanism. To address this, we exploit the 2022 clearance of accumulated arrears under China's feed-in-tariff (FIT) program—a one-time, largely unanticipated cash-flow shock to FIT-eligible customers—and trace its propagation upstream to suppliers' patenting.

As discussed in Section 2.1, FIT subsidies apply to Chinese firms operating solar or wind power plants. Because firm-level FIT amounts are not publicly disclosed, we estimate each firm's subsidy receivable from plant-level data in Global Energy Monitor (GEM). For each plant k in region c commissioned in year t_0, the annual subsidy is:

$$FIT_Subsidy_{k,t} = \left(FIT_rate_{c,t_0} - CoalPrice_t\right) \times OperatingHours_{k,t} \times Capacity_k, \quad (8)$$

where FIT_rate_{c,t_0} is the benchmark tariff at commissioning, $CoalPrice_t$ the benchmark coal-fired electricity price, and $OperatingHours_{k,t}$ annual plant utilization.[15]

China financed FIT subsidies through a renewable energy surcharge on electricity consumption, but surcharge revenues fell persistently short of subsidy obligations.[16] Figure 6 plots the national-level FIT subsidy payable (aggregated from plant-level estimates) alongside actual FIT-related fiscal expenditures; in 2021, the latter covered only 51% of the former. Starting in 2022, the Ministry of Finance began disbursing the accumulated arrears through

[15] We hold FIT_rate_{c,t_0} fixed over each plant's lifecycle because policy adjustments only apply to newly commissioned projects. FIT rates by region and resource tier are from NDRC policy documents; operating hours are from the National Energy Administration. We aggregate plant-level subsidies to the firm level by matching plant owners to firms in our sample.

[16] The NPC's "Inspection of the Implementation of the Renewable Energy Law" reports that during 2016–2020, funding had not been secured for more than 90% of newly added renewable energy generation projects; see http://www.npc.gov.cn/npc/c2/c30834/201912/t20191224_303904.html. Jinko Power separately disclosed that nearly 95% of its accounts receivable consisted of overdue FIT subsidy payments; see https://stock.10jqka.com.cn/20241104/c663161493.shtml.

special-purpose central government funds, generating a substantial and largely unanticipated cash-flow improvement for FIT-eligible firms.[17]

We exploit this shock in a difference-in-differences framework. Treated customers are Chinese firms that operated solar or wind plants before 2020 and were therefore FIT-eligible and likely to receive lump-sum disbursements in 2022; controls are Chinese customers that did not operate such plants before 2020.[18]

We first verify the empirical premise that the shock indeed increased treated customers' cash flow and investment by estimating:

$$OCF^{C}_{c,t} = \beta_1 \, Treat^{C} \times Post_t + \gamma_1 \, Controls^{S}_{s,t} + \gamma_2 \, Controls^{C}_{c,t} + \epsilon_{s,c,t} \tag{9}$$

$$CapEx^{C}_{c,t+1} = \beta_1 \, Treat^{C} \times Post_t + \gamma_1 \, Controls^{S}_{s,t} + \gamma_2 \, Controls^{C}_{c,t} + \epsilon_{s,c,t+1} \tag{10}$$

where $Treat^{C}$ equals 1 if the firm is FIT-eligible, $Post$ equals 1 for 2022 and after, and controls include the characteristics of both customer and supplier, such as $\ln(Asset)$, ROA, $CapEx$, and $Tangibility$. Columns (1)–(2) of Table 7 show that the shock significantly raises treated customers' operating cash flow contemporaneously and their capital expenditure in the following year, confirming that the disbursement translated into expanded downstream procurement capacity.

We then estimate the effect on supplier patenting:

$$Patent^{S}_{s,t+1} = \beta_1 \, Treat^{C} \times Post_t + \gamma_1 \, Controls^{S}_{s,t} + \gamma_2 \, Controls^{C}_{c,t} + \epsilon_{s,c,t+1} \tag{11}$$

[17] See https://sgnec.sgcc.com.cn/home/newsenergydetail?newsId=2207150404300032986. As one example, Longyuan Power disclosed receiving RMB 11.4 billion in the first half of 2022 from the RMB 100 billion tranche of disbursed arrears; see https://news.qq.com/rain/a/20231226A073YQ00.

[18] We do not observe each firm's actual accumulated arrears, so we use FIT eligibility as a proxy for likely disbursement. Because eligibility is defined by asset holdings rather than corporate structure, the treatment cuts across the 5M6S/non-5M6S distinction in Section 4.3: the treated set includes not only the 5M6S but also other electricity generators with eligible renewable assets, while the control set spans both electricity firms without such assets and customers in other industries. The identification therefore exploits time-series rather than cross-sectional variation in political incentives.

Columns (3)–(5) of Table 7 show that $Treat^C \times Post_t$ is significantly positive across specifications: suppliers of treated customers experience a 32.2% ($e^{0.279} - 1$) increase in patent filings in the year following the shock. Figure 7 verifies the parallel-trend assumption, with the coefficients on $Treat^C \times$ year dummies statistically insignificant for all pre-2022 years.

4.5 Role of government subsidies

Government subsidies are widely viewed as a central driver of China's renewable energy expansion (e.g., Helveston and Nahm, 2019; Auffhammer et al., 2021; Dong, Zhou and Li, 2021). Whether they translate into firm-level innovation is less clear: economists have long warned that industrial policies can be undercut by information asymmetries between governments and firms (Hayek, 1945; Kornai, 1980; Noman and Stiglitz, 2016). We examine the effectiveness of subsidies directly within our supply-chain framework.

Publicly listed Chinese A-share firms must disclose government subsidies received in their annual statements. We construct $Subsidy^S$ and $Subsidy^C$ as total subsidies scaled by revenue for suppliers and customers, respectively, restrict the sample to supplier–customer pairs in which both sides are listed in China, and estimate the following Poisson model with fixed effects:

$$\begin{aligned} Patent^S_{s,t+1} = {} & \beta_1 \, \Delta Revenue^C_{s,c,t-2\to t} + \beta_2 \, \Delta Revenue^C_{s,c,t-2\to t} \times HighSubsidy^C_{s,c,t} \\ & + \beta_3 \, HighSubsidy^C_{s,c,t} + \beta_4 \, Subsidy^S_{s,c,t} + \gamma_1 \, Controls^S_{s,t} \\ & + \gamma_2 \, Controls^C_{c,t} + \epsilon_{s,c,t+1} \end{aligned} \tag{12}$$

where $HighSubsidy^C$ equals one if $Subsidy^C$ is above the year median; Columns (3)–(4) of Table 8 replace it with the continuous $Subsidy^C$, and Columns (2) and (4) additionally include $Industry^S \times Year$ and $Industry^C \times Year$ fixed effects to absorb industry-level subsidy heterogeneity. The interaction—$\Delta Revenue^C \times HighSubsidy^C$ in the dummy specifications and $\Delta Revenue^C \times Subsidy^C$ in the continuous ones—is significantly positive across all four

columns, whereas the standalone coefficients on $HighSubsidy^C$ are not. Across all specifications, the coefficient on direct subsidies to suppliers ($Subsidy^S$) is also insignificant. Subsidies thus do not, by themselves, stimulate upstream innovation; they amplify the demand-pull effect only when channeled to fast-growing downstream customers.

This pattern is consistent with an information-asymmetry interpretation: governments cannot directly identify which upstream firms will convert subsidies into innovation, but fast-growing downstream customers can, and their procurement decisions transmit a credible signal that subsidies amplify. The result echoes Aghion et al. (2025)'s argument that subsidizing the downstream sector is more effective than subsidizing the upstream.

4.6 Overcapacity

Overcapacity has been a central concern in discussions of China's renewable energy industry (e.g., Yellen, 2024). When upstream manufacturers base production and investment decisions on anticipated future demand, downstream demand shocks propagate and can be amplified along the supply chain (Leng et al., 2025); economies of scale further reward suppliers for expanding capacity. The same demand-pull that drives innovation may therefore also drive over-investment and over-production.

We examine this by replacing supplier patenting in Equations (1) and (2) with supplier overcapacity, $OverCapacity^S_{s,t\to t+K}$, averaged over horizons $K \in \{1,2,3\}$:

$$OverCapacity^S_{s,t\to t+K} = \beta_1\, \Delta Revenue^C_{s,c,t-2\to t} + \gamma_1\, Controls^S_{s,t} + \gamma_2\, Controls^C_{c,t} + \epsilon_{s,c,t+1} \tag{13}$$

$$\begin{aligned} OverCapacity^S_{s,t\to t+K} = {} & \beta_1\, \Delta Revenue^C_{s,c,t-2\to t} + \beta_2\, \Delta Revenue^C_{s,c,t-2\to t} \times isCN^C_{s,c} \\ & + \gamma_1\, Controls^S_{s,t} + \gamma_2\, Controls^C_{c,t} + \epsilon_{s,c,t+1} \end{aligned} \tag{14}$$

We use two proxies for $OverCapacity$: $\Delta Inventory$, the annual change in inventory scaled by COGS; and ΔPPE, investment in property, plant, and equipment scaled by total assets.

Table 9 reports the $\Delta Inventory$ results. Panel A estimates Equation (13) separately

for Chinese and non-Chinese customers: the coefficient on $\Delta Revenue^{C}_{t-2\to t}$ is positive and significant across all three horizons for Chinese customers but small and insignificant for non-Chinese ones. Panel B confirms the gap on the full sample: the interaction $\Delta Revenue^{C} \times isCN^{C}$ in Equation (14) is significantly positive at $k = 1$.

Table 10 reports the ΔPPE results, following the same panel structure. For Chinese customers, the coefficient is positive and becomes significant at the 5% level from $k = 2$ onward; for non-Chinese customers, it remains small and insignificant. The interaction $\Delta Revenue^{C} \times isCN^{C}$ is positive and significant for $k = 2$ and $k = 3$.

Together, these results show that the demand-pull from Chinese customers translates not only into upstream patenting but also into persistent inventory build-up and fixed capital investment over the following years—suggesting that overcapacity is a natural byproduct of China's state-driven approach to developing its renewable energy industry.

5 Conclusion

China has transformed within a single decade from one of the world's most heavily polluted countries into the dominant global force in the manufacturing and innovation of renewable energy technologies. This paper examines the institutional mechanisms behind this transformation. We argue that China's hybrid economic system—in which state-owned enterprises dominate the downstream electricity segment while private, competitive firms drive upstream equipment manufacturing—generates an unusually effective demand-pull channel for green innovation. National renewable energy targets set in successive Five-Year Plans, enforced through career incentives for state-owned power group managers, create strong, credible, and persistent downstream demand that stimulates innovation among upstream suppliers.

