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The green leap forward? State capitalism, industrial policy, and the limits of green transformation in China

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ABSTRACT

China's rapid expansion in green industries – the green leap forward – is frequently cited as evidence of the effectiveness of state-led industrial policy in accelerating technological upgrading and decarbonisation. This article critically examines that claim through a comparative analysis of two flagship sectors: solar photovoltaics and electric vehicles. Drawing on ecological modernisation theory and the political economy of industrial policy, the paper conceptualises green industrialisation as a politically embedded process shaped by persistent trade-offs between scale expansion, market discipline, and environmental sustainability. Using qualitative document analysis and secondary data, the study traces the evolution of state support instruments in both sectors and evaluates their effectiveness through Rodrik's criteria of embeddedness, discipline, and accountability. The findings show that while state intervention has been instrumental in overcoming entry barriers, coordinating large-scale investment, and enabling the emergence of globally competitive firms, it has also generated enduring distortions, including overcapacity, policy dependence, and environmental ambiguity.

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1. Introduction: China's green leap forward as industrial transformation

The global push towards decarbonisation has placed green industries at the centre of contemporary debates on industrial policy and economic transformation. China's rapid rise as a global leader in sectors such as solar photovoltaics[1] (PV)and electric vehicles (EVs) is frequently portrayed as evidence of the effectiveness of strong state intervention in accelerating technological upgrading and green transformation (Wu, 2023; Zhang et al., 2023). Through a dense web of subsidies, state-directed finance, regulatory coordination, and strategic planning, the Chinese state has played a decisive role in shaping the development trajectories of these industries. Yet, the apparent success of China's green industrial strategy has also generated growing controversy. Critics point to persistent overcapacity, distorted price signals, mounting corporate indebtedness, and escalating trade conflicts as systemic side effects of prolonged state support (Liu, 2024; Shen et al.,

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2021). These tensions raise an analytical question that goes beyond whether state intervention 'works' in promoting green industries, and instead concerns how, under what conditions, and at what cost such intervention reshapes markets, firms, and global competition.

In the case of China's green leap forward (GLF) – the term employed in this article to denote the state-led expansion of green industries such as PVs and EVs – state support coincides with multiple and partially overlapping state interests. One such dimension is the mitigation of environmental degradation. Since the onset of Reform and Opening-up, China's growth model has been anchored in resource-intensive production, extensive exploitation of natural resources, and severe environmental externalities, particularly air pollution (Harris, 2004). As a result, China became the world's largest carbon dioxide emitter by 2006. Although China's engagement with climate-related issues dates back to the late 1980s, environmental protection only gained political prominence with the 2007 National Climate Change Programme. Since then, climate objectives have been increasingly embedded in long-term development strategies, culminating in China's pledge to achieve carbon neutrality by 2060 (Wu, 2023).

At the same time, the GLF is not driven by environmental considerations alone. The sustainability of China's growth model has broader political-economic significance, as economic performance has served as a central source of regime legitimacy since the end of the Cold War (Holzmann & Grünberg, 2021). GLF thus represent an opportunity to reconcile continued economic expansion with mounting ecological and social pressures. Moreover, the emergence of globally competitive Chinese firms in PV and EV industries allows the Chinese leadership to showcase indigenous innovation capabilities, strengthen China's international economic position, and challenge established industrial hierarchies (Nölke et al., 2015). These ambitions are reflected in tangible outcomes: China now hosts the world's largest manufacturing capacity and installed base in wind and solar power, while its EV market has become the largest and fastest growing globally, with Chinese firms increasingly competing in international markets.

This article argues that China's green industrial policy should not be assessed solely through indicators of output growth, export performance, or technological catch-up. Instead, it must be examined as a political-economic process characterised by trade-offs between industrial upgrading, market discipline, and long-term sustainability. The PV and EV industries are particularly instructive in this regard. PVs represent one of the earliest successes of the GLF, while EVs constitute its most recent and strategically ambitious manifestation. While both are often cited as emblematic success stories, closer examination reveals persistent structural tensions inherent in state-led green industrialisation, including cycles of overinvestment, uneven firm performance, and repeated policy recalibration.

The article addresses four interrelated research questions. First, how has the Chinese state structured and adjusted its industrial policy instruments in the PV and EV sectors over time? Second, what political-economic trade-offs emerge from sustained state intervention, particularly with respect to overcapacity, market distortion, and firm-level performance? Third, to what extent do the PV and EV industries represent scalable models of green industrialisation, as opposed to sector-specific or historically contingent outcomes? Finally, what role do environmental objectives actually play relative to industrial competitiveness and geopolitical considerations in shaping China's GLF? By addressing these questions, the article moves beyond celebratory or dismissive narratives and instead offers a balanced assessment of the opportunities, limits, and unintended consequences of large-scale green industrial policy. In doing so, it contributes to broader debates on ecological modernisation, new state capitalism, and the political economy of green transitions.

Methodologically, the article employs qualitative research methods, primarily qualitative document analysis, to examine policy documents, strategic plans, and sectoral data related to China's PV and EV industries. This is complemented by an extensive review of secondary academic literature and policy-oriented analyses, as well as selected media sources to capture recent developments. To situate industrial policy within its institutional and political context, the analysis draws on government reports and official publications, including materials from the Ministry of Industry and Information Technology (MIIT, 2020, 2022a, 2022b), the Ministry of Science and Technology (MST, 2017, 2021), and Chinese and international statistical sources.

The article is structured as follows. After this introduction, sections two and three review the relevant literature and outline the analytical framework, drawing on debates on green industrial policy, ecological modernisation, and new state capitalism. The fourth and fifth sections examine state support for the PV and EV industries, respectively. The sixth section offers a comparative assessment of the two cases, focusing on efficiency, discipline, and policy learning. The final section returns to the theoretical framework, summarises the main findings, and highlights the broader dilemmas and implications of China's green leap forward.

