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China's Model of Technology Leapfrog: A Case Study of electric vehicle policies and the development of green technology

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Highlights

- China has leapfrogged global competitors, becoming an leader in the EV industry;
- Political and economic factors influenced China's EV development strategies;
- Top-down approach to EV policies and local pilot programs facilitated EV deployment;
- Framework established for understanding China's technological leapfrogging model.
- Transition to low-carbon economy requires phasing out initial subsidies while fostering technological innovation to sustain momentum.

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Abstract
The development of green technology is vital for driving economic growth and building low-carbon economies. In this era of technological advancement, the concept of "leapfrogging" has gained importance as emerging economies adopt advanced technologies, bypassing traditional stages of development. China, once a latecomer in the global automobile sector, strategically embraced electric vehicles (EVs) in the early 2000s and, after two decades of sustained policy and industrial efforts, has overtaken major competitors to become the world leader in the EV market. Yet there is limited systematic analysis of how China's policy design, political economy, and industrial strategies jointly enabled this leapfrogging. This study addresses this gap through a systematic policy review and a case study of China's EV sector. We analyze the drivers of government decision-making, the political economy of EV policy, the design of policy frameworks, and their impacts at both national and global levels. Our findings show how China combined early entry into a new technological field with coordinated state intervention, integrating EV technology development, manufacturing capacity, domestic demand, and industrial transformation. By tracing the evolution of EV policies over the past 20 years, the study develops a framework for understanding China's technological leapfrogging model and contributes to global debates on sustainable technology transitions by offering insights for other emerging economies to design green technology pathways.

Keywords: Electric Vehicle Policy, Technology Leapfrogging, Green Technology, Research and Development, China

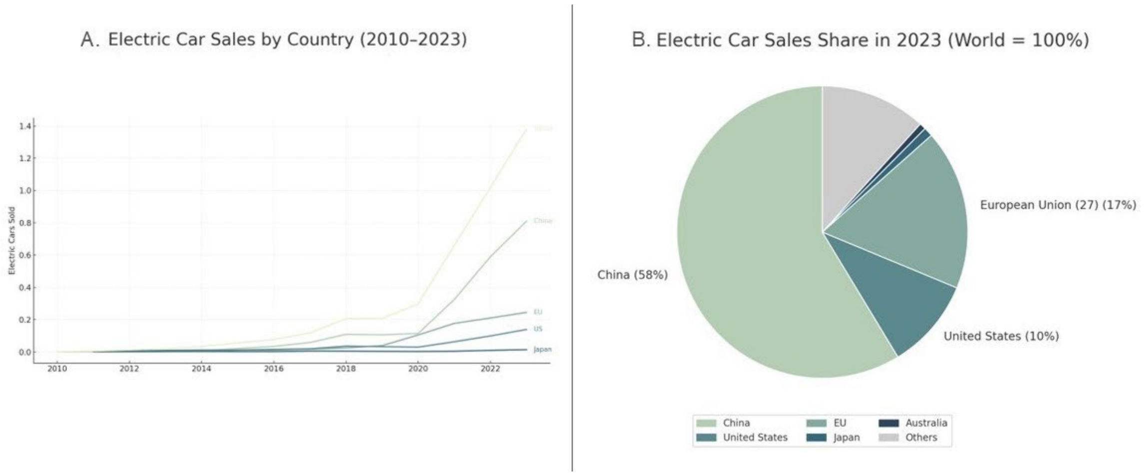
1. Introduction

Global environmental challenges, such as climate change, rising greenhouse gas emissions, and deteriorating air quality, have intensified the urgency for countries to seek sustainable development pathways. In response, the international community has set ambitious goals, most notably the Paris Agreement's target of achieving global carbon neutrality by 2050.

These goals are further reinforced by the United Nations Sustainable Development Goals (SDGs), particularly SDG3 (good health and well-being), SDG7 (affordable and clean energy), SDG11 (sustainable cities and communities), SDG12 (responsible consumption and production), and SDG13 (climate action) (Kumar et al., 2024). To meet these targets, many countries have turned their attention to the transportation sector, one of the largest contributors to carbon emissions. Electrification of road transport has thus become a key strategy, as electric vehicles (EVs) can significantly reduce fossil fuel dependency, lower greenhouse gas emissions, and improve urban air quality. Among various green technologies, EVs are therefore regarded as one of the most promising solutions for decarbonizing transportation and advancing sustainable mobility (Chandra, 2022; Ullah, 2023; Zhu et al., 2022).

By 2023 there were more than 40 million EVs in use worldwide—up from just 26 million in 2022—yet the results of global efforts have significantly differed across countries. As shown in Figure 1. A, EV sales in the United States, European Union, and Japan have grown steadily but remained relatively modest. The United States, despite early technological leadership and substantial federal incentives, accounted for only 10% of global EV sales. The European Union, supported by stringent emission regulations and generous subsidies, held approximately 17% of the market. Japan, once the leader in hybrid technologies, has experienced limited EV adoption, with sales remaining low despite its established role in the automotive industry. Even Germany, Europe’s automotive powerhouse, reached only 18% EV market share by 2023, reflecting a slower transition in mature automobile markets. In contrast, China has experienced a dramatic surge in EV deployment, as illustrated in Figure A by its steep sales growth after 2018. By 2023, China alone accounted for about 58% of global EV sales (Figure 1.B), far exceeding other major economies. This rapid expansion highlights China’s unique trajectory: while many countries have adopted EV policies, only China has achieved such a large-scale automotive market. These disparities raise critical questions about what distinguishes China’s approach from those of other nations and provides provide a foundation for analyzing its leapfrogging pathway.

Figure 1. Global Electric Car Sales Overview



Note: The Data source is from Official statistics published by the International Energy Agency (IEA).

The term “technology leapfrogging” refers to an emerging market economy rapidly transitioning to develop and adopt more advanced technologies that are more commonly used in advanced market economies, bypassing the traditional or intermediate stages of technological development experienced by the latter (Soete, 1985; Davison et al., 2000; Fong, 2009; Chen & Li, 2011). Unlike the gradual approach of “technological catching-up,” which involves steady imitation of advanced technologies, leapfrogging enables quicker advancement through innovation or by adopting more advanced technologies directly (Moon et al., 2021). This is made possible because adopting the latest technologies is more cost-effective and efficient, requiring less infrastructure and investment to set up. By successfully leapfrogging into advanced technology sectors within emerging markets, a country can establish a dominant position in specific technology fields, close the technological gap with more developed counterparts, and ultimately accelerate its development and enhance its global competitiveness. China provides a compelling example of this process in the EV industry.

Historically, China was a follower in the conventional automotive sector, heavily reliant on foreign investment and technology (Liu & Dicken, 2006; Chu, 2011; Harwit, 2016). Without a strong legacy in traditional car manufacturing, China was less constrained by path dependence and thus embraced EV technologies early, positioning itself to leapfrog global competitors that had long dominated the industry. For the past two decades, China has implemented national-level policy measures and local demonstration programs to promote

EV deployment, alongside significant investments in research and development of core components such as batteries, power systems, power electronics, intelligent systems, and charging infrastructure (Zheng et al., 2012; Du & Ouyang, 2017; Wang et al., 2017; Zhang et al., 2017; Zhang & Bai, 2017; Qiu et al., 2019; Wu et al., 2019; Muniz et al., 2019; Shang et al., 2024). These supportive policies, framed within a national strategic roadmap, have not only contributed to the government's climate goals by reducing transport emissions (Zhang & Hanaoka, 2021), but also facilitated leapfrogging in the automobile industry.

China's EV manufacturing and production capacity further illustrate this leapfrogging trajectory. As planned in the "Technology Roadmap 2.0 for Energy-Saving and New Energy Vehicles, [1]" over 50% of new car sales in China are now attributed to EVs, making it the first major economy to achieve such a milestone (International Energy Agency, 2024; China Society of Automotive Engineers, 2020). This market maturity is the outcome of aggressive national and local policies over the past decade, which have produced not only environmental benefits but also far-reaching impacts on the domestic automobile market, international trade, and national competitiveness. China's strategic deployment of EVs, aligned with climate and sustainability initiatives, has empowered indigenous green technology development, particularly in batteries, and stimulated the growth of a low-carbon economy.