Using global supplier–customer pair data, we first establish the demand-pull mechanism empirically. A one-standard-deviation increase in Chinese customers' three-year average revenue growth is associated with a 12.0% increase in supplier patent filings in the subsequent

year. This effect holds for both domestic and foreign suppliers serving Chinese customers, but is absent for suppliers of non-Chinese customers.

Then, we document the managerial incentive mechanism at the heart of this system. Using data on career movements of executives of the 5M6S power groups, we show that the leaders with stronger renewable energy installation achievements are significantly more likely to be promoted to senior positions, controlling for financial performance. This relationship has strengthened over time as SASAC has progressively built sustainable development into the central-SOE performance evaluation framework, culminating in the 2021 policy that explicitly incorporated the "dual-carbon" goals. These tournament-style incentives align managerial career concerns with national sustainability goals and—critically—make downstream demand commitments credible and predictable to upstream suppliers.

Further, we find that the demand-pull effect is substantially stronger for pairs with the 5M6S as customers—approximately 73% per one-standard-deviation revenue growth, compared with about 10% for other Chinese customers—and stronger still for 5M6S managed by CEOs with longer remaining promotion horizons.

To establish causality, we exploit the Chinese government's 2022 clearance of accumulated FIT subsidy arrears as a quasi-natural experiment: suppliers serving treated electricity firms filed approximately 32.2% more patents following the cash-flow shock.

We also examine the role of government subsidies in driving supply-chain innovation. Direct subsidies to suppliers, or to average downstream customers, have no significant association with upstream patenting—consistent with the view that governments face information frictions in identifying productive innovators. In contrast, subsidies directed to fast-growing downstream customers effectively stimulate upstream innovation.

Finally, we show that the same institutional forces driving innovation also generate overcapacity. Following periods of strong Chinese customer revenue growth, suppliers accumulate excess inventory and expand fixed capital investment over one-to-three-year horizons. These effects are absent for suppliers of non-Chinese customers. Our findings suggest that over-

capacity in China's renewable energy sector is not a separate policy failure but an inherent byproduct of the same institutional mechanism that drives innovation.

Our findings offer broader insights for the economics of green transition. Standard policy prescriptions—carbon pricing, direct subsidies, sustainable investment mandates—are facing challenges. China's unique approach largely sidesteps these by using the career incentive structure of its electricity sector to generate credible, large-scale downstream demand, effectively delegating the innovation decision to competitive upstream markets while anchoring long-run demand expectations through national planning.

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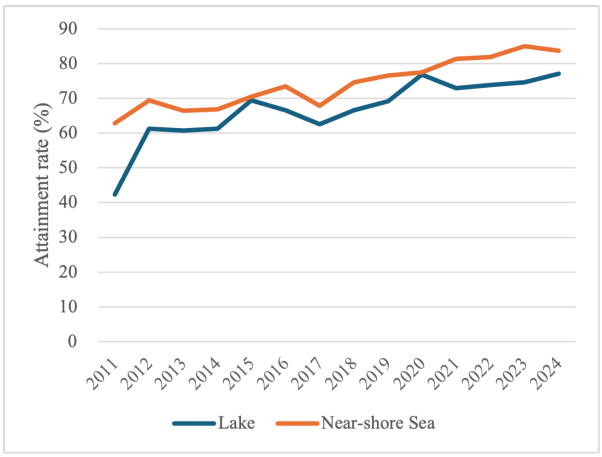
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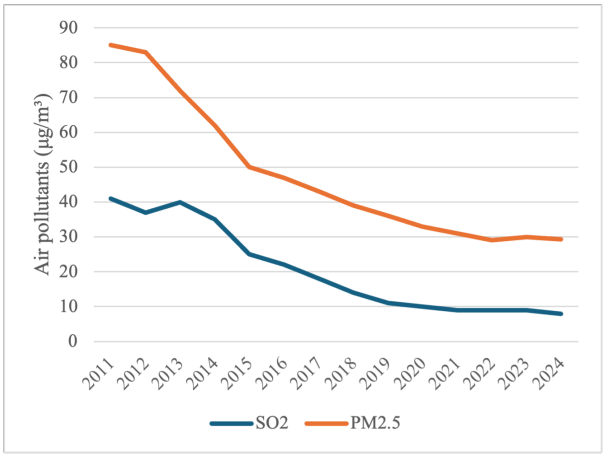
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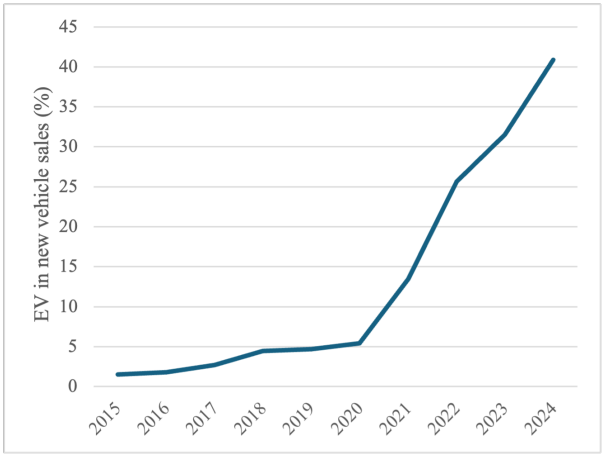
Figure 1: Trends of China's Green Transition



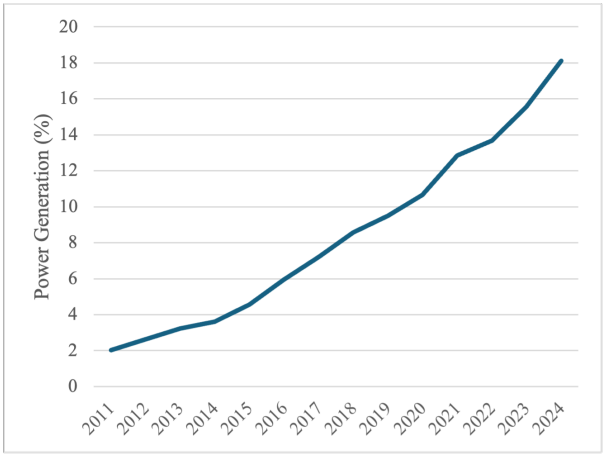
(a) Water Quality



(b) Air Pollutants



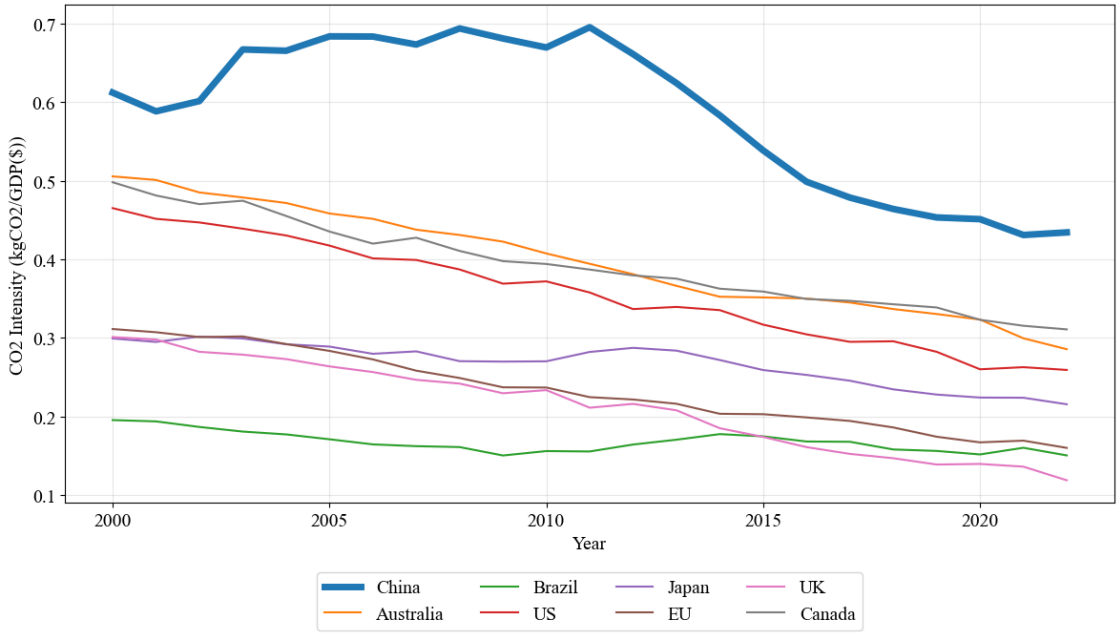
(c) EV Market Share



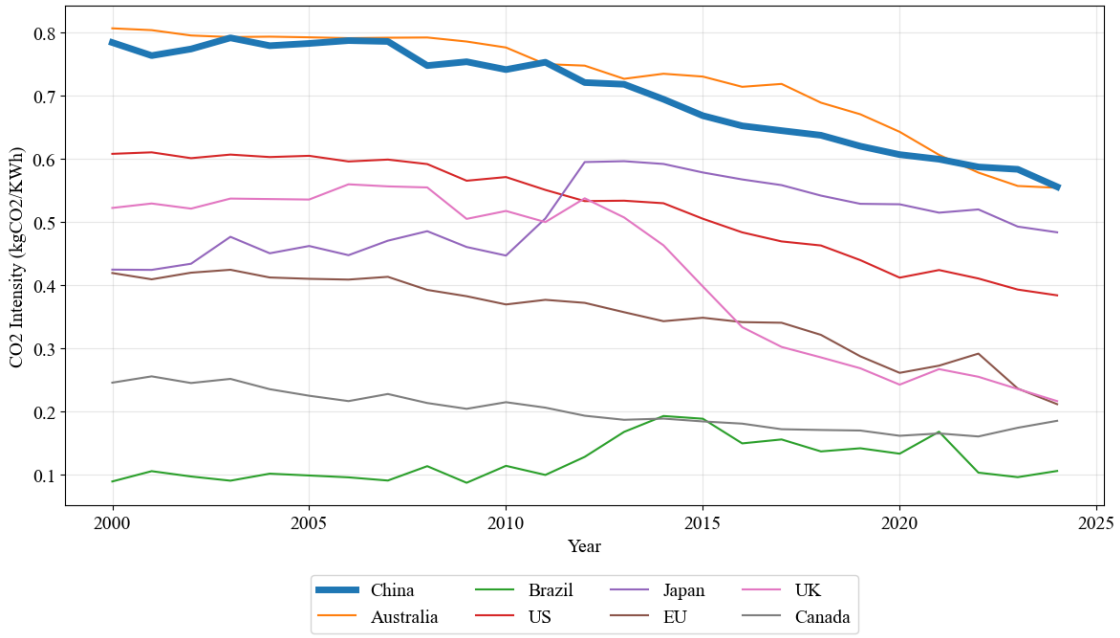
(d) Renewable Energy Adoption

Notes: This figure presents environment related indicators for China from 2011 to 2024. Panel A reports measures of water quality, including the attainment rate of lake and near-shore sea water quality (Near-shore Sea); Panel B reports measures of air quality, including average intensity of SO_2 and $PM_{2.5}$. Panel C reports the share of new energy vehicles in total new vehicle; Panel D reports the share of non-hydropower renewable energy in total electricity generation. Detailed source of these data is shown in Appendix A.1.