2. Literature review: green industrial policy, state capitalism, and China's green transformation

The past decade has witnessed the emergence of what has been described as new state capitalism, characterised by states assuming expanded roles as industrial policy actors, owners of capital, and investor shareholders (Alami et al., 2022). Across advanced and emerging economies alike, governments have adopted diverse national development strategies and revived industrial policy instruments (Mazzucato, 2013; Stiglitz et al., 2013). A series of overlapping shocks – including the global financial crisis, the erosion of confidence in neoliberal economic governance, the COVID-19 pandemic, and rising geopolitical tensions – have intensified concerns over economic and national security, supply chain resilience, and the capacity of markets to allocate resources efficiently. The growing salience of climate change as a political and economic challenge further amplifies these uncertainties. As Alami (2023) argues, moments of civilisational transformation – or potential collapse – often coincide with ecological crises, creating conditions for an expansion of state prerogatives. In this sense, climate change may act as a catalyst for the diffusion and consolidation of new state capitalist practices, potentially ushering in a new phase of state – market relations. Within this broader context, renewed forms of state intervention have increasingly taken shape through industrial policies explicitly aligned with innovation and environmental objectives (Johnstone et al., 2021; Pegels, 2014).

Against this backdrop, the growing prominence of green industrial policy has revitalised long-standing debates on the role of the state in shaping industrial development. Classical accounts of industrial policy emphasise the state's capacity to coordinate investment, facilitate learning processes, and correct market failures associated with late industrialisation (Amsden, 2008; Wade, 2012). Historical analyses of industrialisation in advanced economies, including the United States and Europe, show that state intervention has frequently played a central role in fostering industrial development, often in ways that are obscured in contemporary policy debates (Chang, 2002). At the same time, the industrial policy literature emphasises that such support is most effective when combined with clear performance criteria, monitoring, and the possibility of withdrawing support from underperforming firms (Rodrik, 2004, 2009). More recent contributions suggest that the transition towards low-carbon technologies intensifies these coordination challenges, as green industries are typically characterised by high capital intensity, long payback periods, and significant technological uncertainty (Mazzucato, 2013; Rodrik, 2014). From this perspective, proactive state intervention is widely viewed as a necessary condition for accelerating decarbonisation and supporting structural transformation, even as it raises new questions regarding efficiency, discipline, and long-term sustainability.

In this extensive discourse, China has become the most notable – and contentious – illustration of extensive green industrial policy implementation. An expanding corpus of literature illustrates the methods employed by the Chinese state to utilise various policy instruments in promoting renewable energy and electric mobility, including subsidies, state-directed finance, public procurement, regulatory mandates, and strategic planning (Holzmann & Grünberg, 2021; Naughton & Tsai, 2015; Wu, 2023; Zhang et al., 2013). Research on China's PV sector underscores the role of synchronised central-local governmental efforts in facilitating swift capacity growth, cost diminishment, and international market infiltration, thereby establishing China as the pre-eminent global producer in a brief timeframe (Corwin & Johnson, 2019; Wang & Liu, 2024). Similar analyses of the EV sector emphasise the significance of industrial strategy in cultivating domestic leaders, enhancing battery production, and establishing technological ecosystems that encompass manufacturing, infrastructure, and standards (Dent, 2015; Liu & Kokko, 2013).

At the same time, critical political economy scholarship has increasingly questioned the sustainability and broader consequences of China's state-led green industrialisation. State capitalism literature emphasise that extensive state support can generate systemic distortions, including soft budget constraints, rent-seeking behaviour, and misallocation of capital, particularly when market exit mechanisms remain weak (Alami & Dixon, 2024). In the PV sector, several studies document cycles of subsidy-driven overinvestment followed by price collapses, firm bankruptcies, and international trade disputes, suggesting that global competitiveness has come at the cost of domestic financial instability and external tensions (Wang et al., 2022; Xu et al., 2025). The literature on China's EV industry reflects similar ambivalence. While some authors view EVs as evidence of policy learning and technological upgrading beyond earlier renewable energy experiences, others warn that the sector exhibits familiar patterns of fragmented local protectionism, excess capacity, and heavy reliance on public support (Xu et al., 2025; Zhang et al., 2013). These tensions raise questions about whether China's GLF represents a durable model of sustainable development or a politically driven growth strategy whose environmental benefits remain contingent and uneven.

Despite these rich debates, two gaps remain in the existing literature. First, most studies assess China's green industrial policy either from a national perspective or through firm-level performance, paying less attention to the structural political-economic trade-offs embedded in prolonged state intervention. Second, comparative analyses that examine how different green sectors evolve under similar policy logics – and whether lessons are effectively transferred across industries – remain limited. As a result, the relationship between industrial success, market discipline, and environmental sustainability is often assumed rather than critically interrogated.

3. Theoretical framework: ecological modernisation and the political economy of state industrial policy

To fill the above mentioned gaps in the literature, this article draws on two influential but contested strands of scholarship: ecological modernisation theory and the political economy of industrial policy. Both approaches provide important insights into the role of the state in steering economic transformation, yet neither offers a fully sufficient framework for assessing the long-term political-economic consequences of large-scale green industrial intervention. Rather than treating these perspectives as normative benchmarks, this paper mobilises them as analytical lenses whose internal tensions and limitations are central to understanding China's GLF.

Ecological modernisation theory (EMT)aims to understand the transformability of capitalist production and consumption practices, in particular the so-called ecological imperative (Mol & Sonnenfeld, 2000; Spaargaren, 2000). According to this social theoretical concept, dominant economic institutions and technologies, and the social and economic norms that build on them, can be changed in different ways. These changes can be understood as consequences of a shift to more sustainable growth models. Although the theory is largely based on the experience of the core countries, its findings are also valid for China, which is deeply integrated into the capitalist world economy. Sonnenfeld and Mol (2006) and Zhang et al. (2007), analysing rapidly developing Asian countries both pointed out that the concept and practices of ecological modernisation are most useful for these countries, includng China. The applicability of the theory to China is also demonstrated by its subsequent discovery by the Chinese leadership and the Chinese Academy of Sciences (CAS, 2007).

The EMT literature does not merely attempt to understand how advanced industrial societies are overcoming the environmental crisis they have generated (Mol & Sonnenfeld, 2000, p. 5). Alongside this claim is a normative assertion about the desirability for capitalist modernity to embrace, indeed spearhead, the ecological turn in the 21st century. The normativity is thus also evident in the active advocacy of state involvement: 'the only possible way out of the ecological crisis is by going further into the process of modernization' (Mol, 2002, p. 92). In this approach, the root problem of 'parallel economic growth and increasing ecological disruption' is not inevitable (Mol, 2002, p. 93). To secure the coexistence between capitalism and the environment, the EMT literature develops a novel ecological rationality under which existing economic practices undergo a fundamental transformation. Of all actors involved in this process, the state is expected to take the lead. Because these practices are entrenched and wedded to an extractive, profit-seeking motive, the greening of production activity is not necessarily triggered under market conditions. This explains the need for the state to establish 'pathways for ecological modernization' (Andersen & Massa, 2000, p. 343). For a wide array of businesses and industries to start green transition, there has to be an 'eco-modernist rationalization' articulated and actively supported by the state (Andersen & Massa, 2000, p. 344).