In response to climate change and the urgent global mission to achieve carbon neutrality by 2050 as outlined in the Paris Agreement, there is a growing interest in accelerating electric mobility worldwide. This also strongly aligns with several Sustainable Development Goals (SDGs), including SDG3 (good health and well-being), SDG7 (affordable and clean energy), SDG11 (sustainable cities and communities), SDG12 (responsible consumption and production), and SDG13 (climate action) (Kumar et al., 2024). The adoption of EVs reduces fossil fuel dependency, greenhouse gas emissions, and air pollution, helping mitigate climate change and create healthier, more sustainable communities (Ullah, 2023). Since the transportation sector is a major source of greenhouse gas emissions, electric mobility is seen as a promising solution to reduce carbon emissions (Zhu et al., 2022). To achieve environmental goals, countries around the world have proposed and implemented various policy measures to accelerate the deployment of EVs, including monetary incentives (e.g.

[1] Technology Roadmap 2.0 for Energy-Saving and New Energy Vehicles. Society of Automotive Engineers of China (SAE-China). Accessed April 4, 2025. https://en.sae-china.org/a3967.html.

purchase subsidies, registration tax deductions and exemptions), as well as non-monetary incentives (e.g. road access privilege, free parking for EVs, investments in charging infrastructure, bans on sales and registrations of conventional cars, and regulatory instruments and standards in vehicle manufacturing). The global automotive market is shifting toward electric vehicles, recognizing their ability to lower transportation costs, reduce carbon emissions, and improve air quality. Existing policies also facilitated the sustainable growth of EVs during the pandemic, alongside shifts in travel behavior (Zhu & Guo, 2022).

Against this backdrop, this study contributes in three ways. **First**, it investigates how China's multi-level EV policies enabled leapfrogging, advancing understanding of the interaction between state intervention, market growth, and technological innovation. **Second**, it develops a framework to analyze leapfrogging pathways that integrates government policy, EV market expansion, green technology development, and industrial transformation. **Third**, by situating China's experience within the global context, the study provides insights for other emerging economies seeking to leverage policy to accelerate sustainable industrial transitions. By addressing these gaps, the paper advances the discourse on both EV policy and leapfrogging in emerging technologies.

The structure of this paper is as follows. Section 2 outlines the research methodology. Section 3 examines the factors shaping China's EV policy. Section 4 analyzes the evolution of EV policy implementation across four stages. Finally, Section 5 reviews China's EV development and conceptualizes its leapfrogging model within the broader global context.

2. Methodology

The promotion of EVs in China is an interesting case study of how national-level policies foster the development of an emerging technology field, shift market behavior, facilitate industrial growth, and, consequently, contribute to technology leapfrogging for both environmental and economic reasons. This study addresses four guiding questions:

1) What factors influenced China's policy decision-making over EV development? We will explore why the development of EVs is critical for China's automobile industry and disentangle the political economy behind China's leapfrog in EVs as a strategic, technological field.

2) The promotion of EV adoption has become a part of the Chinese government's agenda in the past decade and has received increasing attention in policy making. What are the key driving forces of the Chinese government in making policy decisions to deploy EV in the automobile market?
3) How are policies for EV adoption formulated and how do these evolve in China? What changes have been made to China's EV policies to address the key challenges in achieving widespread adoption of EVs in the Chinese automobile market?
4) To conceptualize China's model of technology leapfrogging in the case of EVs, how do China's EV policies help foster the local EV market and facilitate indigenous innovation and development of core technologies in EVs? And how does this ultimately expand the country's technology influence?

To address these questions, the study employs a retrospective case study and systematic policy review of China's EV sector, which represents the world's largest and fastest-growing EV market and a representative example of policy-driven technological leapfrogging. Battery technology is emphasized because it constitutes the core of EVs, accounts for the highest cost share and presents the greatest technological barriers, and thus plays a decisive role in driving competitiveness and leapfrogging. The review covers official documents issued primarily by central government agencies—including the State Council, NDRC, MIIT, MOST, and MOF—from the early 1990s to 2024. These documents include strategic plans, Five-Year Plans, administrative regulations, subsidy programs, and regulatory instruments such as the dual-credit policy. Screening is based on keywords such as "electric vehicle," "new energy vehicle," and "green technology." Policies are then coded by function (e.g., financial incentives, regulatory instruments, R&D support, infrastructure development), enabling the analysis of their evolution across four stages. A longitudinal qualitative approach complements this retrospective review by examining how these policies shaped industrial development, market transformation, and the domestic low-carbon economy.

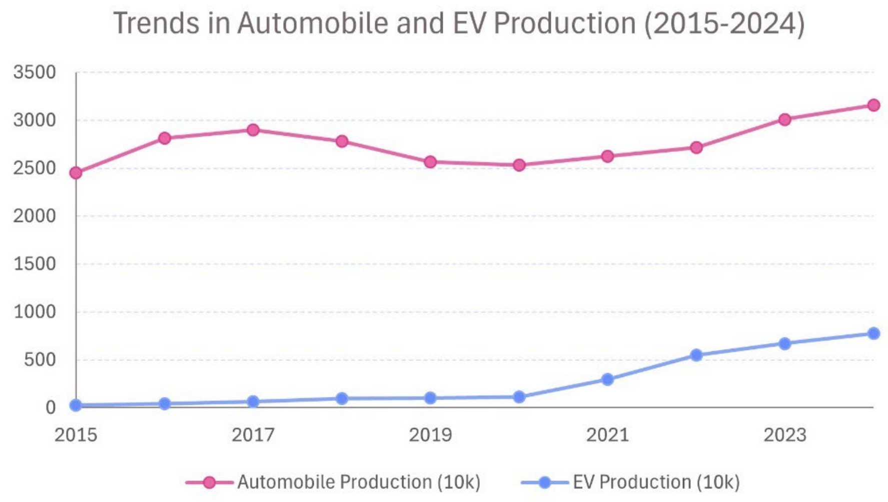
The analysis is informed by leapfrogging theory, which traditionally argues that latecomers can bypass intermediate stages by adopting advanced technologies (Perez & Soete, 1988). Building on this perspective, the study develops the concept of a Chinese Technological Leapfrogging Model as an integrated development strategy characterized by: (1) proactive market creation through comprehensive policy interventions; (2) simultaneous development of complete industrial ecosystems; (3) dynamic policy evolution across development stages; and (4) strategic balance between indigenous innovation and international collaboration.

Finally, while the scope of this study focuses primarily on China, it also situates the case within the broader emergence of the global EV market. By revisiting how governments worldwide have framed EVs as a response to climate change, the study highlights both the uniqueness of China's policy trajectory and the potential relevance of its experience to other countries and to the broader development of green technologies.

3. What Influenced China's Decision-Making on EV Development

Global climate change mitigation policies often include electrifying light-duty road transport to meet transportation-sector carbon-emission standards and achieve carbon-neutrality goals. EVs are widely regarded as the most promising alternative to internal combustion engine vehicles (ICEVs), as they are more effective in lowering greenhouse gas emissions, urban air pollution, and energy consumption (Casals et al., 2016; Nordelöf et al., 2014; Archsmith & Rapson, 2015; Hardman et al., 2017). China's strong policy push for EVs can be explained by five interrelated factors: energy security, climate goals, technological dependency, R&D and manufacturing capacity, and the necessity of industrial transformation. As shown in Figure 2, while overall automobile production in China has remained relatively stable between 2015 and 2024, EV production has grown rapidly, especially after 2020. This sharp increase reflects the effectiveness of China's industrial policies and demonstrates how EVs have become a critical pillar for both carbon reduction and industrial upgrading.