Figure 2: Carbon Intensity



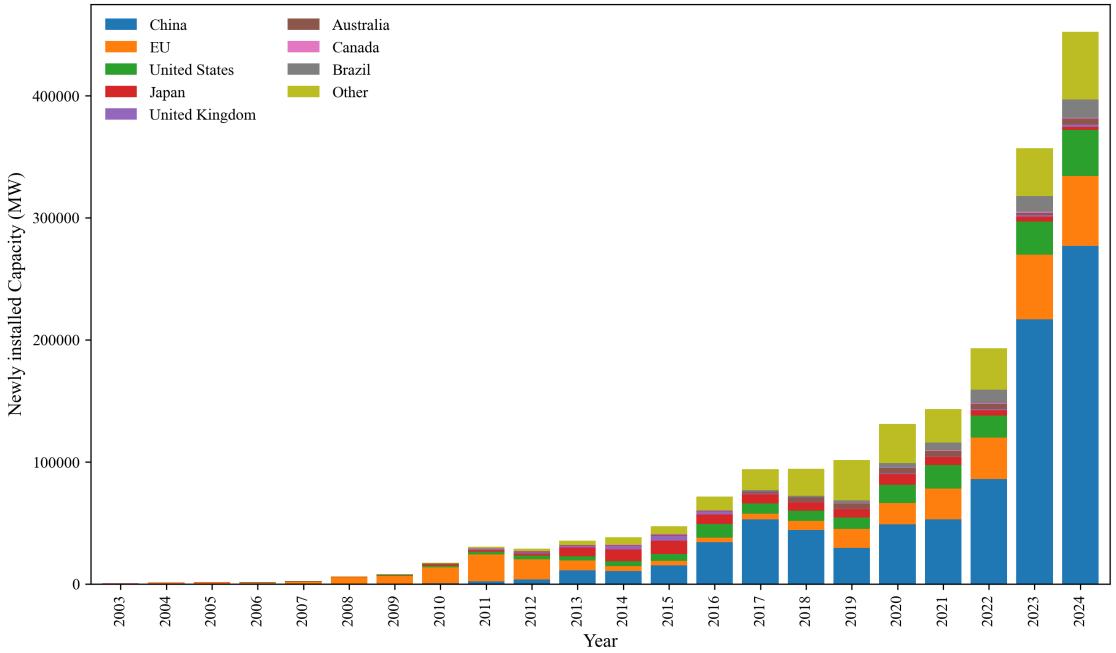
(a) Carbon Intensity of GDP



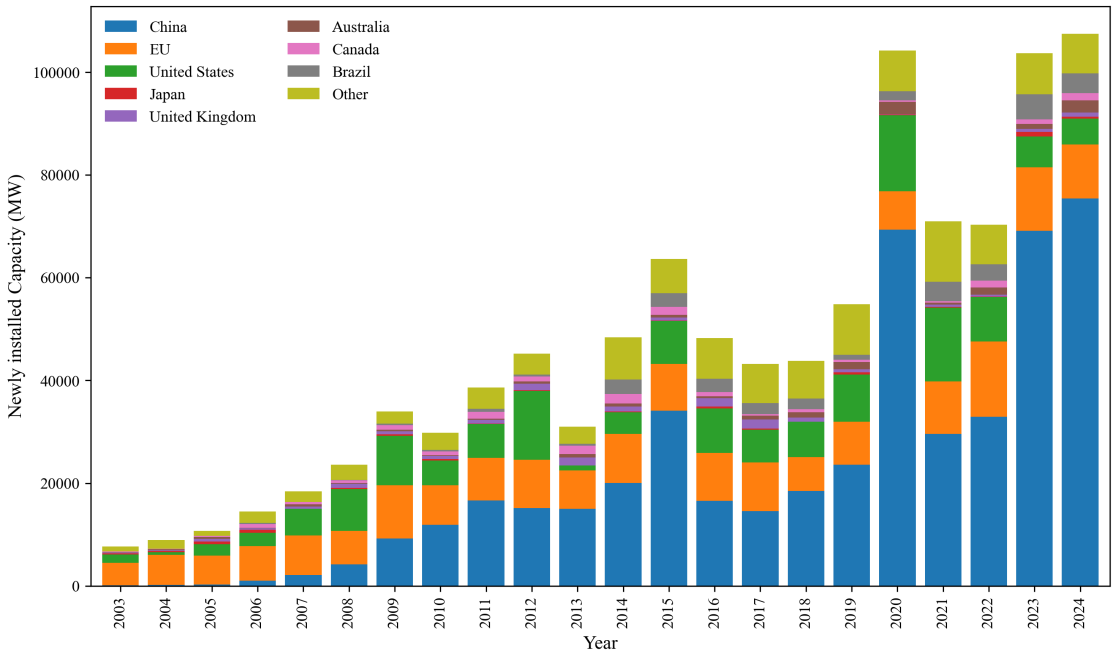
(b) Carbon Intensity of Power Generation

Notes: This figure shows carbon intensity in GDP (Panel A) and power generation (Panel B) for each country from 2000 to 2024. Data is collected from Our World in Data.

Figure 3: Newly Built Renewable Energy Capacity



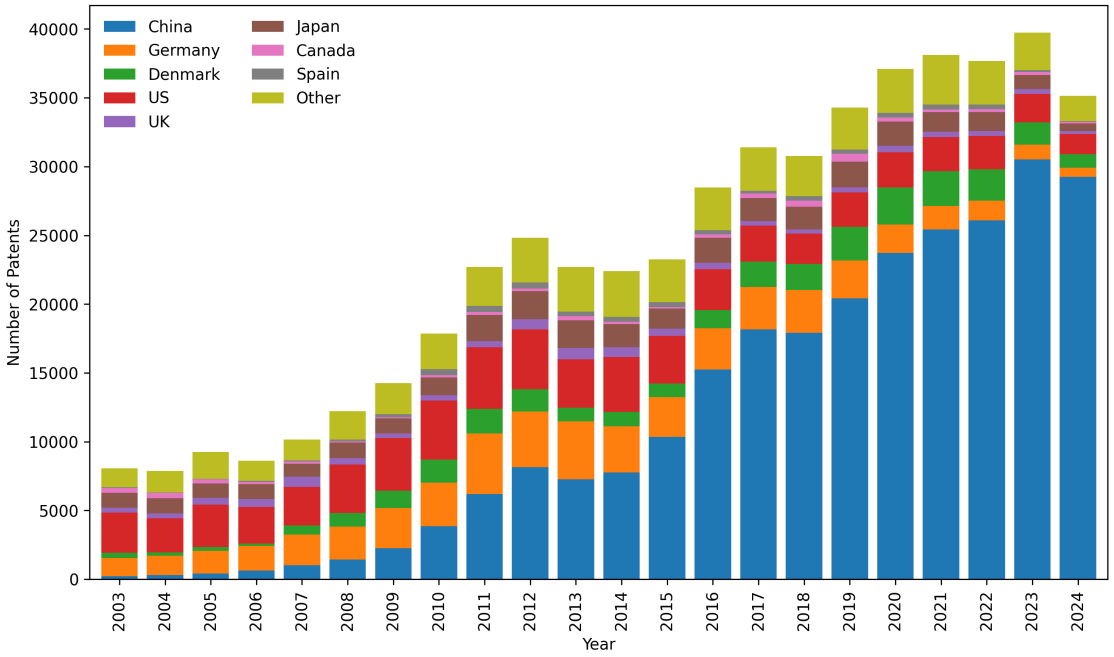
(a) Solar PV



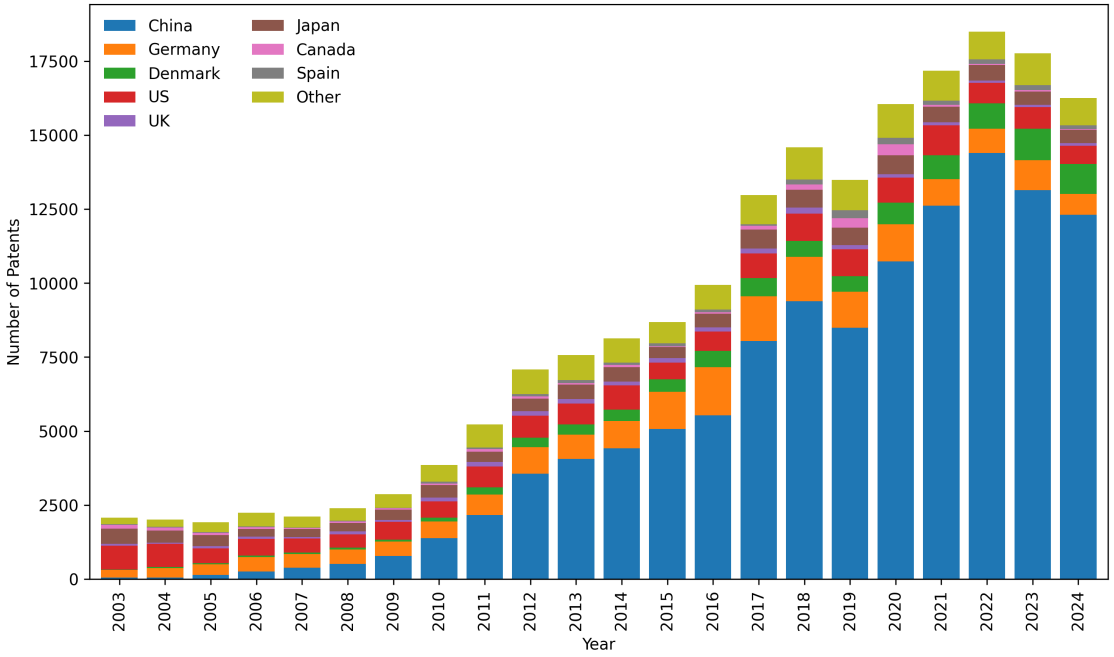
(b) Wind Energy

Notes: This figure shows the newly built renewable energy capacity, including solar PV installation (Panel A) and wind energy installation (Panel B) for each country from 2003 to 2024. Data is collected from IRENA.