Industrial policy scholarship helps assess more generally the involvement of the state in these processes. More recent contributions argue that green sectors are especially prone to coordination failures due to high capital intensity, technological uncertainty, and long investment horizons, making them legitimate targets of state intervention (Mazzucato, 2013; Rodrik, 2014). Much thinking in industrial theory and the necessity of industrial policy intervention is informed by two assumptions. The first is that negative externalities generated by market processes, including environmental damage are not properly managed by market forces. The second is that the management of these damages can only be taken over by the state through the transformation of the support environment and the use of instruments to change the harmful behaviour.

Building on the works of Dani Rodrik (2004, 2009, 2014), industrial policy serves as a 'discovery process' between public and private actors engaged in strategic coordination (Rodrik, 2004, p. 3). The efficiency and distinctiveness of this process depends on three requirements. The first is the requirement of *embeddedness*: policymakers need to be aware of – and metaphorically close to – the challenges and dilemmas facing private actors. This proximity is guaranteed by the embeddedness between state institutions and firms (Rodrik, 2009, pp. 26–28). In the context of green industrial policy, Rodrik (2014, p. 485)specifically highlights the need for cooperation with the private sector and the existence of the necessary processes and institutions to achieve this. The second requirement is *discipline*, i.e. the combined use of carrots and sticks, that is, incentives and penalties by the state. On the incentive side of industrial policy, the aim is to reinforce and encourage good corporate endeavours and change, while it is important to envisage negative consequences whereby failed attempts shall fail rather than being kept alive artificially by the state (Rodrik, 2009, pp. 29–30). With clear and measurable targets, close monitoring, proper evaluation, well-designed rules, it becomes easier to review ongoing green policies and programmes and let go projects that fail (Rodrik, 2014, p. 488). This also guarantees that state support is not misused by rent-seekers. The third requirement is *accountability*. This refers to the need for the political actors that shape and manage active industrial policy to conduct their activities in a transparent manner, visible and accountable before the public (Rodrik, 2009, pp. 29–30). In the context of green industrial policy, Rodrik (2014, pp. 488–498) proposes the appointment of high-level political leaders to ensure visibility and accountability and also highlights the role of a proactive communication strategy (publication of minutes, reports, independent peer reviews).

This paper conceptualises green industrial policy, including China's GLF, as a tension-filled process situated at the intersection of ecological modernisation and industrial policy theories. These tensions also resonate with broader debates in sustainability transitions literature, including competing paradigms such as green growth, degrowth, and a-growth. While green industrial policy is typically aligned with green growth assumptions – emphasising technological innovation and continued expansion – the Chinese case raises questions about whether large-scale industrial expansion can be reconciled with ecological limits. This paper does not seek to resolve these debates but situates China's green industrial policy within this broader spectrum of perspectives. Rather than assuming that environmental imperatives automatically discipline industrial intervention, it treats green sectors as arenas in which developmental, environmental, and political objectives frequently collide. This approach allows for a more nuanced assessment of whether – and under what conditions – state-led green industrialisation can produce sustainable economic and environmental outcomes.

4. State support for the Chinese PV industry

Since the mid-1990s, the Chinese PV industry – one of the first flagships of China's green transition – has experienced remarkable growth, establishing China as the world's foremost PV manufacturer by 2008. China's solar module production capacity was merely 5 MW, with actual output at only 1.4 MW (Zhang et al., 2013).[2] As of 2023, capacity had reached 1000 GW, with actual production at 500 GW, representing over 80% of the total global module production capacity and output (Wood Mackenzie, 2023). Domestic PV installation has progressed at a slower pace, however gained momentum in recent years, with China achieving 609 GW of installed solar capacity by 2023, accounting for around 40% of the global cumulative capacity (International Energy Agency, 2024).[3] During the 2020 UN Climate Change Summit, President Xi Jinping committed to attaining 1200 GW of cumulative installed wind and solar power by 2030. According to the China National Energy Administration, this aim was already achieved by the end of July 2024 (China Daily, 2024).

The significant achievements in China's solar PV production (or the relatively modest progress in deployment)are not attributable to a unified policy framework. Since the mid-1990s, Chinese solar policy has undergone multiple changes, influenced by global events and internal factors, including the political priorities of other sectors.

Table 1 provides an overview of the evolution of state support instruments in the PV sector, including their objectives, mechanisms, and associated risks. The following sections elaborate on these developments in greater detail.

4.1. From rural development to export orientation

Despite rural electrification being a priority for the Chinese government since the establishment of the People's Republic of China, by 1996, when rural electrification initiatives were primarily characterised by fossil fuel-based grid expansion, over 70 million individuals were still living without electricity, predominantly in the northern and western provinces of China (Pan et al., 2006). Although these regions were remote from electrical grids and the enhancement of current grids posed technical and financial difficulties, they possessed ample renewable energy resources, including wind and solar (Zhang et al., 2013). Consequently, the government resolved in the mid-1990s to supply electricity in these regions through renewable energy sources.

In 1996, the Brightness Programme was initiated to supply electricity to 23 million people in rural regions by 2010 with solar energy (Bhattacharyya & Ohiare, 2012). This objective has also been incorporated into national development strategies (Pan et al., 2006): in 2000, the Chinese government implemented a long-term initiative, the Western Development Strategy, to mitigate the increasing income gaps between coastal and inland provinces, which encompassed enhancing access to electricity. The 10th Five-

Table 1. PV industry support instruments in China.