Figure 2 Trends in Automobile and EV Production in China (2015-2024)



Note: Unit: 10k vehicle; The data source is from National Bureau of Statistics of China

3.1 Energy security

Power relations often refer to the influence and control one country exerts over another, which can be economic, political, or military (Barnett & Duvall, 2005; Swyngedouw, 2009; Meierding & Sigman, 2021). In the context of China's EV industry, the concept of power relations can be used to analyze how China has strategically positioned itself in the global EV market. The rise of China's EV industry is not merely a technological shift but also a geopolitical maneuver aimed at altering global energy dependencies and strengthening national security.

Energy stability has been a military and economic focus for China for much of the last three decades. Since 1993, China has been a net importer of crude oil and is projected to soon surpass the United States as the world's largest oil importer (Daojiong, 2006). Currently, about half of its oil consumption is imported, with transportation accounting for one quarter of total demand (IEA, 2012). Around 60% of imported oil comes from the Middle East and passes through the Malacca Straits- a vulnerable chokepoint that adversaries could threaten. According to the Ministry of Industry and Information Technology (MIIT), new car purchases account for 70% of China's annual growth in gasoline and diesel consumption. This dependence exposes China to oil price volatility and potential supply disruptions, pushing the government to prioritize indigenous energy supplies, both traditional and renewable (Howell et al., 2014).

Against this backdrop, the promotion and adoption of EVs directly enhance China's energy security by reducing its reliance on foreign oil. EV leadership also shifts the global energy balance: it reduces China's exposure to oil market fluctuations and undermines the dominance of traditional oil-producing countries. In doing so, it reinforces China's long-term economic resilience and supports its broader aspiration to become a global superpower.

The electrification of transportation thus serves multiple strategic purposes. By accelerating EV adoption, China not only reduces oil dependency but also builds indigenous capabilities in energy production, storage, and distribution. This is essential as China transitions toward cleaner, domestically produced energy sources, aligning with its long-term strategy to ensure a stable energy supply and support sustainable development. The political economy of China's energy transition highlights how EVs link technological innovation with structural power. As Strange (1988) observes, structural power derives from setting the rules: by shifting from imported oil to domestically generated electricity, China moves from being a "price-taker" in oil markets to a "rule-maker" in battery technology. This transformation represents not only enhanced energy security but also a fundamental reshaping of global industrial hierarchies.

3.2 Climate goals and the ambition to build a global leadership profile

China's EV strategy aligns with both domestic environmental priorities and international climate commitments. Domestically, China has set incremental increases in climate change abatement targets in recent years, aiming to peak carbon emissions by 2030 and reach carbon neutrality by 2060 (Zhong et al., 2019; Zhao, 2022). China plans to increase the proportion of non-fossil fuels used in primary energy consumption to about 20% by 2030, as outlined in the Intended Nationally Determined Contributions (INDC) (He, 2015). In the 14th Five-Year Plan (2021-2025)[2], China set targets to reduce carbon intensity (carbon emissions per unit of GDP) and energy intensity by 18% and 13.5%, respectively. The positive co-benefits between climate change, energy conservation, and environmental quality triggered the

[2] Xinhua News Agency. (2021). Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035. Retrieved from https://cdn.climatepolicyradar.org/navigator/CHN/2021/outline-of-the-people-s-republic-of-china-14th-five-year-plan-for-national-economic-and-social-development-and-long-range-objectives-for-2035_a2ad3e061fca627d9a44d7b91f7aa210.pdf

establishment of the Department of Climate Change[3] in 2018, which makes key decisions on China's climate policy and influences the national development plan (Teng & Wang, 2021). Under the unitary hierarchy of China's political system, climate policy made by the central government shares a wide consensus with provincial and local governments, who are responsible for its implementation (Qi & Wu, 2013). Leading provinces in terms of emission mitigation exemplify the positive climate impacts of industrial structure and energy transitions (Mi & Sun, 2021).

At the same time, EVs directly address local environmental concerns. In 2004, seven of the world's ten most polluted cities were in China(Asian Development Bank, 2012). Battery EVs, with zero tailpipe emissions, provide a concrete solution for reducing urban air pollution (Smith, 2010; Manjunath & Gross, 2017). Thus, EV adoption serves both as a domestic priority to improve air quality and as a national instrument for meeting international pledges.

As the world's largest emitter of greenhouse gases, China's commitments under the Paris Accord signal both responsibility and ambition on the global stage. Promoting EVs helps China demonstrate credibility in addressing climate change while strengthening its role in global climate dialogues. In the broader context of sustainable development and the low-carbon economy, China's EV policy thus positions the country as both a domestic reformer and an international leader in transport sustainability.

3.3 Demand for technological advancements in the face of sanctions and historical dependency

China's pursuit of EV development is also shaped by its historical dependence on foreign technologies and the constraints this has placed on domestic innovation. For decades, the automobile sector relied on joint ventures with foreign firms, which provided access to advanced manufacturing knowledge but restricted the transfer of core technologies (Liu et al., 2022). This created a structural disadvantage: while joint ventures enabled "leapfrogging development" to avoid carbon-intensive phases (Liddle & Huntington, 2021), they also

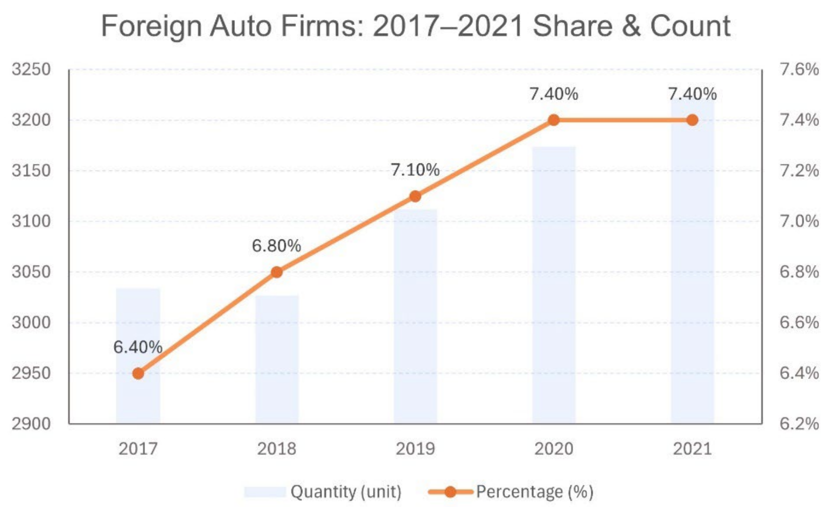
[33] Ministry of Ecology and Environment (MEE). (2021). China's policies and actions to address climate change. http://www.mee.gov.cn/ywgz/ydqhbh/syqhbh/202107/W020210713306911348109.pdf

reinforced foreign control over key technologies and limited China's capacity for independent innovation.

Dependency theory suggests that developing countries often rely on early industrialized, developed nations for technology and expertise, which hinders their ability to innovate independently (Hein, 1992; Lall, 1975; Vernengo, 2006; Ghosh, 2019; Gao et al., 2023). In China's auto sector, this manifested as a "technology trap": joint ventures provided market access but locked Chinese firms into permanent junior partnerships, extracting what has been described as "technological rents" (Cantwell, 1989) without capability transfer. The U.S.–China trade war, which intensified after 2018, further exposed China's vulnerability in global value chains and highlighted the risks of technological dependency. The semiconductor sanctions transformed technology from an economic to a security issue, validating China's fears of the "chokehold" problem. To mitigate these risks, China prioritized domestic innovation in strategic industries, particularly in the EV sector.

Rennings (2000) argues that corporate green innovation bears a high level of uncertainty in relation to external costs and spillover effects. Therefore, external sources and support are required for promoting green technology innovations. In China, reliance on foreign direct investment limited incentives for indigenous innovation, producing a technological gap in conventional vehicles. Game theory explains this stasis: foreign firms maximized profits by maintaining technological superiority, while Chinese firms accepted subordinate but profitable positions—a stable but suboptimal equilibrium. EVs disrupted this equilibrium by resetting the technological playing field, where China's control over battery materials and manufacturing scale could overcome foreign firms' accumulated advantages. By focusing on EVs, China reduced dependence on Western-dominated engine technologies and advanced its industrial upgrading strategy. As shown in Figure 3, the proportion of foreign-invested automobile firms in China increased by 0.7% from 2017 to 2019, but only 0.3% from 2019 to 2021, reflecting a slowdown in reliance on foreign investment.