Figure 4: Renewable Energy Equipment Firms' Patent Application



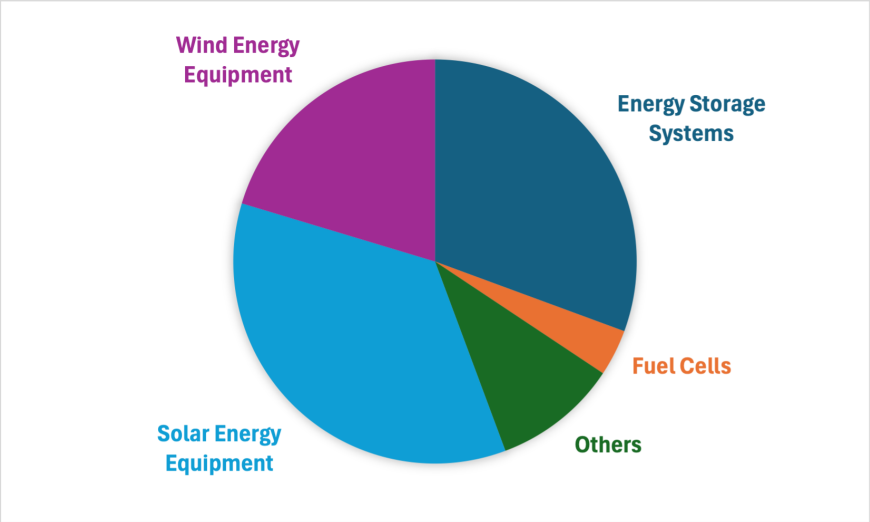
(a) Patents Applied



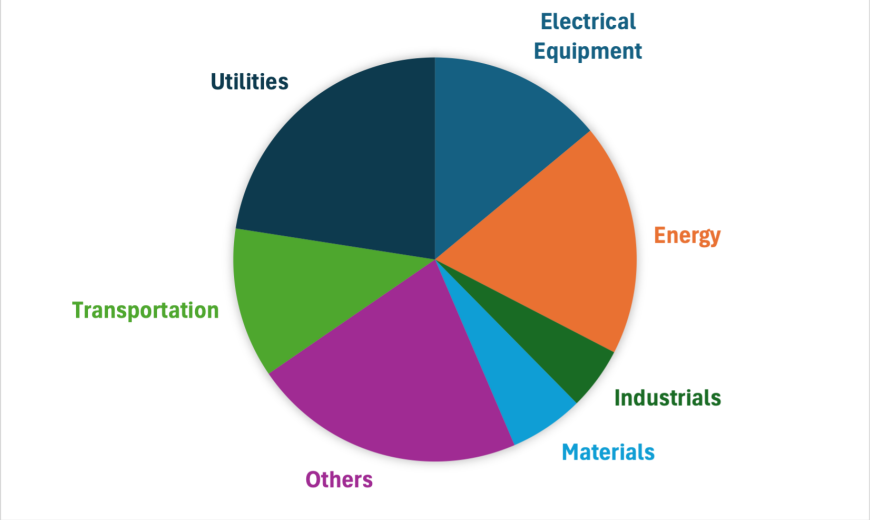
(b) Patents Granted

Notes: This figure shows the number of patents filed (Panel A) and granted (Panel B) by firms in BICS sub-industry *Renewable Energy Equipment* for each country.

Figure 5: Industry Distribution of Suppliers and Customers



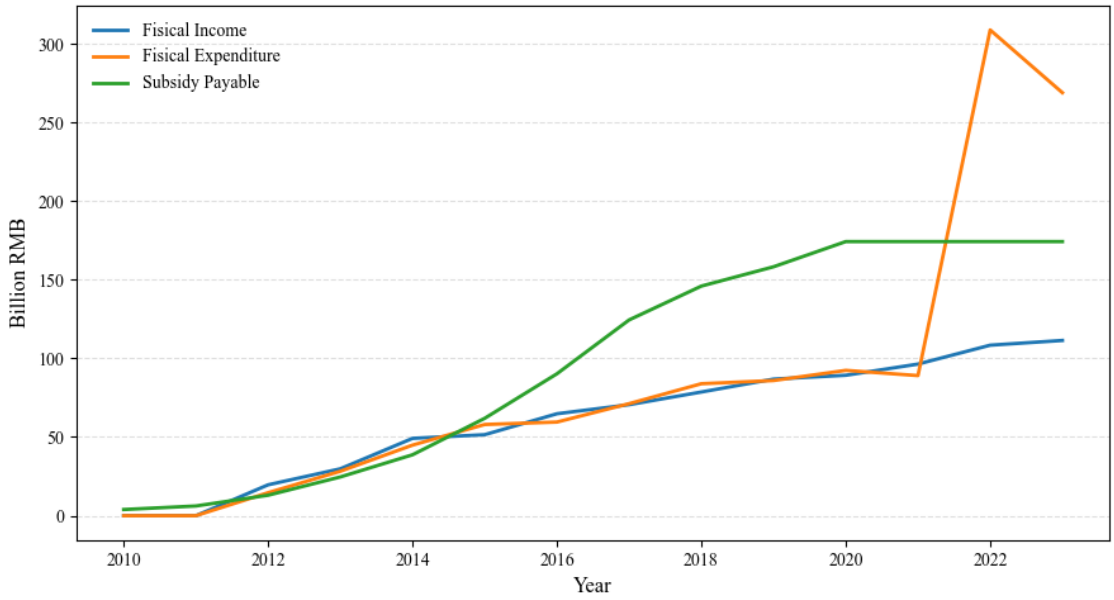
(a) Supplier industry



(b) Customer industry

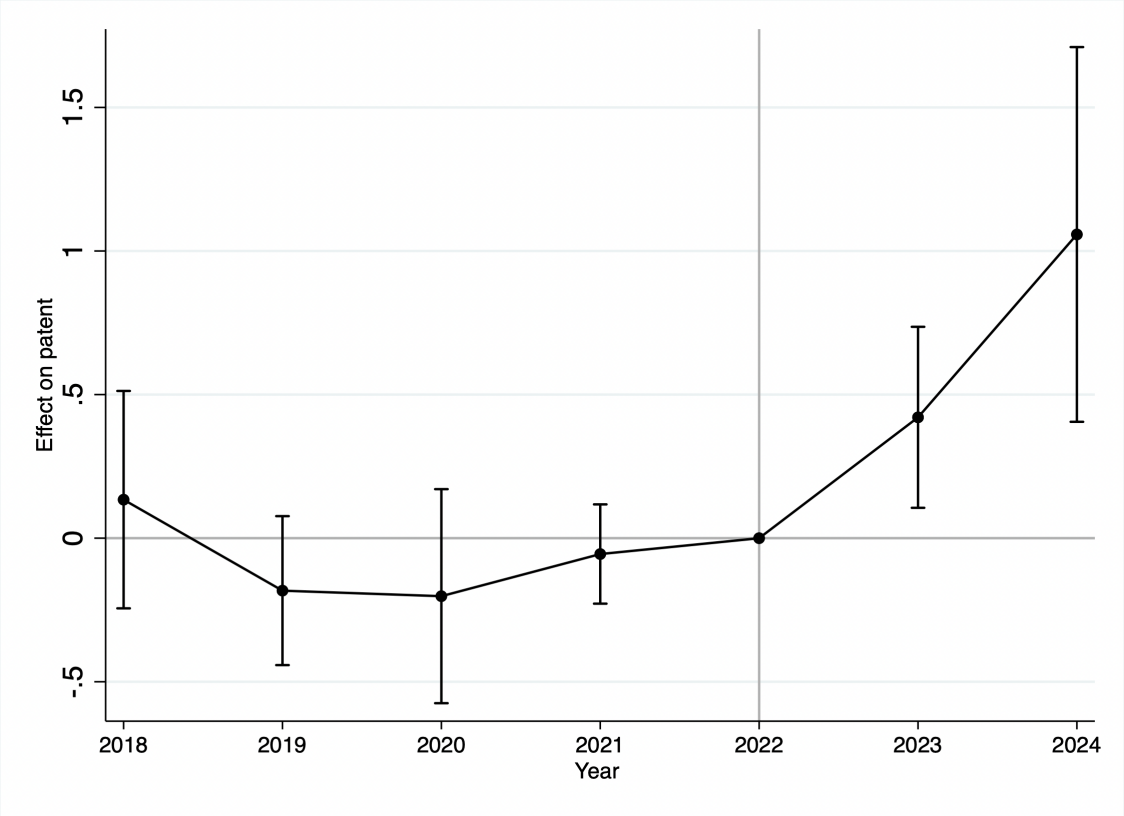
Notes: This figure shows the industry distribution of customer and supplier under the BICS industry classification.

Figure 6: China's FIT Subsidy Arrear and Clearance



Notes: This figure demonstrate FIT subsidy arrear and clearance in China by showing the difference between FIT subsidy payable and the actual fiscal expenditure for this type of subsidy.

Figure 7: Placebo Test of Subsidy Shock



Notes: This figure test the parallel trend after 2018 by estimating the Poisson equation :

$$Patent_{i,t+1} = \sum_{\tau=2018, \tau \neq 2021}^{2022} \beta_\tau (Treat_i^C \times Year_\tau) + Pair_{s,c} + \delta_t + \varepsilon_{c,s,t}$$

We plots the estimated coefficients β_τ along with their 95% confidence intervals.