Period	Primary policy objective	Key instruments (supply-side)	Key instruments (demand-side)	Main beneficiaries	Intended mechanism	Main political-economic risks / issues
mid-1990s – early 2000s	Rural electrification; regional development	Direct state funding; program budgeting; concessional support	Off-grid installations; township electrification programs	Local/state actors; early PV firms; rural communities	Deployment + capability formation	Weak maintenance incentives; uneven implementation; quality issues; limited monitoring
2004–2008	Build global manufacturing champions; export growth	Preferential finance; export loans/ insurance; R&D support; local tax/land incentives	Limited (domestic market weak)	PV manufacturers (SOEs/POEs); local governments	Rapid scaling; economies of scale	Export dependence; entry surge; debt/overexpansion; weak domestic absorption
2009–2011	Stabilise sector post-crisis; stimulate domestic demand	Expansion lending; tax incentives; strategic emerging industry framing	Rooftop Subsidy; Golden Sun; early FIT	Producers; project developers; utilities; consumers	Demand formation + continued expansion	Misaligned incentives; regional inequality in returns; risk of overinvestment
2012–2018	Contain overcapacity; manage trade conflict; increase domestic use	Consolidation/restructuring; adjustments in finance and approvals	FIT reforms; promotion of distributed PV; tariff adjustments	Larger firms; utilities; distributed project developers	Rebalancing + gradual discipline	Persistent overcapacity; price wars; trade disputes; fiscal burden; uneven exit
2019–present	Move towards subsidy reduction; stabilise deployment	Auctions; evolving utility-linked funding; local land/tax supports	Grid-parity incentives; quotas/preferential grid purchase	Utilities; developers; provinces	Reduced subsidy intensity; deployment at scale	'Soft exit'; continued policy dependence; grid integration constraints

Year Plan (2001–2005)placed particular emphasis on rural electrification (Pan et al., 2006). In 2002, the China Township Electrification Program was initiated to enhance PV manufacturing and installation, supported by government investment of 2,600 million yuan (about US$314 million at the time) (Xu & Chen, 2006). Alongside these domestic policy initiatives, the Chinese government has initiated various international cooperation projects with global organisations and foreign governments to provide renewable energy to remote rural regions, amounting to over 800 million yuan in collaboration with partners including the World Bank, Japan, Canada, Germany, and the Netherlands (Andrews-Speed & Zhang, 2019).

The policy instruments used to facilitate the implementation of PV systems aligned with China's energy policy framework, wherein the state was regarded as pivotal to the governance of the energy sector (Andrews-Speed & Hove, 2023). The programme's implementation received direct state funding primarily for state actors, which enabled deployment but failed to offer incentives for post-installation maintenance, resulting in misuses of funding. Notwithstanding initial challenges – such as local funding limitations, insufficient experience, weak institutional capacity, difficulties in material utilisation, and product quality issues – the rural electrification programme resulted in increased installed capacity and rapidly growing domestic demand (Lee, 2012). The regulations drew the greatest global solar businesses – including BP, Shell, Siemens Solar, Sharp, Sayo, and SEC – to China, while also facilitating the establishment of prominent Chinese PV companies like Trina Solar and Yingli (Zhang et al., 2013).

The popularity of PVs extended beyond China. Following the Kyoto Protocol (1997), global demand for PVs rose consistently, but from 2004 onward, it surged dramatically, primarily driven by European demand, particularly from Germany and Spain (Grau et al., 2011; Lee, 2012). Consequently, China's PV policy transitioned towards an export-driven growth phase. Alongside these external factors, internal sources also influenced this trend: the Chinese central and local governments provided robust support for PV production. This was both a response to increasing global demand and a consequence of the Chinese leadership's acknowledgement of the significance of emerging green technologies, coupled with its ambition to establish itself as an economic and technological leader in this domain, following four years of relatively sluggish growth after the Asian financial crisis (Zhang et al., 2013).

In the framework of export-oriented development, local governments also promoted the expansion of the local PV industry, providing greater preferential treatment compared to other sectors (Zhang et al., 2013). Due to governmental support and the industry's prospective growth, several Chinese companies, including many POEs, have entered the industry. To rapidly attain economies of scale, these enterprises required resources to augment output. Financial incentives were available both on the central and local level: since the central government identified the PV sector as a pivotal industry in 2006, companies manufacturing these products became eligible for enhanced financial support for R&D activities, export loans at preferential interest rates, as well as export guarantees and insurance (Andrews-Speed & Zhang, 2019). Unlike in the past, the government no longer provided direct support programmes to the industry due to prior financial mismanagement and implementation delays, opting instead for auction programmes. Chinese PV companies have also secured additional funding through overseas stock exchange listings, including Suntech's listing on the New York Stock Exchange (NYSE)in

2005, followed by Trina Solar and Solarfun in 2006 (NYSE, Nasdaq), and Yingli (NYSE), JA Solar, and China Sunergy in 2007 (Nasdaq). The substantial influx of capital from international stock exchanges has facilitated an unprecedented rate of expansion, resulting in China emerging as the world's largest PV producer by 2008.

Despite the expansion in PV panel output in China, the domestic market has expanded sluggishly, primarily due to insufficient local incentives. This was mostly because China emphasised wind power development in the 2006 Renewable Energy Law, since its costs were perceived to be significantly lower at that time. This indicated that China exported nearly all of its PV modules, with exports surging post-2006, facilitated by China's entry into the World Trade Organization in 2001 (Cao & Groba, 2013). Consequently, it is evident that during this period, the impetus for the GLF sprang not from environmental considerations, but from export policy and an internal, fundamentally cost-driven, electrification initiative.

4.2. Focus on domestic use

The 2008 global financial crisis and the resulting global drop in demand adversely impacted the Chinese PV industry, leading to a significant decrease in shipments in early 2009. The Chinese government tried to counteract the effects of the crisis through a combination of macroeconomic and industrial policy measures, both by increasing the level of direct industry support and by introducing various policies to stimulate domestic demand for solar energy (Zhang et al., 2013). The main macroeconomic initiative was a 4 trillion yuan package for 2009–2010, designed to stimulate domestic demand through enhanced governmental expenditure. The PV industry has largely profited from this. The major industrial policy measure was the declaration of seven strategic emerging industries, two of which – energy conservation and environmental protection, as well as new energy – pertained to PV technology. The China Development Bank facilitated the industry output by providing 250 billion yuan in expansion loans to PV module producers (Grau et al., 2011). Local governments also promoted further industrial investment via tax incentives. As a result, PV production has experienced a resurgence, with China's global market share in PV cell manufacturing increasing to 60% by 2011 (Cao & Groba, 2013).