Figure 3 Statistics on the Number and Share of Large-Scale Foreign-Invested Automobile Manufacturing Enterprises (2017–2021)



In the past decade, the Chinese government has been shifting its role and restructuring its national innovation system, allocating enormous funds in the Major National Science and Technology Projects[4] and targeting specific areas to achieve its technology ambitions (Schaaper, 2009; Sun & Liu, 2010; Băzăvan, 2019). With intensifying global competition and sanctions, particularly in chips and semiconductors, Beijing has emphasized breakthroughs in batteries, drivetrains, and autonomous driving systems. In this context, EVs have become a strategic sector through which China demonstrates its capacity to overcome technological barriers, achieve self-reliance, and establish itself as a global green-tech leader.

3.4 Foundations for EV technology leapfrogging: R&D and manufacturing capacities

China has established itself as a global leader in green technology development, particularly in the areas of renewable energy and manufacturing capacities. The country has made significant investments in research and development (R&D), with R&D expenditure reaching $378 billion in 2020, accounting for 2.4% of its GDP. China's R&D intensity has steadily increased, nearly reaching the OECD level. Additionally, China has surpassed the European

[4] Major National Science and Technology Projects," Ministry of Science and Technology of the People's Republic of China, April 21, 2016, accessed April 4, 2025. https://en.most.gov.cn/pressroom/201604/t20160421_125257.htm.

Union in R&D spending, further highlighting its commitment to technological advancement (Daxue Consulting, 2020; OECD, 2018).

China's manufacturing capabilities have also played a crucial role in its green technology dominance. The country experienced remarkable growth in its solar photovoltaic (PV) industry during the 2010s, becoming the world's largest producer of solar panels. China's solar-PV industry demonstrated the importance of a well-functioning national innovation framework and a favorable business environment in driving technology procurement, adaptation, and growth. Indigenous innovation, advanced R&D, and strong collaborations between institutions, universities, and research organizations have been key factors in China's solar-PV industry success (Bloomberg, 2021; Strangway et al., 2009; Zhang et al., 2014; Lema et al., 2012; Fu & Zhang, 2011).

China's manufacturing prowess extends to the electric vehicle (EV) sector, particularly in battery production. The country currently dominates EV battery manufacturing, as well as mining and refining critical battery materials. With 78% of the world's cell manufacturing capacity for EV batteries, China plays a vital role in the global supply chain for battery production and EV manufacturing. As batteries are the costliest component of EVs, China's ability to lower battery prices through economies of scale has contributed to the overall affordability and success of EVs in the global market (Castillo & Purdy, 2022; Hsieh et al., 2019).

The parallels between the solar-PV and EV industries suggest that China's model of technological leapfrogging, demonstrated in the solar-PV sector, can be applicable to the deployment of EVs. Both industries rely on green technology innovation, with private firms playing a significant role in technological development and commercialization. Leveraging China's experience in the solar-PV industry, emerging markets can learn how to keep pace with advanced economies in green industries and achieve sustainable low-carbon economies (Hsieh et al., 2019).

3.5 Necessities for industrial transformation in the automobile industry

In the 1990s, the Chinese automobile industry experienced rapid growth in response to increased demand for passenger cars. However, Chinese firms lacked the technological capabilities to develop and manufacture new vehicles independently, relying on foreign investors and joint ventures for advanced technologies (Gallagher, 2006). While international cooperation brought technological spillovers, dependence on foreign direct investment hindered the emergence of autonomous R&D (Meier, 2018).

To overcome these challenges and prevent stagnation, China implemented a national industrial policy framework that prioritized R&D and technological upgrades (in der Heiden, 2016). Recognizing that long-term competitiveness required more than capacity expansion, the Chinese Communist Party introduced an innovation-driven strategy to promote value-adding manufacturing and high-end technologies (18th National Congress of the Chinese Communist Party, 2012[5]). These policies aligned with broader societal goals such as energy efficiency and sustainability, positioning innovation as central to both industrial transformation and leapfrogging development (Yap et al., 2022).

In this context, the automobile industry emerged as a strategic focus area, aligning with China's broader goals of economic modernization and global leadership. The electric vehicle (EV) market, in particular, was identified as a critical driver of this transformation, offering opportunities to revolutionize the automotive sector and establish China as a leader in sustainable technologies (Howell et al., 2014; Mekky & Collins, 2023). President Xi Jinping emphasized the strategic importance of developing new energy vehicles (NEVs), including plug-in EVs, as a means of propelling China's automotive industry forward (2012-2020 Development Plan for Energy Saving and New Energy Vehicle Industry[6]).

The development of NEVs also capitalizes on China's resource advantages. The country controls a significant share of global cobalt and lithium reserves, critical for battery production (Benchmark Mineral Intelligence, 2022; Cobalt Institute, 2022). This access

[5] 18th National Congress of the Chinese Communist Party, China.org.cn, November 16, 2012, accessed April 4, 2025, http://www.china.org.cn/china/18th_cpc_congress/2012-11/16/content_27137540.htm.

[6] 2012-2020 Development Plan for Energy Saving and New Energy Vehicle Industry, State Council of the People's Republic of China, July 9, 2012, (Chinese only) accessed April 4, 2025, https://www.gov.cn/zwgk/2012-07/09/content_2179032.htm.

strengthens China's capacity to develop indigenous battery technologies and secure a leadership position in the global EV market (Krieger et al., 2012).

In summary, China's automobile industry recognized the need for industrial transformation and technological leapfrogging to compete globally. With a focus on R&D, technological upgrades, and the development of NEVs, China aims to achieve its goal of becoming a powerful automobile country and secure a leadership position in the EV market.

4. Review of the Evolutionary Path of China's EV Policies

Since the early 2000s, China has made significant progress in EV development through extensive policy support. Consistent with the logic of industrial policy—that governments can intervene to promote strategic industries and facilitate structural transformation (Westphal, 1990; Lall, 2003)—China introduced direct investments in R&D and charging infrastructure; financial incentives, such as purchase rebates, tax credits, and sales tax exemptions; and regulatory requirements for manufacturers and importers. Together, these measures altered car purchasing behaviors, reshaped production, and enabled the rapid growth of EVs. On this basis, the relevant policies can be organized into four stages.

In the infancy stage, the Chinese government prioritized large-scale demonstration projects to showcase the benefits of EVs. This was to strategically plan the management guidelines of the industry and approval of qualified manufacturers to produce EVs. In the second stage, EV adoption in some cities was boosted by supportive subsidies. With the gradual maturity of EV technology and the decline of subsidy policies, the EV market was transformed from a policy-incentivized market back to a pure, free market in the third stage of phasing out subsidies and industrial restructuring (Qadir, 2024). And finally, in stage four, regulations to strengthen EV market growth were ramped up to align with environmental priorities for sustainable technology development.

4.1 Stage I-Infancy: Demonstration Projects

China's EV policy foundation was laid well before large-scale demonstrations.. In the Eighth Five-Year Plan (1991–1995) [7], the government launched the project "*Research of the Key Technologies of EVs*" to support this initiative (Chen et al., 2006). Later documents, such as "*The Mid- and Long-term Special Planning for Energy Conservation,*"[8] launched by the National Development and Reform Commission (NDRC) in 2004, highlighted the appeal of studying fiscal and taxation policies to encourage the development of car models with higher energy efficiency. In 2007, "*The International Science and Technology Cooperation Plan for Renewable Energy and New Energy*"[9] was proposed by the Ministry of Science and Technology (MOST) and NDRC, which emphasized support for R&D in fuel cell vehicle technology. In the eleven Five-Year Plan (2006-2010) for energy development[10], a greater focus was placed on the development of hybrid EVs (or PHEVs) in the "*Clean Vehicle Action Plan*". From 2009 onwards, China started to enhance its guidance for pure EV (or BEVs) development by explicitly increasing financial support and setting specific promotion targets[11].