Table 1: China's Five-Year Plan on Energy Transition

This table presents the energy transition target outlined in China's Five-Year Plans and the actual achievements. [19]

	Planning Period					
	2011–2015		2016–2020		2021–2025	
	Target	Actual	Target	Actual	Target	Actual
Total installed capacity (GW)						
Solar PV	21	43.2	110	250	650	1200
Wind	100	130.8	210	280	450	600
Energy consumption structure (%)						
Non Fossil	11.4	12	15	15.8	20	21.5
Coal	65	64	58	56.8	/	53.2*

[19] Data on coal energy consumption shares are as of 2024.

Table 2: Summary Statistics

This table shows summary statistics. We report the *Patent* (patent filed each year), *EnvPatent* (environment-related patent filed each year), for the supplier. We also report the $\Delta Revenue$ (growth rate of total revenue), $R\&D$ (R&D expenditure scaled by total revenue), $\ln(Asset)$ (natural logarithm of total assets), ROA (net income divided by total assets), $CapEx$ (capital expenditures scaled by total assets), and $Tangibility$ (property, plant, and equipment divided by total assets) for both supplier (with superscript S) and customer (with superscript C)

	N	Mean	sd	p1	p25	p50	p75	p99
	Panel A: Statistics for the Global Customer-Supplier Pairs							
$Patent^S$	8998	206.839	341.262	0.000	7.000	40.000	204.000	1312.000
$EnvPatent^S$	8998	202.802	335.332	0.000	7.000	39.000	195.000	1251.000
$\Delta Revenue^C$	8998	0.131	0.302	-0.353	-0.016	0.060	0.188	1.448
$\Delta Revenue^S$	8998	0.207	0.413	-0.414	-0.015	0.120	0.320	1.905
$\ln(Asset)^C$	8998	23.144	2.090	18.713	21.571	23.320	24.705	27.049
$CapEX^C$	8998	0.051	0.046	0.000	0.018	0.041	0.070	0.233
$Tangibility^C$	8998	0.606	0.410	0.000	0.269	0.557	0.889	2.021
ROA_C	8998	0.027	0.059	-0.212	0.003	0.025	0.050	0.220
$Patent^C$	8998	1201.073	3531.352	0.000	0.000	21.000	378.000	18062.000
$\ln(Asset)^S$	8998	21.266	2.139	16.453	19.686	21.481	22.685	26.251
$CapEX^S$	8998	0.047	0.051	0.000	0.010	0.033	0.065	0.241
$Tangibility^S$	8998	0.375	0.257	0.018	0.179	0.309	0.501	1.229
ROA_S	8998	-0.032	0.152	-0.892	-0.027	0.000	0.033	0.168
$R\&D^S$	8998	0.097	0.334	0.000	0.009	0.027	0.062	1.839
	Panel B: Statistics for SOE Energy Group in China							
$Promotion$	107	0.121	0.328	0.000	0.000	0.000	0.000	1.000
$RenewAdp$	107	0.023	0.016	0.001	0.010	0.021	0.033	0.063
$ln(Asset)$	107	25.540	0.628	23.751	25.330	25.553	25.966	26.660
ROE	107	0.064	0.033	-0.001	0.039	0.069	0.081	0.135
$\Delta Revenue$	96	0.083	0.116	-0.165	0.018	0.068	0.126	0.737
$GrossMargin(\%)$	107	0.274	0.105	0.104	0.204	0.253	0.327	0.536

Table 3: Main Result: Demand-pull Innovation among Suppliers

This table presents the results of the fixed effect Poisson regression model. Panel A reports the results of Equation (1) for samples with Chinese and non-Chinese customers separately, further distinguishing between Chinese suppliers ($isCN^S = 1$) in Column (3) and non-Chinese suppliers ($isCN^S = 0$) in Column (4). Panel B reports the results of Equation (2) for the full sample. The dependent variable $Patent$ is the number of patent filed by the supplier. $\Delta Revenue^C_{t-2\to t}$ is the average revenue growth of customer in the past 3 years. $isCN^C$ is a dummy variable distinguishing whether the customer is a Chinese firm. Throughout the paper, control variables on the supplier side includes $\Delta Revenue^S_{t-2\to t}$, $R\&D^S$, $\ln(Asset^S)$, ROA^S, $CapEx^S$, and $Tangibility^S$); control variables on the customer side includes $\ln(Asset^C)$, ROA^C, $CapEx^C$ and $Tangibility^C$. We also control for $\ln(Patent^C)$ when the dependent variable is $Patent$. t-stats in parentheses are calculated using standard errors clustered at the customer-supplier pair level.

Panel A

	$Patent_{t+1}$						
	Chinese Customer				Non-Chinese Customer		
	All sample		$isCN^S = 1$	$isCN^S = 0$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta Revenue^C_{t-2\to t}$	0.351***	0.376***	0.445***	0.281**	-0.052	-0.086	-0.086**
	(3.465)	(3.465)	(3.440)	(2.067)	(-1.108)	(-1.473)	(-2.024)
$\Delta Revenue^S_{t-2\to t}$	-0.000	-0.003	-0.026	0.128	-0.099	-0.142**	0.016
	(-0.001)	(-0.015)	(-0.139)	(0.511)	(-1.314)	(-2.058)	(0.225)
Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	Yes	No	No
$Country^C \times Year$ FE	-	-	-	-	No	Yes	Yes
$Country^S \times Year$ FE	No	Yes	No	No	No	No	Yes
Supplier Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1071	1027	818	252	7923	7440	7369
Pseudo R-square	0.948	0.953	0.943	0.975	0.953	0.960	0.973

Table 3: Main Result: Demand-pull Innovation among Suppliers (Continued)

Panel B

	$Patent_{t+1}$		
	(1)	(2)	(3)
$\Delta Revenue^{C}_{t-2\to t}$	-0.047	-0.074	-0.077*
	(-1.011)	(-1.276)	(-1.751)
$\Delta Revenue^{C}_{t-2\to} \times isCN^{C}$	0.261**	0.336***	0.284***
	(2.331)	(2.949)	(2.586)
$\Delta Revenue^{S}_{t-2\to t}$	-0.075	-0.088	0.061
	(-1.019)	(-1.218)	(0.673)
Pair FE	Yes	Yes	Yes
Year FE	Yes	No	No
$Country^{C} \times Year$ FE	No	Yes	Yes
$Country^{S} \times Year$ FE	No	No	Yes
Supplier Controls	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes
Observations	8998	8511	8444
Pseudo R-square	0.952	0.958	0.970

Table 4: Newly Installed Renewable Capacity and Demand-pull Innovation

This table presents the results of the robustness test of the main result using *RenewAdp* to proxy customer's demand for renewable energy equipment, where *RenewAdp* is the newly installed renewable energy capacity in the recent 3 years scaled by total assets. We restrict the sample to pairs where wind and solar energy equipment firms serve as the suppliers. t-stats in parentheses are calculated using standard errors clustered at the customer-supplier pair level.

	$Patent_{t+1}$					
	Chinese Customer		Non-Chinese Customer		Full Sample	
	(1)	(2)	(3)	(4)	(5)	(6)
$RenewAdp^{C}_{t-2\to t}$	2.683**	2.273**	0.038	0.042	0.030	0.036
	(2.260)	(2.012)	(0.443)	(1.174)	(0.346)	(0.994)
$RenewAdp^{C}_{t-2\to t} \times isCN^{C}$					2.633*	2.178*
					(1.928)	(1.729)
$\Delta Revenue^{S}_{t-2\to t}$	-0.067	-0.063	-0.093	0.020	-0.081	0.044
	(-0.368)	(-0.339)	(-1.189)	(0.264)	(-1.079)	(0.508)
Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No	Yes	No
$Country^{C} \times Year$ FE	-	-	No	Yes	No	Yes
$Country^{S} \times Year$ FE	No	Yes	No	Yes	No	Yes
Supplier Controls	Yes	Yes	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1071	1027	7923	7369	8998	8444
Pseudo R-square	0.948	0.952	0.953	0.973	0.952	0.970

Table 5: Executive Promotion for SOE Managers

This table examines how renewable energy adoption affects the probability of executive promotion among 11 central state owned energy corporation, using logit models with year fixed effects as specified in Equation (3) and Equation (4). The dependent variable, $Promotion_{t \to t+k}$, is a dummy equal to one if either the CEO or the board chair is promoted during this period. $RenewAdp$ is measured as newly installed renewable energy capacity scaled by total assets. t is a time trend variable. Control variables include firm size ($\ln(Asset)$), return on equity (ROE), revenue growth (RG), and gross margin ($GrossMargin$). t-stats in parentheses are calculated using robust standard errors.

	$Promotion_{t+1}$		$Promotion_{t+1 \to t+2}$		$Promotion_{t+1 \to t+3}$	
	(1)	(2)	(3)	(4)	(5)	(6)
$RenewAdp_std_t$	0.944*	-0.861	0.681**	0.027	1.278***	1.741***
	(1.665)	(-0.898)	(2.277)	(0.061)	(4.516)	(2.590)
$RenewAdp_std_t \times t_t$		0.403*		0.172*		-0.107
		(1.849)		(1.721)		(-0.770)
Year Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Observations	64	64	96	96	96	96
Pseudo R-square	0.204	0.254	0.200	0.221	0.250	0.254

Table 6: Political Incentive and Demand-pull Innovation

This table presents the results of Equation (5), (6) and (7). $5M6S^C$ is a dummy variable distinguishing whether the customer belongs to the eleven "five major and six secondary" power groups (5M6S). $Years_to_Retire$ is the years to retirement of the CEO for customers with $5M6S^C = 1$ and zero otherwise. $YoungCEO$ is a dummy variable equal to one if customers with $5M6S^C = 1$ are managed by a CEO no older than 55; $OldCEO$ is a dummy variable equal to one if customers with $5M6S^C = 1$ are managed by a CEO older than 55. t-stats in parentheses are calculated using standard errors clustered at the customer-supplier pair level.[20]

Panel A

	$Patent_{t+1}$			
	(1)	(2)	(3)	(4)
$\Delta Revenue^C_{t-2\to t}$	0.304***	0.330***	-0.291	-0.656
	(3.081)	(3.012)	(-0.193)	(-0.419)
$\Delta Revenue^C_{t-2\to t} \times 5M6S^C$	1.511**	1.312**	1.668**	1.521**
	(2.300)	(1.990)	(2.511)	(2.289)
$\Delta Revenue^S_{t-2\to t}$	-0.067	-0.058	-0.073	-0.045
	(-0.364)	(-0.305)	(-0.408)	(-0.243)
Pair FE	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No
$Country^S \times Year$ FE	No	Yes	No	Yes
Supplier Controls	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes
$Control^C \times \Delta Revenue^C_{t-2\to t}$	No	No	Yes	Yes
Observations	1071	1027	1071	1027
Pseudo R-square	0.949	0.954	0.950	0.954

[20] In Columns (1) to (2) of Panel B, the t-stats are calculated using robust standard errors due to the sample size.