The government's initiative to encourage domestic consumption was not only a reaction to the decline in global demand caused by the crisis but also aligned with the transition of the Chinese economic model from export-driven to domestic demand-led growth (Szunomar Agnes Peragovics Tamas, 2022). From 2009 to 2011, two national PV subsidy initiatives were introduced: the Rooftop Subsidy Programme and the Golden Sun Demonstration Programme. Both offered initial financial assistance for investments in PV installations. Furthermore, the government introduced the first national feed-in-tariff (FIT)scheme, allowing the sale of surplus energy to utility providers. Nonetheless, the system was imperfect, neglecting the unequal distribution of solar energy resources, which led to substantial profitability disparities between the sun-rich western regions and the less sunny eastern regions. Despite the relative immaturity of the domestic Chinese PV sector, China's total installed solar capacity has surged from 300 MW in 2009 to 33,000 MW in 2011 (Gang, 2015).

By 2012, a substantial overcapacity in PV production existed, as Chinese PV capacity attained 150% of annual global consumption (European Commission, 2013). The oversupply generated price cuts, resulting in foreign – EU and US – manufacturers going bankrupt. In response to these developments, the EU and the US initiated anti-dumping and anti-subsidy investigations, subsequently imposing tariffs on Chinese PVs (European Commission, 2013). In 2012, Chinese PV exports to the US and Europe declined by 35% relative to the prior year (Zhang et al., 2013). To counteract these developments, the Chinese government has focused on restructuring the PV sector and support schemes and enhance domestic PV deployment. First, the government has prioritised the expansion of small-scale distributed PV projects (DPVs)[4] alongside previously favoured large-scale power plants (Zhang, 2015). Secondly, drawing lessons from prior system failures, the government modified the FIT system by categorising it based on the available solar resources. Consequently, northern and western regions with superior resources received lower tariff subsidies. With the rise in solar penetration, the tariff rate was annually reduced, culminating in a 60% decrease from 2011 to 2019 (Shen et al., 2021).

Table 1 summarises the evolution of state support for the Chinese PV industry, highlighting the sequencing of policy instruments, their intended objectives, and the discipline mechanisms – or lack thereof – that accompanied rapid industrial expansion.

In summary, environmental factors have gained prominence in PV subsidies over the past fifteen years; yet, it remains uncertain whether all state subsidies have been implemented with this aspect in mind. With the decreasing cost of solar panels and the rapid expansion of solar power output, China is approaching grid parity, a condition where the cost of solar energy is comparable to – or less than that of – grid electricity.[5] Since 2019, Chinese energy regulators have implemented various policy measures to promote grid-parity PV projects (Wu & Zhang, 2022): these projects receive preferential treatment from utility companies (e.g. a commitment to purchase all electricity generated by grid-parity projects)and local governments (e.g. exemption from the provincial renewable energy development quota). Subsidy funding has evolved considerably since the initial phases of PV development (from direct financing by producers to auctioning); state-owned utilities now utilise ‘solar PV funds’ to finance their projects. In the early 1990s, state-owned utilities imposed a renewable energy surcharge on end-users, which was subsequently allocated to project developers to offset the disparity between solar and conventional coal-fired power, as well as the supplementary expenses of grid connection (Shen et al., 2021). This support mechanism is enhanced, for instance, by advantageous tax and land use laws provided by municipal governments. The government periodically modifies and diminishes these mechanisms, however, they have not been entirely phased out yet.

5. State support for the Chinese EV industry

The PV case illustrates an early model of China’s GLF: rapid capability-building and global competitiveness were achieved primarily through scale-oriented support and export-led growth, while domestic demand formation and market discipline lagged behind. The resulting structural imbalance – especially overcapacity and trade backlash – triggered subsequent rounds of policy recalibration and a gradual shift towards deployment, auctions, and differentiated support mechanisms. This experience provides an important reference point for understanding China’s EV strategy. In the EV sector, the state appears to have internalised some lessons from PV by combining technological upgrading with earlier and more systematic market-making through consumer incentives, infrastructure build-out, and regulatory steering. Yet, as the following section shows, these refinements do not fully resolve the underlying tensions identified in the theoretical framework: policy dependence, risks of distortion and capacity expansion, and ambiguity regarding the environmental ‘greenness’ of industrial outcomes.

Table 2 summarises the main policy instruments shaping the EV sector, highlighting the sequencing of supply- and demand-side measures as well as their governance implications. The following sections elaborate on these developments in greater detail.

5.1. State-led technological development

As a result of the procedures detailed above – the deliberate advancement of green technology to enhance the economy – China started supporting the EV sector as early as 2001. The first tool was the 863 Program for Strategic Technology Development. This programme allocated 2 billion yuan over the following decade to support the research initiatives of Chinese automobile manufacturers, universities, and research institutions (Liu & Kokko, 2013). Subsequently, in the 2010 State Council Decision on Accelerating the Promotion and Development of Strategic Emerging Industries, and in the Twelfth Five-Year Plan (2011–2015), the EV industry was identified as one of the seven strategic emerging industries. The ambitious Made in China 2025 initiative also sought to establish ten internationally competitive Chinese EV manufacturers (Schwabe, 2020; Shih, 2019). To achieve these goals, China have aimed to dominate the EV value chain, encompassing raw material acquisition, semiconductor sourcing, and battery recycling technology.

The Energy-saving and New Energy Vehicle Industry Development Plan (2012–2020) was dedicated to advancing the EV industry, with the objective of achieving a technological and manufacturing capacity that satisfies domestic demand. Per the plan’s directives, industry stakeholders should concentrate on the following fundamental technologies: batteries and their associated safety systems, lightweight design, and electric steering and braking technology. The plan anticipated several research activities to advance these technologies. In this endeavour, focus has been given to already established enterprises to enhance their inventive potential and enable them to become dominant players globally. The strategy highlighted the government’s objective to enhance independent innovation and foster open international competition to provide new collaboration prospects (Gov.cn, 2012). The initiative has yielded some tangible results between 2012 and 2020, notably the rise of various Chinese EV manufacturers, such as BYD, SAIC, Geely, Nio, and Xpeng, as well as battery producers, such as CATL.