In the infancy stage, the Chinese government prioritized large-scale demonstration projects to showcase the benefits of EVs. This was to strategically plan the management guidelines of the industry and the approval of qualified manufacturers to produce EVs. The manufactured EVs for some of the demonstration projects were mainly deployed in public areas, which were led by the government and enterprises. The policies implemented in this stage primarily aimed to demonstrate the advantages of EVs rather than to promote their widespread adoption.

As early as 1999, 14 central ministries and commissions jointly initiated a national Clean Vehicle Action program to address automobile pollution and to guide relevant R&D activities in the automotive industry. The program was established by MOST and the State Environmental Protection Administration (SEPA), and 12 cities were selected to pilot it. It

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[7] "The National Eighth Five-Year Plan (1991-1995), State Council of the People's Republic of China, accessed April 4, 2025, (Chinese only) https://www.gov.cn/ztzl/content_87115.htm.
[8] NDRC. (2004). The Mid- and Long-term Special Planning for Energy Conservation. (Chinese only). https://www.ndrc.gov.cn/xxgk/jd/jd/200506/t20050628_1183006.html
[9] China Climate Change Info-Net. (2007). The International Science and Technology Cooperation Plan for Renewable Energy and New Energy. (Chinese only). ccchina.org.cn/Detail.aspx?newsId=28030&TId=60
[10] NDRC. (2007). The Eleven Five-Year Plan (2006-2010) for Energy Development. (Chinese only). https://www.ndrc.gov.cn/fggz/fzzlgh/gjjzxgh/200709/P020191104623138936402.pdf
[11] Ministry of Finance, Ministry of Technology. (2009). Notice on carrying out pilot demonstration projects of energy-saving and new energy vehicles. (Chinese only). https://www.gov.cn/zwgk/2009-02/05/content_1222338.htm

aimed to have 10 percent of all taxis and 20 percent of all buses transformed to alternative-fuel capable vehicles by 2001. However, this effort did not have significant effects on the new purchases of EVs.

In 2005, China introduced its first fuel-efficiency and exhaust emission standards for automobiles, which came into effect in 2006. These tightened standards and encouraged manufacturers to improve fuel efficiency, leading to improved environmental performance of automobiles. However, these standards and regulations made only little progress in the adoption of EVs, both regarding production and consumption. It was not until 2007, when the National Development and Reform Commission (NDRC) launched management rules for the production and market access of NEVs to approve their mass production, that EVs found room for growth and development in the automobile market (Du & Ouyang, 2017; Yang & Li, 2021).

In 2009, the Chinese government unveiled its road map for EV deployment in the automobile market and launched a demonstration and promotion program for NEVs. The program was established as the *Thousands of Vehicles, Tens of Cities* (TVTC) program,[12] with a goal for piloting 10 cities to add 1,000 NEVs annually over a three-year period. The aim was to accelerate commercialization and popularization of EVs. The program engaged 25 municipal governments across China to adopt EVs into their fleets. The following year, the central government designated the promotion of NEVs as a national priority. As a result of this policy shift, EV production increased considerably by 2011, although the deployment of NEVs for the TVTC Program still lagged behind the original plan (Gong et al., 2013).

4.2 Stage II-Rapid growth: Using subsidies to push adoptions and productions

Following the designation of NEVs as a national priority in 2010, the MOF, MOST, MIIT, and the NDRC jointly launched pilot projects to provide subsidies for privately purchased NEVs and EVs from 2010 to 2012 (Zhao et al., 2024).[13] [14]. Five cities were chosen based on their automobile industry foundation, residents' purchasing power, and relevant requirements.

[12] Ministry of Finance (MOF) and Ministry of Science and Technology (MOST) (2009) Notice on implementing energy saving and new energy vehicle pilot program., Beijing, P. R. China

[13] NDRS. (2010). Notice on the subsidy pilot promotion of private purchase NEVs (Chinese only). https://www.ndrc.gov.cn/fggz/hjyzy/jnhnx/201006/t20100603_1134366.html

[14] NDRC. (2010). Interim Measures for the Management of Financial Subsidy Funds for the Pilot Purchasing of NEVs by Private People. (Chinese only). https://www.ndrc.gov.cn/fggz/hjyzy/jnhnx/201006/t20100603_1134366.html

Subsidies of up to 50,000 yuan for PHEVs and up to 60,000 yuan for pure passenger EVs were provided to both automobile manufacturers and battery lease companies. These entities then offered EVs/NEVs to consumers at reduced prices after deducting the subsidy.

The interim and pilot plan for subsidies was expanded in 2013, when the three ministries and NDRC issued a notice[15] stating that consumers in major cities would continue to receive subsidies for purchasing NEVs from 2013 to 2015. The focus was on pilot cities, especially megacities, and regions with severe PM2.5 pollution issues, such as the Beijing-Tianjin-Hebei region, the Yangtze River Delta, and the Pearl River Delta. Subsidies for BEVs and PHEVs ranged from 35,000 to 60,000 yuan depending on various factors.

In 2015, the Chinese government launched the "*Made in China 2025*[16]" plan, incorporating EV subsidy policies to encourage widespread adoption and strengthen China's battery technology. Subsidies were provided only to EVs using domestically produced battery cells, incentivizing local R&D and innovation. The subsidies provided to EV buyers, including commercial fleet operators, between 2009 and 2021 amounted to around 100 billion yuan ($14.8 billion) (Reuters, 2022). This policy benefited companies like Contemporary Amperex Technology Limited (CATL), a Chinese battery giant and global leader in lithium-ion battery production. The increased demand for batteries, driven by the subsidy policy, boosted investment in battery R&D and the development of the entire battery supply chain, from mining and manufacturing to cell making and recycling. However, the rapid expansion of subsidies also created distortions, with some firms becoming overly dependent on policy incentives rather than technological innovation.

The increase in financial subsidies from the central and local governments led to significant growth in China's NEV sales from 2014 to 2015. In 2015, China became the world's largest NEV market, with sales exceeding 330,000 units, accounting for nearly 60% of global new energy vehicle sales (NDRC, 2017) as shown in Figure 3. The integration of government-funded research programs with China's broader innovation agenda has played a decisive role in enabling the EV industry to achieve technological leapfrogging, strengthening its competitive edge in global markets (Altenburg et al., 2022). By the end of China's 12th five-

[15] The Central Government of China. (2013) Notice on Continuing the Promotion and Application of NEVs. https://www.gov.cn/zwgk/2013-09/17/content_2490108.htm
[16] "Made in China 2025," State Council of the People's Republic of China, accessed April 4, 2025, https://english.www.gov.cn/2016special/madeinchina2025/.

year plan[17] period (2011-2015), China had made major advancements in lithium-ion battery technology, leading globally in electrode materials and industrial capacity. Some domestic companies became the main international suppliers of EV batteries. Battery production was moving towards full automation and low carbonization, while the performance integration technology was pursuing intelligence and modularity. Breakthroughs were also achieved in electric drive motors, narrowing the gap with international standards. Nonetheless, gaps persisted in areas such as battery consistency and integrated power electronics in comparison with advanced international technologies (Zhang & Qin, 2018). At the same time, consumers became more receptive to EVs with the improvements in the EV market and increased environmental awareness in Chinese society. While certain attributes of EVs, such as range anxiety and technology uncertainty, could be barriers to adoption, environmental awareness and psychological needs played a role in increasing the Chinese public's preference for EVs (Schuitema et al., 2013; Zhang et al., 2013; Wiedere & Philip, 2010).

4.3 Stage III-Adjustment: Phasing out subsidies and industrial restructuring

After implementing substantial EV subsidy incentives, fraudulent incidents involving subsidy provision led to the withdrawal of battery giant companies (e.g. CATL) from the Chinese market. As EV technology matured and subsidy policies declined, the EV market shifted from a policy-driven market to a free market. Some manufacturers exploited policy loopholes by fabricating NEV production and sales to fraudulently obtain subsidies[18], such as registering vehicles illegally, using smaller batteries than claimed, and falsifying clients (International Council on Clean Transportation, 2017). The major problem of the subsidy policy for manufacturers was that the subsidies applied to EVs regardless of their level of technological sophistication. These scandals not only damaged public trust but also revealed structural weaknesses in China’s EV sector, including overcapacity risks, uneven technological standards, and financial pressures on smaller firms.