Table 6: Political Incentive and Demand-pull Innovation (Continued)

Panel B

	$Patent_{t+1}$			
	5M6S Customer		China Customer	
	(1)	(2)	(3)	(4)
$\Delta Revenue^{C}_{t-2\to t}$	-2.669***	-0.601	0.290***	0.307***
	(-2.819)	(-1.361)	(2.861)	(3.075)
$\Delta Revenue^{C}_{t-2\to t} \times Years_to_Retire$	0.419***		0.282*	
	(3.655)		(1.923)	
$Years_to_Retire$	0.073***		0.067**	
	(3.118)		(2.070)	
$\Delta Revenue^{C}_{t-2\to t} \times YoungCEO$		3.003***		4.812*
		(4.614)		(1.732)
$\Delta Revenue^{C}_{t-2\to t} \times OldCEO$				1.448**
				(2.240)
$YoungCEO$		0.352***		0.305
		(4.602)		(1.540)
$\Delta Revenue^{S}_{t-2\to t}$	0.601***	0.647***	-0.068	-0.071
	(2.770)	(3.689)	(-0.383)	(-0.376)
Pair FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Supplier Controls	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes
Observations	113	113	1071	1071
Pseudo R-square	0.973	0.974	0.950	0.950

Table 7: Policy Experiment

This table presents results using the 2022 change in subsidy policy as an exogenous demand shock. Columns (1) and (2) report the regression results of Equation (9) and Equation (10), with the OCF^C (operating cash flow scaled by total asset) and $CapEx^C$ (capital expenditure scaled by total asset) as dependent variables respectively. Columns (3) to (5) report the results of the fixed-effect Poisson model in Equation (11). $Treat^C$ is a dummy variable equal to one if the firm is eligible to receive feed-in tariff subsidies from the Chinese government, and $Post$ equals one for years beginning from 2022. The sample is restricted to cases in which both the customer and the supplier are Chinese firms, and the supplier has at least one customer eligible for feed-in tariff subsidies. Customer side and supplier side control variables are provided in Table 3. t-stats in parentheses are calculated using standard errors clustered at the customer-supplier pair level.

	OCF_t^C	$CapEx_{t+1}^C$	$Patent_{t+1}$		
	(2)	(1)	(3)	(4)	(5)
$Treat^C \times Post_t$	0.030***	0.013*	0.631***	0.561***	0.279**
	(2.696)	(1.788)	(3.241)	(3.093)	(2.149)
Pair FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
$Industry^S \times Year$ FE	No	No	No	No	Yes
Supplier Controls	Yes	Yes	No	Yes	Yes
Customer Controls	Yes	Yes	No	Yes	Yes
Observations	579	579	579	579	569
Pseudo R^2	0.769	0.824	0.933	0.958	0.965

Table 8: Role of Government Subsidies

This table shows the result the Poisson regression model with fixed effect in Equation (12). The sample is restricted to cases in which both the customer and the supplier are Chinese firms. Customer's subsidy ratio ($Subsidy^C$) is the amount of government subsidy granted to that firm scaled by firms' total revenue. $HighSubsidy^C$ is a dummy equals to 1 if $Subsidy^C$ is above median in that year. In addition to firm characteristics from supplier side and customer side described in Table 3, we also control for $Subsidy^S$ (the supplier's subsidy ratio). $Industry^C$ is the BICS sector for customers, and $Industry^S$ is the BICS level-5 subindustry group. t-stats in parentheses are calculated using standard errors clustered at the customer-supplier pair level.

	$Patent_{t+1}$			
	(1)	(2)	(3)	(4)
$\Delta Revenue^C_{t-2\to t}$	0.045	0.029	0.149	0.078
	(0.374)	(0.235)	(1.412)	(0.929)
$HighSusidy^C$	-0.022	-0.054		
	(-0.394)	(-0.761)		
$\Delta Revenue^C_{t-2\to t} \times HighSusidy^C$	0.275**	0.229**		
	(2.276)	(1.978)		
$Subsidy^C$			1.389	0.462
			(0.542)	(0.173)
$\Delta Revenue^C_{t-2\to t} \times Subsidy^C$			11.504*	11.451**
			(1.950)	(2.014)
$Subsidy^S$	4.271	3.933	3.830	2.951
	(1.478)	(1.297)	(1.361)	(0.975)
Pair FE	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No
$Industry^C \times Year$ FE	No	Yes	No	Yes
$Industry^S \times Year$ FE	No	Yes	No	Yes
Supplier Controls	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes
Observations	644	595	644	595
Pseudo R-square	0.955	0.966	0.955	0.967

Table 9: Overcapacity-Inventory

This table examines whether customer revenue growth is associated with changes in suppliers' overcapacity. Panel A reports the results of Equation (13) for samples with Chinese and non-Chinese customers separately, while Panel B reports the results of Equation (14) for the full sample. Supplier overcapacity is proxied by the change in inventory ($\Delta Invt$). Customer side and supplier side control variables are provided in Table 3. t-stats in parentheses are calculated using standard errors clustered at the customer–supplier pair level.

Panel A

	Chinese Customer $\Delta Inventory_{t+1\to t+k}$			Non-Chinese Customer $\Delta Inventory_{t+1\to t+k}$		
	$k=1$	$k=2$	$k=3$	$k=1$	$k=2$	$k=3$
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Revenue^{C}_{t-2\to t}$	0.095***	0.057*	0.047**	0.001	-0.005	0.001
	(3.006)	(1.708)	(2.370)	(0.092)	(-0.495)	(0.059)
$\Delta Revenue^{S}_{t-2\to t}$	-0.180***	-0.206***	-0.145***	-0.059***	-0.009	0.011
	(-3.905)	(-5.670)	(-4.275)	(-4.990)	(-1.022)	(1.620)
Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
$Country^{C} \times Year$ FE	-	-	-	Yes	Yes	Yes
$Country^{S} \times Year$ FE	Yes	Yes	Yes	Yes	Yes	Yes
Supplier Controls	Yes	Yes	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	983	749	506	5792	5019	4074
Pseudo R^2	0.582	0.772	0.894	0.713	0.826	0.909

Panel B

	$\Delta Inventory_{t+1\to t+k}$		
	$k=1$	$k=2$	$k=3$
	(1)	(2)	(3)
$\Delta Revenue^{C}_{t-2\to t}$	0.001	-0.003	0.003
	(0.083)	(-0.322)	(0.307)
$\Delta Revenue^{C}_{t-2\to} \times isCN^{C}$	0.070**	0.030	0.018
	(2.261)	(1.039)	(0.962)
$\Delta Revenue^{S}_{t-2\to t}$	-0.094***	-0.047***	-0.015*
	(-6.860)	(-4.138)	(-1.854)
Pair FE	Yes	Yes	Yes
$Country^{C} \times Year$ FE	Yes	Yes	Yes
$Country^{S} \times Year$ FE	Yes	Yes	Yes
Supplier Controls	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes
Observations	6806	5797	4603
Pseudo R^2	0.669	0.803	0.903

Table 10: Overcapacity-PPE

This table examines whether customer revenue growth is associated with changes in suppliers' overcapacity. Panel A reports the results of Equation (13) for samples with Chinese and non-Chinese customers separately, while Panel B reports the results of Equation (14) for the full sample. Supplier overcapacity is proxied by the change in Property, Plant, and Equipment (ΔPPE). Customer side and supplier side control variables are provided in Table 3. t-stats in parentheses are calculated using standard errors clustered at the customer–supplier pair level.

Panel A

	Chinese Customer $\Delta PPE_{t+1\to t+k}$			Non-Chinese Customer $\Delta PPE_{t+1\to t+k}$		
	$k=1$	$k=2$	$k=3$	$k=1$	$k=2$	$k=3$
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Revenue^{C}_{t-2\to t}$	0.024	0.044***	0.021**	0.002	0.003	-0.001
	(1.609)	(2.912)	(2.004)	(0.201)	(0.415)	(-0.110)
$\Delta Revenue^{S}_{t-2\to t}$	0.012	-0.014	-0.009	0.009	-0.007	-0.008*
	(0.879)	(-1.043)	(-0.912)	(1.248)	(-1.257)	(-1.653)
Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
$Country^{C} \times Year$ FE	-	-	-	Yes	Yes	Yes
$Country^{S} \times Year$ FE	Yes	Yes	Yes	Yes	Yes	Yes
Supplier Controls	Yes	Yes	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	983	749	506	5792	5019	4074
Pseudo R^2	0.731	0.892	0.945	0.782	0.858	0.900

Panel B

	$\Delta PPE_{t+1\to t+k}$		
	$k=1$	$k=2$	$k=3$
	(1)	(2)	(3)
$\Delta Revenue^{C}_{t-2\to t}$	0.002	0.005	0.000
	(0.269)	(0.609)	(0.043)
$\Delta Revenue^{C}_{t-2\to} \times isCN^{C}$	0.020	0.036**	0.028*
	(1.338)	(2.099)	(1.794)
$\Delta Revenue^{S}_{t-2\to t}$	0.010	-0.012**	-0.011**
	(1.593)	(-2.441)	(-2.488)
Pair FE	Yes	Yes	Yes
$Country^{C} \times Year$ FE	Yes	Yes	Yes
$Country^{S} \times Year$ FE	Yes	Yes	Yes
Supplier Controls	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes
Observations	6806	5797	4603
Pseudo R^2	0.773	0.858	0.903

A Appendix

A.1 Environmental Indicators

We construct a comprehensive set of environmental indicators at both the China-specific and global levels to capture trends in environmental quality and the development of clean energy technologies.

China-specific environmental indicators include (1) measures of water pollution and air pollution, and (2) trends in renewable energy adoption. Water pollution indicators include the share of lakes with good water quality and the share of coastal waters with good water quality. Air pollution indicators include the proportion of cities experiencing acid rain, the national average concentration of sulfur dioxide (SO_2), and the national average concentration of fine particulate matter ($PM_{2.5}$). These data are obtained from the *Report on the State of the Ecology and Environment* published by the Ministry of Ecology and Environment. To characterize trends in renewable energy adoption, we construct multiple complementary measures. The share of non-hydropower renewable energy in total electricity generation is provided by CEIC. The market share of electric vehicles (EVs) in new vehicle sales is from the *China Association of Automobile Manufacturers*.