The ongoing development trajectory is shown in the New Energy Vehicle Industry Development Plan (2021–2035), which addresses existing deficiencies, particularly in innovation capability, ecological effect management, and infrastructure adequacy (Gov.cn, 2020). It emphasises the necessity for a digital transformation, in which vehicles evolve into mobile smart terminals. The plan delineates three vertical and three horizontal advancements in the technology of future EVs. The three vertical improvements pertain to three distinct engine types: pure electric, plug-in hybrid, and fuel cell. The three horizontal advances encompass essential technology and components, such as batteries and associated management systems, motors and transmission electronics, as well as grid and smart technology. The plan emphasises the significance of foreign companies in the Chinese market and promotes collaboration through joint ventures, while also urging

Table 2. EV industry support instruments in China.

Time period (approx.)	Policy domain	Instruments / programs	Main target (supply/ demand)	Intended effect	Beneficiaries	Governance / discipline issues (risks / tensions)
2001–	R&D and early technological capability	863 Program; R&D grants; university – industry projects	Supply	Build core technologies; reduce dependence	Automakers; universities; research institutes	Risk of fragmented effort; duplication; uneven commercialisation
2010 –	Strategic planning & mission-setting	Strategic emerging industries; Five-Year Plans; Made in China 2025; NEV plans (2012–2020; 2021–2035)	Supply + system	Coordinate investment; scale firms; standards ecosystem	State agencies; lead firms; local governments	Target-driven expansion; local protectionism; unclear exit mechanisms
2009 –	Consumer incentives	Purchase subsidies; purchase tax exemptions; price caps for eligibility	Demand	Accelerate adoption; build mass market	Consumers; domestic OEMs	Policy dependence; distributional bias; fiscal cost
2009 –	Public procurement / demonstration	'Ten Cities, One Thousand Vehicles' pilots; public transport electrification	Demand	Create early demand; learning effects	Municipalities; bus makers; fleets	Local capture; uneven implementation; procurement distortions
2017 –	Regulatory steering / mandates	NEV credit system; ICEV constraints	Demand (via producers)	Force firm-level transition; shift model portfolios	Automakers; regulators	Compliance gaming; uneven burden; market distortion risk
2020–2025	Infrastructure and system integration	Charging networks; grid upgrades; 'New Infrastructure Plan'	System	Enable adoption; reduce range anxiety	Utilities; local governments; infrastructure firms	Grid constraints; uneven spatial coverage
2015 –	Industrial policy via supply chain strategy	Critical minerals strategy; outbound resource investments; recycling	Supply	Secure inputs; reduce bottlenecks	Battery firms; upstream firms	External dependency relocation; geopolitical exposure
evolving	'Greening' and lifecycle governance	Emissions standards; recycling targets; battery lifecycle rules	System	Ensure environmental legitimacy	Regulators; firms	Coal-heavy power mix; lifecycle emissions; greenwashing risk

domestic companies to engage actively in the international arena, to enhance their competitiveness. The 2035 plan seeks to combine several public interests: integration into global value chains, advancement of critical technologies in energy conservation, and the recruitment of international talent to China. The Chinese government is funding efforts that facilitate collaborative innovation projects between the industry and universities.

Given the relatively long timeframe of 15 years, the plan includes step-by-step targets for the advancement of the Chinese EV sector by 2025 and 2035, respectively. By 2025, the energy consumption of new pure EVs is expected to drop below 12 kWh per 100 km, and the proportion of EVs in total sales should surpass 20%. By 2035, the technological advancement of the Chinese EV sector is expected to align with leading global standards, enabling Chinese EV producers to attain international competitiveness. By 2035, EVs are anticipated to dominate the passenger car market, public transportation will become fully electric, fuel cell vehicles will emerge, self-driving cars will be widely adopted, and the hydrogen fuel supply infrastructure will advance considerably.

The plan detailed above may initially appear futuristic, nonetheless, the parts that have been executed thus far have demonstrated efficacy. CATL and BYD are excellent examples of innovative Chinese development. CATL – the global leader in EV battery production – has commenced battery recycling as scheduled, while BYD – that has replaced Tesla as the pre-eminent EV producer – is increasing its global footprint by successfully selling its EVs in developed markets as well. Telecommunications corporations have recently intensified their involvement in the EV business, facilitating the proliferation of smart and self-driving vehicles. Significant advancements have been made in accessing raw materials, exemplified by Chinese investments in nickel-rich Indonesia, notably by Zhejiang Huayou Cobalt, Eve Energy, and Guangdong Brunp Recycling Technology (Baskaran, 2024). Global rankings further demonstrate the efficacy of the strategy: in 2020, 536 Chinese companies were listed among the top 2500 corporations based on R&D expenditure (Grassano et al., 2020), with 10 Chinese automotive manufacturers in the top 50. In 2021, the trend persisted with 597 Chinese firms among the top 2500 and 9 within the top 50. In 2022, Chinese automobile brands comprised 85.6% of domestic EV sales (NDRC, 2022).

5.2. Public support for the spread of EVs

Measures and programmes aimed at fostering the EV industry in the early 2000s primarily concentrated on supporting R&D activities. However, from 2009 onward, initiatives were implemented to develop domestic markets for EVs, aligned with the macroeconomic strategies to stimulate domestic demand. Several policy packages have been released, encompassing subsidies for customers purchasing EVs, and the promotion of EVs for public transport (Liu & Kokko, 2013; Schwabe, 2020). Consequently, in contrast to the state's approach to PV industry development, the Chinese government has diligently facilitated the expansion of domestic EV usage practically from the beginning, alongside initiatives for technological advancement.

In 2009, the government introduced the 'Ten Cities and one Thousand Vehicles' initiative, designed to encourage the adoption of EVs in public transport (STIP Compass [STIP], 2019). Subsequently, the Chinese Ministry of Finance announced a pilot initiative to subsidise the purchase of EVs by private citizens, indicating that the central government intended to make significant expenditures in this sector. In 2012, the State Council unveiled the above-mentioned Energy-saving and New Energy Vehicle Industry Development Plan with a significant increase in direct and indirect subsidies (Gov.cn, 2012). In 2014, the State Council established directives to promote and enhance the utilisation of EVs, thereby invigorating the industry's development. It also offered tax and other incentives, including the exemption of clients from vehicle purchase tax. In 2015, relevant ministries released a joint communiqué with the National Development and Reform Commission regarding a financial support initiative for the promotion and utilisation of EVs for the period 2016–2020. The document explicitly stated that the central government will support the sales of EVs (Central Government of the People's Republic of China, 2015). The MIIT reported that 33.023 billion yuan was allocated to promote EV sales from 2016 to 2020. Following 2020, the subsidy was scheduled for gradual elimination; however, due to the economic downturn induced by the Covid pandemic, the government opted to extend it until the end of 2022 (Tabeta, 2022).