In response, the government introduced measures to prevent fraud, improve the subsidy policy, and encourage technological standards. In 2016, MOF, MOST, MIIT, and NDRC

[17] “China’s 12th Five-Year Plan," State Council of the People's Republic of China, accessed April 4, 2025, https://english.www.gov.cn/12thFiveYearPlan/.

[18] CCTV.com. (2016). Retrieved from http://news.cctv.com/2016/09/09/ARTIUnbihqs2mtu9EchdrQzQ160909.shtml

jointly signed the "*Notice on Carrying out the Settlement of New Energy Vehicle Subsidy Funds.*"[19] Starting from 2017, the EV subsidy policy was adjusted, the technical threshold was raised, technological progress was emphasized, and central and local subsidy ceilings were set to contain the subsidy amounts to a reasonable level. The adjustments of the EV subsidy policy set higher performance standards for subsidized EV passenger cars, strengthening energy efficiency and driving range requirements. Most importantly, a new national standard for power batteries was introduced to enhance the safety, cycle life, charge-discharge performance, and energy density of EV batteries. This drove up R&D in battery technology, fostering innovations in battery chemistry, materials, and manufacturing processes. Moreover, the policy adjustment also focused on advancing fuel cell vehicle technology. It enhanced the technical requirements for fuel cell vehicles, which promoted the development of more efficient and reliable fuel cell systems. This included improvements in fuel cell stack performance, hydrogen storage and refueling infrastructure, and overall system integration. In addition, to prevent gaming and subsidy frauds, the declaration and distribution of subsidies for car companies were changed from ex-ante allocation to ex-post allocation, with strengthened review, supervision, and punishment mechanisms.

In 2019, the subsidy policy was further tightened in the new official guideline about NEVs,[20] increasing the technological thresholds in terms of energy density of battery systems, energy consumption level of NEVs, and driving range of BEVs. Moreover, NEV subsidies were reduced to promote market competition and technological advancement (Fan et al., 2025). Specifically, the subsidy for plug-in hybrid vehicles was reduced by 55% from 22,000 yuan to 10,000 yuan. The threshold for subsidies for new energy buses was also increased by a considerable amount, and the upper limit of the subsidy amount was reduced from 180,000 to 90,000 - a 50% decline. By the end of 2020, the government decided to completely withdraw EV financial subsidies, although the plan was postponed, and tax exemptions were extended until the end of 2022. The change in subsidy policy forced less competitive enterprises to exit, improving industry efficiency. Auto companies needed to spend money to complete production and sales before they could receive subsidies, which increased the financial pressure on auto companies to some extent. Some companies faced bankruptcy due to poor management, resulting in financial pressures (e.g. difficulties in repayment, tight cash flows,

[19] MOST. (2016). Retrieved from https://www.most.gov.cn/tztg/201701/t20170116_130495.html
[20] The Central Government of the People's Republic of China. (2019). Retrieved from https://www.gov.cn/xinwen/2019-03/27/content_5377123.htm

and lack of technologies). This weeding-out effect helped to remove poor-performing companies from China's EV industry and improve the overall efficiency of the industry. This industry consolidation strategy contrasts sharply with other markets: while Germany maintained subsidies through 2023, its market share reached only 25% before subsidies ended in December, causing an immediate slowdown. The United States continues to rely on USD 7,500 tax credits under the Inflation Reduction Act yet achieved only 10% market penetration by 2023.

The gradual phasing out of subsidies, however, did not slow down the growth of the EV market in China. In fact, China's 2023 performance—35% growth without national subsidies—stands in stark contrast to Germany, where the December 2023 subsidy phase-out led to a 5% decline in Q1 2024 sales. This was partly due to the continued policy incentives provided (Liu et al., 2023) and enhancing charging infrastructure by municipal governments, as well as the improved consumer preference towards EVs (e.g., popularity of EV brands and models). Several factors have influenced consumers' attitudinal and behavioral intentions toward the adoption of EVs beyond just the benefits from financial subsidies. Factors such as perceived benefits of EVs, trust in EV brands, environmental concerns, and economic and social benefits, influenced consumer attitudes and purchase intentions (Yang et al., 2020; Lai et al., 2015; Delang & Cheng, 2012). Consumers' perceptions of EVs also appear to change due to policy incentives, marketing promotions by manufacturers, and a sense of reputation given by early EV users. The purchasing of EVs is now driven by considerations of the advantages of EVs (e.g. energy saving, environmental protection, costs of use), rather than solely relying on subsidies (Li et al., 2023). For example, Sheldon & Dua (2020) used a vehicle choice model to estimate the cost-effectiveness of China's subsidy program for promoting plug-in electric vehicles (PEVs). Although they found that the predicted increase in PEV market share significantly improved vehicle fuel economy and reduced petrol consumption, China's PEV subsidy policy was not efficient due to excessive subsidies being allocated to high-income consumers who are insensitive to fiscal incentives.

4.4 Stage IV-Transformation: Ramping up regulations to strengthen EV market growth and transitioning to the development of intelligent connected vehicles (ICVs)

As a substitute for the previous EV subsidies, a new dual-credit policy (DCP), namely, "*Measures for Passenger Cars Corporate Average Fuel Consumption and New Energy Vehicle Credit Regulation,"*[21] was introduced to establish a long-term management mechanism for EVs and facilitate the sustainable development of the automobile industry. The policy was first announced in September 2017 and was implemented by the MIIT starting from 2018. Designed to be based on the U.S.'s fuel economy standards and California's zero-emission vehicle program, DCP is a combined policy tool of market incentives and environmental regulations (Dong & Zheng, 2022; Peng & Li, 2022). DCP consists of two credit schemes: the Corporate Average Fuel Consumption credit (CAFC credit) and the New Energy Vehicle credit (NEV credit). The CAFC credit sets fuel consumption caps for car manufacturers based on their scale of production, while the NEV credit requires a certain percentage of vehicles sold by the manufacturers to be battery-powered (Ou et al., 2018).

The dual-credit system has a complex formula to calculate the credit for each auto manufacturer, which considers various features of vehicle production, such as energy efficiency and range. Failing to meet the fuel consumption target will lead to penalties, but automakers also have the flexibility to offset negative CAFC credits with NEV credits awarded by producing more EVs (Li et al., 2020; Lou et al., 2020; Ou et al., 2018). Additionally, these credits are tradable among companies. Environmental regulations and coercive pressures are important in terms of stimulating firms' sustainable technology adoption behavior (Fu et al., 2018). Given this dynamic, China's DPC can generate coercive pressures on automakers and on battery producers, encouraging them to develop and adopt relevant green technologies. All of this aims to ultimately help China achieve its climate change goals. A study found that, under the DCP, greenhouse gas emissions of the passenger vehicle fleet in China will peak in 2032 (He et al., 2020), just two years later than the government's emissions target. The researchers also suggest that emissions levels can be

[21] The Central Government of the People's Republic of China. (2017).https://www.gov.cn/zhengce/2022-11/27/content_5722693.htm

further reduced if more NEVs are on the road and further technologies are applied to improve the efficiency of ICEVs.

As seen by the removal of subsidies, the initial price discrepancy between conventional ICEVs and EVs will become more prominent, which can affect the costs, purchasing prices, and eventually the sales of EVs. As a result, China's automobile market can potentially shrink and the adoption of EVs can possibly slow down. However, it is also arguable that the costs of EVs can be controlled by the decrease in battery prices. While the mining and synthesis of raw battery materials are still expensive, the price of the most widely used battery in EVs, lithium-ion batteries (LIBs) will continue to decrease due to "learning effects" (Hsieh et al., 2019). Additionally, the production of EVs and demand for batteries, especially LIBs, will increase because of the mandate.