A.2 More Background Information on China's Green Transition

This appendix provides additional institutional detail on the policies, statutory documents, and supporting infrastructure underlying China's green transition discussed in Section 2.1.

Strategic context and energy security The 2012 strategic turn was articulated by then-President Hu Jintao at the 18th National Congress of the Chinese Communist Party, who formally elevated "ecological civilization" to one of the nation's five overarching development objectives, explicitly emphasizing that economic growth should not come at the

expense of environmental sustainability.[21] The 2013 revised performance evaluation framework for local Party and government cadres is documented in the Organization Department of the Central Committee (2013), "Notice on Improving the Performance Evaluation of Local Party and Government Leadership Teams and Leading Cadres," Document No. 22 [2013].[22] Beyond environmental and climate considerations, the national push for renewable energy also reflects strategic concerns regarding energy security: China continues to depend heavily on imported oil and natural gas to meet domestic energy demand.

The 5M6S power groups and SASAC's evaluation framework The eleven 5M6S power groups emerged from China's 2002 power-sector reform as pure-play power generators: they do not operate the grid (handled by State Grid and Southern Grid), construct power plants (handled by China Energy Engineering and PowerChina), or manufacture equipment (handled by Dongfang Electric, Harbin Electric, and China Electric Equipment). The five major groups—Huaneng, Datang, Huadian, State Power Investment Corporation (SPIC), and China Energy Investment Corporation—are integrated multi-source generators operating thermal, hydro, wind, solar, and in some cases nuclear capacity nationwide. The six secondary groups include China Three Gorges Corporation, China National Nuclear Corporation and CGN Group, CECEP Group, SDIC Power, and China Resources Power. Of the eleven, nine are administered directly by SASAC, and the remaining two (SDIC Power and China Resources Power) are administered indirectly through their SASAC-controlled parent holding companies.

SASAC has progressively strengthened the role of sustainable development in its central-SOE executive evaluation system over the last fifteen years, in three landmark documents: a 2008 directive on corporate social responsibility for centrally-administered enterprises, with environmental performance among the evaluation criteria,[23] a 2019 framework on high-quality development with substantial emphasis on the green transition and quantitative

[21] See https://cpc.people.com.cn/n/2012/1118/c64094-19612151.html.
[22] See https://news.12371.cn/2013/12/09/ARTI1386590057904551.shtml.
[23] See http://www.sasac.gov.cn/n2588035/n2588320/n2588340/c4426934/content.html.

environmental targets,[24] and the 2021 policy that explicitly incorporated the "dual-carbon" goals into the executive performance evaluation framework.[25] Section 8(3) of the 2021 policy specifies the rewards-and-penalties structure:

> *Strengthen assessment constraints. SASAC has incorporated carbon peaking and carbon neutrality work into the central-SOE evaluation system: enterprises with outstanding performance are publicly commended and rewarded, while those that fail to implement the Party Central Committee and State Council's decisions or to meet their assigned targets face public criticism and formal regulatory reprimands, with stricter accountability proceedings for failures causing serious adverse impacts. Central SOEs must establish internal monitoring and assessment mechanisms for their dual-carbon work and report implementation progress to SASAC annually.*

Feed-in tariffs and tax incentives The centerpiece of China's renewable subsidy regime is the feed-in tariff (FIT) system, under which the National Development and Reform Commission (NDRC) introduced benchmark on-grid tariffs for wind power in 2009 and solar PV in 2011, setting prices above the coal-fired benchmark to create an implicit per-unit generation subsidy.[26] Benchmark tariffs were gradually reduced and converged to coal-fired prices by 2020, completing a phased subsidy withdrawal. China's approach is broadly analogous to FIT schemes adopted in Europe.[27] Beyond the FIT, the government provides tax incentives—qualifying renewable energy equipment manufacturers benefit from a three-year

[24] See http://www.sasac.gov.cn/n2588020/n2877938/n2879597/n30275940/c12468278/content.html.

[25] See http://www.sasac.gov.cn/n2588035/c22499825/content.html.

[26] See NDRC Price [2009] No. 1906 (http://ndrc.gov.cn/xxgk/zcfb/tz/200907/t20090727_965206.html) and NDRC Price [2011] No. 1594 (https://www.ndrc.gov.cn/xxgk/zcfb/tz/201108/t20110801_964803.html). Tariffs were set on a zonal basis reflecting regional resource endowments.

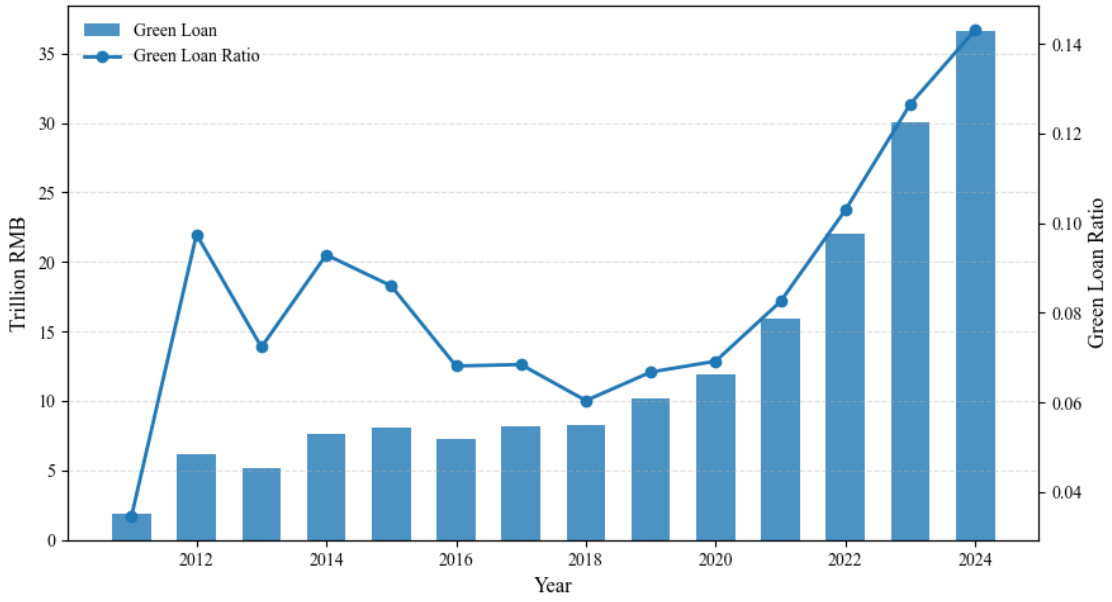
[27] Germany's Renewable Energy Sources Act (EEG, 2000) provided above-market guaranteed tariffs before transitioning to competitive auctions in 2017; the UK's Renewables Obligation scheme (2003–2017) required electricity suppliers to source minimum renewable shares before being replaced by a Contracts for Difference auction mechanism; and Italy's *Conto Energia* program offered differentiated solar PV tariffs until an annual cost cap of €6.7 billion was reached in 2013.

corporate income tax exemption followed by three years at a 50% reduced rate—and channels fiscal grants to renewable energy R&D through the National Key Research and Development Program.

Green loans China's state-owned banking system has directed large volumes of credit toward the green transition through designated green loans, typically extended at preferential interest rates and subject to green project certification standards and ongoing monitoring over the loan period. The People's Bank of China (PBOC) sets national green credit targets, which are then allocated to the five major state-controlled commercial banks. As shown in Online Appendix Figure A1, total green loan balances and their share of total bank credit have risen rapidly since 2012. By contrast, market-based instruments such as sustainable funds and green bonds remain relatively small in scale in China, making the state-directed banking channel the primary source of green financing.

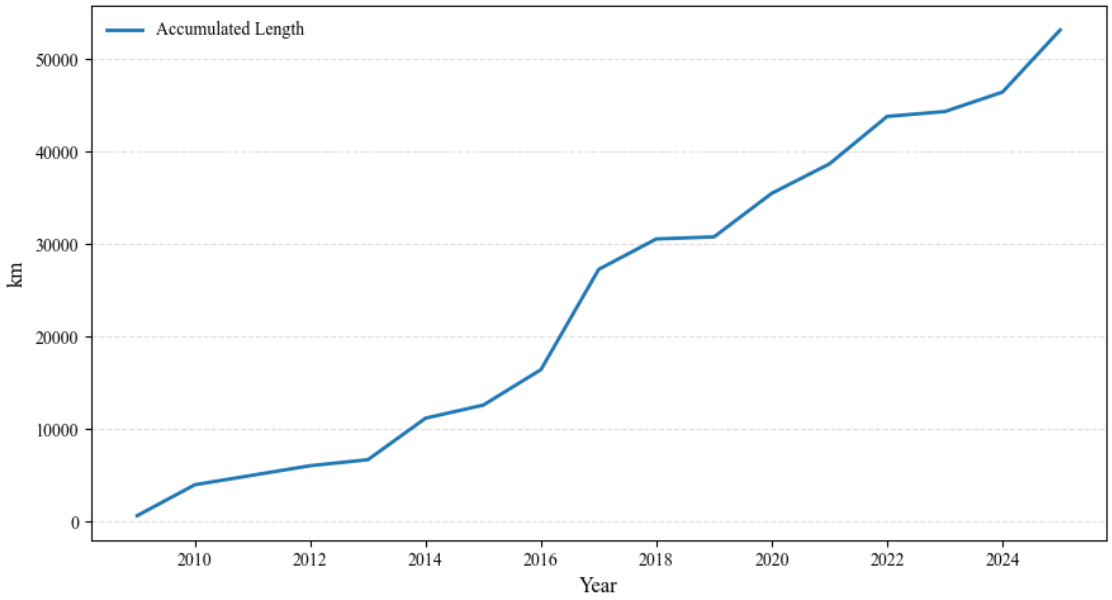
Ultra-high-voltage transmission infrastructure China has invested heavily in ultra-high-voltage (UHV) transmission infrastructure, which is essential for integrating renewable electricity into the national grid. Wind and solar resources are concentrated in economically underdeveloped western regions where local electricity demand is limited, while major consumption centers lie thousands of kilometers to the east. UHV lines—capable of transmitting power at 1,000 kV AC or ±800 kV DC—make long-distance electricity transmission economically viable with minimal energy losses. China began developing UHV technology in 2009 and today operates the world's largest UHV grid; Online Appendix Figure A2 documents the rapid expansion of this infrastructure over time.