For the analysis of the exemption on EV purchases, we used documents published by the MIIT in early 2022. The quantity of pure EV models fluctuated monthly, but the vast majority of the models were from Chinese car manufacturers, with most of them offering one or two models qualifying for the exemption. In terms of popularity, these pure EVs have outperformed their plug-in hybrid and fuel cell counterparts. This is due in part to state support when buying pure EVs and in part to the achievements of BYD and CATL. State support can be observed in the list of fuel cell vehicles, which only features Chinese automotive manufacturers. This indicates that the Chinese support scheme is also intended to weaken Japanese competitors, who have historically excelled in hydrogen technology. In a different type of subsidy, consumers received a discount on the purchase of EVs equipped with batteries manufactured by Chinese firms.

In addition to the above-mentioned schemes, the credit system also serves as a significant mechanism for state intervention. This mandates automobile manufacturers to increase the percentage of EV sales annually and/or to decrease the share of sales of vehicles powered by internal combustion engines (ICEVs)(Yumo, 2020). The New Infrastructure Plan (2020–2025)advocates for the development of next-generation infrastructure, including electric charging stations, current electric grids, and transportation systems (Udemans et al., 2020). In 2020, a new regulation on the purchase subsidy programme was enacted, stipulating that the prior to subsidy retail price of EVs could not exceed 300,000 yuan ($48,000)(Ministry of Finance of China, 2020). In April 2022, the State Council announced decisions to boost domestic consumption, including the purchase of EVs. According to these decisions, local authorities were prohibited from imposing restrictions on new automobile purchases but were urged to promote the purchase of EVs and the development of charging infrastructure (Kennedy, 2024).

Table 2 presents the main policy instruments shaping the development of China's EV industry. In contrast to the PV case (Table 1), EV policy exhibits clearer sequencing between capability building, market creation, and gradual policy recalibration, although important structural tensions remain.

In summary, the environmental implications of industrial policy intervention, specifically its genuinely 'green' nature, remain ambiguous in the context analysed in this chapter. For instance, regarding the undoubtedly growing popularity of EVs in China, it is not enough to concentrate solely on zero emissions of EVs, as the manufacturing process itself produces considerable emissions, potentially exceeding those from the production of ICEVs (Taub, 2022). Furthermore, the ecological consequences of EVs significantly rely on the methods of energy generation and the advancement of battery technology employed (Faria et al., 2013). Although Chinese manufacturers excel in battery technology, the continued reliance on coal-fired power plants undermines the effectiveness of genuinely green industrial policies.

6. Efficiency, discipline, and policy learning: a comparative assessment

A comparative assessment of the PV and EV industries reveals both continuity and evolution in China's green industrial policy. In both sectors, the state has played a central role as coordinator, financier, and regulator, embedding industrial development within long-term strategic planning frameworks and successive Five-Year Plans. Foreign cooperation – through joint ventures, research collaboration, and access to global markets – was particularly important in the early stages of both industries, while later phases saw the rise of globally competitive Chinese firms and a growing emphasis on technological self-reliance. At the same time, the two cases differ markedly in the sequencing, discipline, and adaptive capacity of state intervention, suggesting a process of policy learning rather than a uniform or static model. The comparison also allows for a more general distinction between different configurations of industrial policy instruments and their associated outcomes, as summarised in Table 3.

A shared feature of both sectors is the initial prioritisation of research, development, and production capacity, with domestic market creation following only later. However, the temporal gap between these phases differs significantly. In the PV industry, large-scale domestic deployment lagged behind export-oriented expansion by almost a decade, rendering the sector highly dependent on foreign demand and exposing it to trade conflicts once global overcapacity emerged. By contrast, in the EV sector, domestic demand stimulation through purchase subsidies, public procurement, and infrastructure investment was introduced relatively early, allowing scale expansion to be absorbed more smoothly within the domestic market. This shift can also be interpreted in light of China's broader transition from export-led growth towards a more domestically anchored development model (Szunomar, 2020), often conceptualised as 'dual circulation'. While the PV sector initially relied heavily on external demand, the EV sector reflects a more integrated approach in which domestic market creation plays a central role from an earlier stage.

From the perspective of industrial policy theory, the PV sector exemplifies an early form of green industrial policy characterised by rapid scale expansion combined with weak initial discipline. Subsidies were widely accessible, oversight was limited, and coordination between central and local governments remained imperfect. These features contributed to persistent overcapacity, price wars, and international trade disputes – outcomes widely discussed in the critical literature on industrial policy failures and market distortion. By contrast, the EV sector shows clearer evidence of policy learning. Support instruments were more differentiated, subsidy schemes were gradually tightened, and eligibility criteria were increasingly linked to technical performance and compliance. Mechanisms such as the NEV credit system, phased subsidy reduction, and enhanced auditing reflect

Table 3. Industrial policy configurations and developmental outcomes: PV and EV comparison.

Sector	Policy configurations	Core instruments	Strengths	Risks
PV	Scale-driven, supply-side dominant (weak discipline)	Subsidies, preferential finance, export support, local incentives	Rapid capacity expansion; cost reduction; global competitiveness	Overcapacity; price distortions; trade conflicts; weak exit mechanisms
EV	Sequenced, mixed supply – demand with increasing discipline	R&D support, consumer subsidies, public procurement, infrastructure investment, regulatory mandates (e.g. credit system)	More balanced growth; domestic market formation; policy learning	Policy dependence; fiscal burden; coordination challenges

an explicit attempt to operationalise what Rodrik (2014) terms 'discipline' within state-led industrial transformation.

Ownership structure further illustrates this evolution. While early PV support initially favoured state-owned enterprises, the sector's eventual leaders are predominantly privately owned firms, whose innovative capacity proved decisive. In the EV sector, privately owned enterprises have been central beneficiaries from the outset, alongside major SOEs. This pattern underscores that China's contemporary state capitalism does not hinge on ownership per se, but on performance, scalability, and alignment with strategic objectives. Nevertheless, private ownership does not imply autonomy from the state: political embeddedness, regulatory compliance, and responsiveness to policy priorities remain integral to firm success, consistent with the literature on embedded autonomy and state-business relations (Milhaupt & Zheng, 2015). While SOEs often benefit from preferential access to finance and policy support, private firms have demonstrated greater dynamism in innovation and international competitiveness. The interaction between these firm types suggests a hybrid model in which industrial policy operates through performance-based alignment rather than strict ownership control.