In October 2020, the State Council introduced the "New Energy Vehicle Industry Development Plan,"[22] which envisions that, by 2025, BEVs will have much lower power consumption levels (12.0 kWh/100 km), and the sales of NEVs will reach about 20% of total car sales. By 2035, the Chinese government aims for BEVs to become the majority of new car sales, public vehicles to be fully electrified, and fuel cell vehicles (FCVs) - which use hydrogen gas to produce electricity - to achieve commercialization. To accelerate the emissions peak by 2030, the government in 2021 announced a new mandate to increase the requirements again, targeting a 40% share of EV in total the country's car sales by 2030 and consequently replacing the earlier target of 20% by 2025.

Policy also emphasized industry openness. Among the sweeping national economy reforms announced in 2018, the government will lift and eliminate restrictions on foreign joint-ventures and ownership in China's auto industry by the end of 2023. This movement has attracted a significant capital inflow to the EV industry and contributed to its growth and development. Despite openness to foreign competition, Chinese firms have strengthened their dominant position: while Tesla and Volkswagen have gained a foothold, domestic brands such as BYD, Geely, and NIO together account for more than 80% of China's EV sales. This stands in sharp contrast to the United States, where Tesla remains the leading player, but its market share declined by nearly 15 percentage points between 2020 and 2023. In addition, in

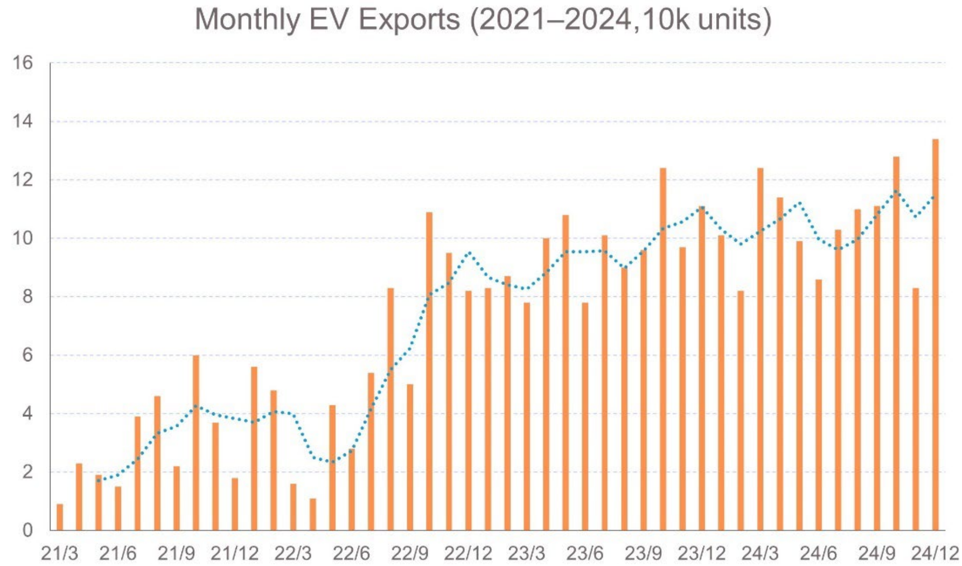
[22] New Energy Vehicle Industry Development Plan, State Council of the People's Republic of China, November 2, 2020, accessed April 4, 2025, https://www.gov.cn/zhengce/content/2020-11/02/content_5556716.htm (Chinese only).

Europe the share of incumbent carmakers fell by almost 20 percentage points between 2015 and 2023. Building on this weakening of traditional players, Chinese manufacturers are rapidly gaining ground overseas—BYD has already surpassed Tesla in EV sales, with its combined BEV and PHEV sales in the region increasing by 359% year-on-year. This contrast highlights how China's policies not only welcomed global players but also nurtured competitive homegrown champions (IEA, 2024; JATO, 2025). Alongside regulatory and market reforms, China advanced innovation policies to accelerate R&D, improve battery technology, and expand infrastructure. These initiatives align with the New Energy Vehicle Industry Development Plan, reinforcing a shift toward market-driven growth and technological leadership (Chorzempa & Huang, 2022).

5. Summarizing China's Model of Technology Leapfrogging for EVs

Looking at the current EV market landscape, China has surpassed the U.S. as the world's leading country in total EV sales, including battery electric cars (BEVs) and plug-in hybrids (PHEVs) since 2015 (IEA, 2018; 2021). As shown in Figure 4, China's EV exports have surged significantly. In March 2021, monthly EV exports stood at 9,000 units, but by March 2024, they had grown to 134,000 units—an astonishing 1,389% increase in just three years. This rapid growth underscores China's expanding role as a global EV supplier, driven by strong policy support, cost advantages, and technological advancements. With this momentum, Chinese automobile companies are expected to continue dominating global EV production in the future.

Figure 4. 2021–2024 Monthly EV Exports



The Chinese EV case provides a clear example of technology leapfrogging, where a latecomer economy accelerates development by bypassing conventional industrial stages. (Tukker, 2005). Rapid market growth was enabled by generous subsidies, heavy investment in EV-related R&D, and integration of industrial and scientific agendas. This represents what Schot & Steinmueller (2018) term “transformative leapfrogging” - policy that not only meets immediate market needs, but that also restructures socio-technical dynamics to sustain long-term growth. The case study of the evolutionary path of EV policies and its deployment in China showcases China's model of technology leapfrog, which fundamentally differs from the export-oriented strategies of East Asian economies or the import-dependent approaches of traditional emerging economies. Figure 5 below conceptualizes the technology leapfrog model that China has succeeded in doing, by developing its EV industry.

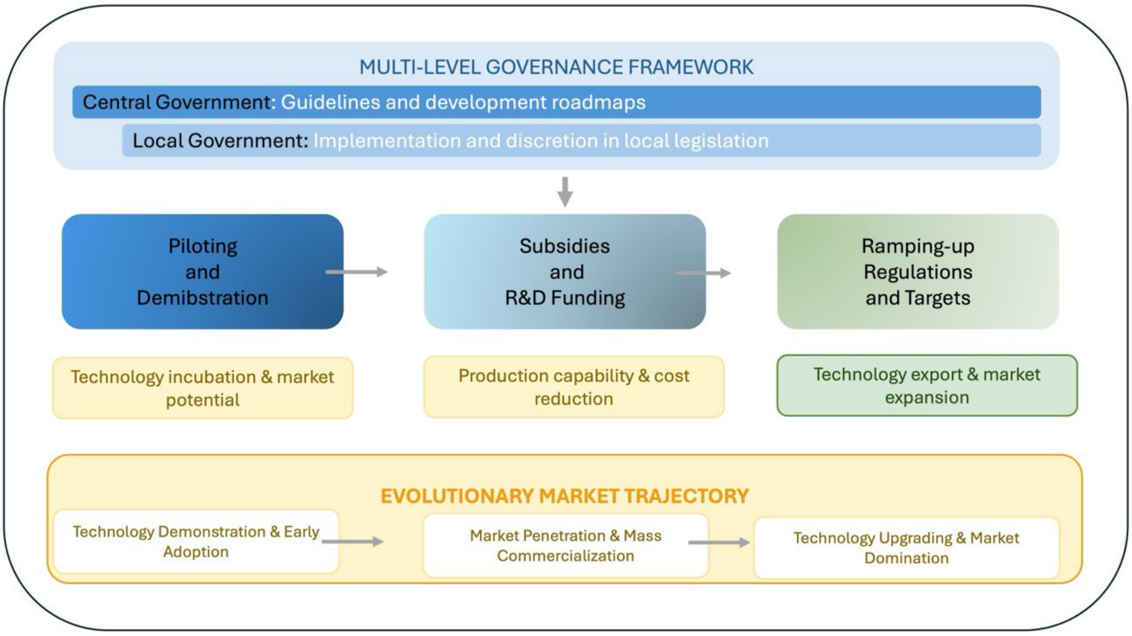


Figure 5. China's model of technology leapfrog (taking EV as the case).