Figure A1: Green Loan in China



Notes: This figure shows the outstanding balance of green loan in China its share among the total loans.

Figure A2: Expansion of Ultra-High-Voltage Transmission Infrastructure



Notes: This figure shows the cumulative length of China's ultra-high-voltage (UHV) transmission infrastructure.

Table A1: Leading Firms by Renewable Energy Equipment Segment

This table shows the leading firms in different BICS Level 5 segments under the renewable energy equipment sub-industry.

Segment	**Leading Firms**
Solar Energy Equipment	JinkoSolar; Trina Solar; LONGi Green Energy; Canadian Solar
Wind Energy Equipment	Vestas; Siemens Gamesa; Goldwind; Mingyang Smart Energy
Energy Storage Systems	ChaoWei; CosMX; Narada Power Exide; Fluence; EnerSys
Fuel Cell	Plug Power

Table A2: Demand persistency of customers

This table shows the demand persistency of customers by estimating an AR(1) model for $\Delta Revenue^C$:

$$\Delta Revenue_{c,t+1} = \beta_1 \, \Delta Revenue_{c,t} + \epsilon_{c,t+1}$$

Panel A

	$\Delta Revenue^C_{t+1}$				
	Chinese Customer		Non Chinese Customer		
	(1)	(2)	(3)	(4)	(5)
$\Delta Revenue^C_t$	0.168***	0.175***	0.102***	0.102***	0.111***
	(6.533)	(6.464)	(7.785)	(7.676)	(8.142)
Country FE	-	Yes	Yes	Yes	No
Year FE	No	Yes	No	Yes	No
$Country \times Year$ FE	-	-	No	No	Yes
Observations	4528	4528	26422	26422	26233
R-square	0.030	0.077	0.023	0.048	0.087

Panel B

	$\Delta Revenue^C_{t+1}$		
	(1)	(2)	(3)
$\Delta Revenue^C_{t+1}$	0.102***	0.106***	0.111***
	(7.787)	(7.975)	(8.160)
$\Delta Revenue^C_t \times is_CN^C$	0.066**	0.055*	0.065**
	(2.296)	(1.921)	(2.109)
Country FE	Yes	Yes	No
Year FE	No	Yes	No
$Country \times Year$ FE	No	No	Yes
Observations	30950	30950	30761
R-square	0.033	0.056	0.091

Table A3: Robustness: Revenue Growth of the Past 1 Year

This table presents the results of the robustness test of the main result, we re-estimate Equation (1) in Panel A and Equation (2) in Panel B by replacing $\Delta Revenue^C$ with the last 1 year revenue growth of the customer.

Panel A

	$Patent_{t+1}$						
	Chinese Customer				Non-Chinese Customer		
	All sample		$isCN^S = 1$	$isCN^S = 0$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta Revenue_t^C$	0.176***	0.180***	0.189***	0.018	-0.003	-0.026	-0.028
	(2.791)	(2.866)	(2.847)	(1.014)	(-0.211)	(-1.142)	(-1.566)
$\Delta Revenue_t^S$	-0.056	-0.040	-0.043	0.226*	-0.151***	-0.148***	0.013
	(-0.775)	(-0.499)	(-0.520)	(1.841)	(-4.482)	(-4.221)	(0.382)
Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	Yes	No	No
$Country^C \times Year$ FE	-	-	-	-	No	Yes	Yes
$Country^S \times Year$ FE	No	Yes	No	No	No	No	Yes
Supplier Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1071	1027	818	208	7995	7495	7429
Pseudo R-square	0.948	0.953	0.942	0.986	0.954	0.960	0.973

Panel B

	$Patent_{t+1}$		
	(1)	(2)	(3)
$\Delta Revenue_t^C$	-0.000	-0.020	-0.021
	(-0.014)	(-0.877)	(-1.185)
$\Delta Revenue_t^C \times isCN^C$	0.120*	0.162**	0.125**
	(1.928)	(2.420)	(1.960)
$\Delta Revenue_t^S$	-0.136***	-0.121***	0.019
	(-4.161)	(-3.491)	(0.428)
Pair FE	Yes	Yes	Yes
Year FE	Yes	No	No
$Country^C \times Year$ FE	No	Yes	Yes
$Country^S \times Year$ FE	No	No	Yes
Supplier Controls	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes
Observations	9070	8566	8504
Pseudo R-square	0.952	0.958	0.970

Table A4: Robustness: Environment-related Patents

This table presents the results of the robustness test of the main result, we re-estimate Equation (1) in Panel A and Equation (2) in Panel B by replacing $Patent_{t+1}$ with $EnvPatent_{t+1}$.

Panel A

	$EnvPatent_{t+1}$						
	Chinese Customer				Non-Chinese Customer		
	All sample		$isCN^S = 1$	$isCN^S = 0$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\Delta Revenue^C_{t-2\to t}$	0.346***	0.366***	0.433***	0.277**	-0.049	-0.086	-0.086**
	(3.369)	(3.360)	(3.312)	(1.995)	(-1.057)	(-1.489)	(-2.039)
$\Delta Revenue^S_{t-2\to t}$	0.005	0.011	-0.011	0.122	-0.111	-0.150**	0.014
	(0.028)	(0.054)	(-0.058)	(0.466)	(-1.466)	(-2.141)	(0.184)
Pair FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	Yes	No	No
$Country^C \times Year$ FE	-	-	-	-	No	Yes	Yes
$Country^S \times Year$ FE	No	Yes	No	No	No	No	Yes
Supplier Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1071	1027	818	252	7921	7438	7369
Pseudo R-square	0.947	0.952	0.941	0.975	0.953	0.960	0.973

Panel B

	$EnvPatent_{t+1}$		
	(1)	(2)	(3)
$\Delta Revenue^C_{t-2\to t}$	-0.044	-0.075	-0.078*
	(-0.950)	(-1.300)	(-1.777)
$\Delta Revenue^C_{t-2\to} \times isCN^C$	0.252**	0.338***	0.284**
	(2.239)	(2.896)	(2.529)
$\Delta Revenue^S_{t-2\to t}$	-0.085	-0.094	0.061
	(-1.141)	(-1.274)	(0.672)
Pair FE	Yes	Yes	Yes
Year FE	Yes	No	No
$Country^C \times Year$ FE	No	Yes	Yes
$Country^S \times Year$ FE	No	No	Yes
Supplier Controls	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes
Observations	8996	8509	8444
Pseudo R-square	0.952	0.958	0.970

Table A5: Robustness: Patents in a Longer Period

This table presents show the effect of $\Delta Revenue^C$ on $Patent$ in a longer period. We replace the dependent variable with the patent filed by the firm in the subsequent 2 to 3 years.

	Chinese Customer		Non-Chinese Customer	
	$Patent_{t+1\to t+2}$	$Patent_{t+1\to t+3}$	$Patent_{t+1\to t+2}$	$Patent_{t+1\to t+3}$
	(1)	(2)	(3)	(4)
$\Delta Revenue^C_{t-2\to t}$	0.247***	0.170**	-0.072**	-0.050*
	(2.859)	(2.536)	(-2.151)	(-1.929)
$\Delta Revenue^S_{t-2\to t}$	-0.042	-0.013	-0.058	-0.038
	(-0.257)	(-0.104)	(-0.874)	(-0.624)
Pair FE	Yes	Yes	Yes	Yes
Year FE	No	No	No	No
$Country^C \times Year$ FE	-	-	Yes	Yes
$Country^S \times Year$ FE	Yes	Yes	Yes	Yes
Supplier Controls	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes
Observations	1027	1027	7369	7369
Pseudo R-square	0.970	0.981	0.983	0.987

Table A6: Main Result with Industry × Year Fixed effects

This table presents the robustness of main result after controlling for the Supplier-Industry × Year fixed effects and Customer-Industry × Year.

	$Patent_{t+1}$					
	Chinese Customer		Non-Chinese Customer		Full Sample	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta Revenue_t^C$	0.362***	0.252***	-0.010	-0.040	-0.009	-0.039
	(4.620)	(2.981)	(-0.290)	(-1.157)	(-0.262)	(-1.190)
$\Delta Revenue_t^C \times isCN^C$					0.269**	0.213**
					(2.540)	(2.413)
$\Delta Revenue_t^S$	0.017	0.014	-0.317***	0.145**	-0.258***	0.168**
	(0.125)	(0.091)	(-4.522)	(2.191)	(-3.718)	(2.108)
Pair FE	Yes	Yes	Yes	Yes	Yes	Yes
$Country^C \times Year$ FE	-	-	No	Yes	No	Yes
$Country^S \times Year$ FE	No	Yes	No	Yes	No	Yes
$Industry^S \times Year$ FE	Yes	Yes	Yes	Yes	Yes	Yes
$Industry^C \times Year$ FE	Yes	Yes	Yes	Yes	Yes	Yes
Supplier Controls	Yes	Yes	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1015	970	7684	7207	8737	8262
Pseudo R-square	0.964	0.968	0.962	0.977	0.961	0.974

Table A7: Falsification Test

This table presents the results of the falsification test, we re-estimate Equation (1) by replacing the actual customer in each supplier–customer relationship with a fictitious customer. The fictitious customer is a firm in our sample that is located in the same country as the original customer and has the closest total assets in that year. Control variables include firm characteristics from both supplier side firm characteristics and customer side. t-stat in parentheses are calculated using standard errors clustered at the customer-supplier pair level.

	$Patent_{t+1}$				
	Chinese Customer		Non-Chinese Customer		
	(1)	(2)	(3)	(4)	(5)
$\Delta Revenue^{C}_{t-2\to t}$	0.086	0.059	-0.001	0.020	0.018
	(0.719)	(0.474)	(-0.012)	(0.329)	(0.486)
$\Delta Revenue^{S}_{t-2\to t}$	0.032	0.071	-0.091	-0.118*	0.041
	(0.140)	(0.309)	(-1.182)	(-1.727)	(0.538)
Pair FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No	No
$Country^{C} \times Year$ FE	No	Yes	No	Yes	Yes
$Country^{S} \times Year$ FE	No	Yes	No	No	Yes
Supplier Controls	Yes	Yes	Yes	Yes	Yes
Customer Controls	Yes	Yes	Yes	Yes	Yes
Observations	985	920	7295	7116	6501
Pseudo R-square	0.946	0.950	0.955	0.961	0.973