Despite these improvements, persistent inefficiencies and distortions remain. Provincial protectionism, fragmented incentive schemes, and documented cases of subsidy misuse point to the limits of centralised oversight in a large and decentralised political economy (Wang & Liu, 2024; Wu, 2019). In both sectors, the state has responded to such failures not by retreating, but by recalibrating instruments, tightening enforcement, and shifting from direct subsidies towards more indirect forms of support (Wu & Zhang, 2022; Xu et al., 2025). This pattern reinforces the view that Chinese industrial policy operates through iterative adjustment rather than once-and-for-all design.

However, the formal reduction of direct subsidies should not be conflated with state withdrawal. In the PV sector, Wood Mackenzie (2023) suggests that investment amounting to several tens of billions of dollars was mobilised in recent years via policy-enabled channels, mainly directed towards capacity expansion and large-scale deployment rather than firm-level fiscal transfers. This scale of capital mobilisation continues to shape global price dynamics and export competitiveness, even in the absence of explicit production subsidies. Similarly, in the EV sector, the phase-out of purchase subsidies has been accompanied by tax exemptions, infrastructure investment, and regulatory mandates that sustain demand and shape market outcomes. These developments highlight a structural shift from visible subsidies towards more indirect, yet still consequential, forms of state intervention.

7. Conclusions: the green leap forward between transformation and contradiction

This article introduced the concept of a green leap forward to capture China's attempt to compress industrial upgrading, technological catch-up, and ecological transition into a single, state-coordinated developmental project. Rather than treating China's green industries as either a success story of ecological modernisation or a distortionary case of state capitalism, our research highlights the productive tensions between these logics. Through a comparative analysis of the photovoltaic (PV)and electric vehicle (EV)industries, the article has examined how GLF operates in practice, and where its promises encounter structural limits.

The analysis demonstrates that state intervention has been indispensable in both sectors for overcoming entry barriers, coordinating large-scale investment, and enabling Chinese firms to achieve global competitiveness in technologically demanding industries. In this respect, the GLF aligns with core insights from the developmental state literature and recent work on new state capitalism, which emphasise embeddedness, coordination, and strategic selectivity. Both the PV and EV cases show how the Chinese state has mobilised policy instruments across finance, regulation, procurement, and infrastructure to shape markets rather than merely correct them.

At the same time, applying Rodrik's efficiency criteria reveals that the GLF is not a frictionless or purely efficiency-enhancing process. Embeddedness is clearly present, as policy design has emerged from sustained interaction between state actors, firms, utilities, and research institutions. Discipline has improved over time, particularly in the EV sector, where subsidies have been progressively conditioned, reduced, and monitored. Accountability has also increased through greater transparency, public reporting, and audits. Yet these mechanisms remain incomplete and uneven, and tensions persist between scale expansion, fiscal sustainability, and market distortion. In this sense, the GLF reflects policy learning rather than policy resolution.

From the perspective of ecological modernisation, the findings are even more ambivalent. While the expansion of PV and EV industries contributes to decarbonisation at the margin, environmental objectives have consistently remained subordinate to industrial upgrading and geopolitical considerations. The continued dominance of coal in China's energy mix (above 50%), the emissions embedded in manufacturing, and the raw material intensity of battery production limit the immediate ecological gains of the transition. Rather than representing a linear shift towards sustainability, the GLF operates as a hybrid project in which environmental goals function simultaneously as policy drivers and legitimising narratives for industrial transformation.

The comparative analysis highlights important differences between the two sectors. The PV industry represents an early phase of green industrial policy characterised by rapid expansion, weak initial discipline, and severe overcapacity, followed by reactive adjustment. The EV sector, by contrast, shows more deliberate sequencing, earlier demand-side support, and stronger mechanisms of monitoring and conditionality. However, these improvements do not resolve the deeper contradictions inherent in large-scale state-led transformation under conditions of global competition, where the pursuit of rapid industrial expansion and global market leadership continues to generate pressures towards overcapacity, policy dependence, and trade tensions, while environmental objectives remain only partially integrated into industrial outcomes.

Taken together, the findings suggest that the GLF is neither a purely celebratory success nor a fundamentally flawed experiment. It is best understood as an ongoing, adaptive process in which industrial upgrading has advanced faster than ecological transformation. The central dilemma is therefore not whether state intervention is necessary – the cases strongly suggest that it is – but how long and under what conditions such intervention can remain effective without reproducing new forms of dependency, overcapacity, and environmental externalities. From this perspective, China's green leap forward appears to align more closely with a green growth paradigm than with degrowth-oriented approaches, as industrial expansion remains central despite persistent environmental trade-offs.

Future research should build on the GLF experience by examining its applicability beyond flagship green sectors and beyond China, comparing how different political economies manage the trade-offs between industrial ambition, environmental credibility, and global integration. In particular, a more systematic comparison with industrial policy experiences in advanced economies such as the United States and the European Union, as well as with earlier industrialisation phases of newly industrialised economies in East Asia, could provide valuable historical perspective on the role of discipline, conditionality, and policy learning in state-led development processes. Such work would help clarify whether the green leap forward represents a context-specific trajectory enabled by scale and state capacity, or a broader template for late-developing economies navigating the pressures of green transformation under conditions of geopolitical fragmentation.

Notes

1. Photovoltaics (PV)refer to technology converting sunlight directly into electricity.
2. Production capacity refers to maximum potential production, while output reflects actual production; the gap between these is relevant for overcapacity debates.
3. Installed capacity is the operational production capacity connected to the grid, usually measured in GW, rather than the actual electricity generated.
4. Distributed PV projects (DPVs)are small-scale, decentralised installations (e.g. rooftop solar), contrasted with utility-scale power plants.
5. Grid parity is the point where the cost of solar electricity equals or undercuts conventional grid electricity without subsidies.

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CRediT: **Ágnes Szunomár:** Conceptualization, Formal analysis, Methodology, Writing – original draft.

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