Note: The graph illustrates the distinctive features of China's technological leapfrogging model in the EV sector. The progression from demonstration to market domination, supported by multi-level government coordination and comprehensive policy tools, exemplifies how China's technological leapfrogging model operates in practice.

China's policy for EV deployment went through a *top-down* approach. The central government and the Communist Party provided management guidelines and development roadmaps for the EV industry, while provincial and municipal governments implemented policies that catered to the local situation. Local governments also had a certain level of discretion in terms of the provision of subsidy incentives and legislation for EV charging infrastructure.

When the EV industry was in its early stages and many of its technologies and applications were still in incubation, the government used pilot programs and demonstration projects to showcase the applicability and marketability of EVs. Most notably, the government's subsidy policy and investment in scientific R&D were the main drivers encouraging technology development, especially battery technology, in private companies in the EV industry. These incentives helped improve manufacturing capabilities and made large-scale commercialization of EVs possible. Purchase subsidies and tax exemptions, combined with the reduction in production costs due to improved manufacturing capabilities, have incentivized individual consumers' EV purchasing behavior and contributed to the wide adoption of EVs. However, continuing the immense government expenditure on EV subsidies is not sustainable and has imposed significant social costs. China's technology leapfrog in the EV industry is now shifting to the stage of phasing out subsidies and increasing regulations and emission targets to push industry players to advance their technologies and improve efficiencies. Looking forward, the government can also provide a more open environment for foreign investments and cooperation on EVs to strengthen local industries and to facilitate the expansion to the overseas market

With this model of technology leapfrogging, we show that aggressive policy actions in deploying EVs from national to local levels not only produce environmental benefits, but also have far-reaching impacts on the domestic automobile market, international trade, and national competitiveness. China's strategic deployment of EVs, aligning with climate and sustainability initiatives, has empowered the indigenous development of relevant green technologies (batteries in particular), and it has stimulated the growth of low-carbon economies in the domestic market. These positive effects on technology development and the economy will further enhance China's market competitiveness and strengthen its role and voice in international climate change and sustainability discussions, with significant implications for other green technology developments and other emerging economies. This four-staged leapfrog forward made China a global technology leader in the EV industry. An emerging economy aiming to establish itself in a new industry could learn from this model successfully for any number of technological developments. Researchers have documented leapfrogging in technologies ranging from biomass and biofuels to solar electricity production and financial services (Goldemberg, 2011; Yap, et al., 2022), and this model could shape the future of countries across the Global South and Africa in particular (Cilliers, 2021).

6. Discussion

In response to global climate change and the urgent mission to achieve carbon neutrality by 2050 as outlined in the Paris Agreement, there is a growing global interest in accelerating electric mobility. The increasing importance of electric mobility is not only driven by the need for environmental protection, but by other factors, including high energy prices and changes in mobility patterns, especially the rise of car-sharing and better systems of intermodality (Dijk et al., 2013). Since the transportation sector is one of the main sources of

greenhouse gas emissions, electric mobility is seen as a promising solution for reducing carbon emissions. At the same time, the expansion of EV fleets raises new sustainability questions, such as how to ensure the broad accessibility of clean mobility and how to manage the environmental footprint of electricity generation and raw material extraction.
To achieve such environmental goals, countries around the world have proposed and implemented various policy measures to accelerate the deployment of EVs, including monetary incentives (e.g. purchase subsidies, registration tax deductions and exemptions), and non-monetary incentives (e.g. road access privilege, free parking for EVs, investments in charging infrastructure, bans on sales and registrations of conventional cars, and regulatory instruments and standards in vehicle manufacturing). Yet the durability of these measures is not guaranteed. Governments must balance fiscal affordability with the need to expand charging networks, while also preparing for potential volatility in global battery supply chains. More than 20 countries around the world have announced plans to restrict sales to only electrified or zero-emission vehicles. The global automobile market is shifting towards electric vehicles, recognizing its ability to lessen transportation expenditure, reduce carbon emissions, and improve air quality. From an industrial perspective, numerous automaker groups have also announced plans to increase investments in EV production, capitalizing on this emerging market (Lutsey et al., 2018). According to the Global EV Outlook 2021 (IEA), there were 10 million EVs in use globally, and adoption is expected to accelerate. For emerging economies, this trajectory illustrates that ambitious adoption targets can stimulate industry growth, but careful sequencing of subsidies and infrastructure investment is critical for long-term stability.

China's promotion of EVs represents a particularly valuable case for understanding how national-level policies can foster new technology fields, shift market behavior, and facilitate industrial growth, thereby contributing to leapfrogging with both environmental and economic consequences. In this study, we take a retrospective approach to trace and analyze the development of EV policies implemented in China and study how these policies contribute to technology leapfrogging, or the rapid transitioning of an emerging market economy to develop and adopt advanced technologies more commonly used in advanced market economies, and the development of a more circular economy. A prospective approach is also utilized to discuss how likely policymakers will stick to the current but relatively ambitious plans for EV deployment and green development. Such a forward-looking view reveals potential risks—overcapacity, uneven technological standards, and battery bottlenecks—that could undermine policy sustainability if not carefully managed. Our analysis therefore also considers the policy adjustments and institutional responses that are likely to shape the next phase of China's EV evolution. For other emerging markets, the Chinese case highlights the importance of combining ambitious deployment targets with governance mechanisms to prevent market distortions and sustained investment in R&D to reduce dependency on foreign technologies.

While this qualitative case study traces the development of China's EV technology leapfrogging model and provides important implications for other countries, and particularly emerging economies, we also recognize that this study has its limitations. Future work could build upon our findings by drawing on more recent datasets and employing complementary quantitative analyses to test policy effectiveness more systematically.

Over the past two decades, China has implemented national-level measures and local demonstration programs to promote EV deployment alongside strong support for R&D into core components (e.g., battery technology, power systems, charging infrastructure) (Zheng et al., 2012; Du & Ouyang, 2017; Wang et al., 2017; Zhang et al., 2017; Qiu et al., 2019; Wu et al. 2021). These policies not only help achieve climate goals (Zhang & Hanaoka, 2021), but also enable "technology leapfrogging" in an industry where China was once a follower (Liu & Dicken, 2006; Chu et al., 2019; Harwit, 2016). The sustainability of this leap, however, will depend on the continued evolution of China's innovation system and the ability to align industrial expansion with environmental and social priorities.

From the perspective of the development of a major economy, it is crucial to explore China's approach to entering and succeeding in a new technology field. In the context of China's development of EVs, it is especially important to decode its policy framework in achieving such a technology leapfrog, noting that the process has also been accompanied by challenges such as subsidy fraud and persistent technological bottlenecks. This study attempts to understand the factors that influenced the government's policy on EVs, the role of the policy development framework for EVs (e.g., centralized guiding strategies and local piloting, showcasing programs), and the effects of different policy instruments on the development of EVs in terms of manufacturing capacities and domestic demands. At the same time, risks of overcapacity and market distortions have highlighted the darker side of rapid growth, prompting policy reforms such as stricter subsidy auditing, the gradual phase-out of purchase incentives, and the introduction of the dual-credit policy. Further, probing into the evolutionary path of EV policies and the EV market development in China, including both achievements and these corrective measures, could provide meaningful insights for the development of technology in other global markets. For policymakers in the Global South, the lesson is to design EV roadmaps that anticipate not only rapid growth but also the governance mechanisms needed to ensure long-term sustainability.

The enhancement of R&D capacity depends on constructing an enabling national innovation framework, which encompasses commercially-driven private sector entities, multi-level public institutions, research and educational organizations, funding intermediaries, and the synergistic relationships among these participants (Balzat et al., 2004). Additionally, market demand and technological inventions and transformations are affected by the system's regulatory framework (Walz, 2010). It is necessary, therefore, for the government to impose regulations that will direct the evolution of a country's innovation system and assist in determining competencies as well as the international competitiveness of domestic industries. Environmental policies to increase domestic demand for more efficient water, electricity, or transportation technologies, can provide emerging markets with opportunities to develop alternative pathways to growth and to leapfrog into a competitive low-carbon economy.

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