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Industrial Policy and Automotive Innovation in China and Japan (1990s–2024)

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Abstract

This thesis examines how industrial policy has influenced automotive innovation in China and Japan from the 1990s to 2024. I develop a comparative analytical framework with four criteria: (1) Innovation Inputs, (2) Innovation Outputs, (3) Industry Competitiveness, and (4) Policy Implementation; and apply it to evidence from official and industry sources (e.g., OECD for R&D, WIPO/PCT for patents, OICA for production, UN Comtrade/CAAM/JAMA for trade and market indicators). The empirical chapter presents long-run trends in nominal values and a concise policy timeline; the analytical chapter synthesizes results with a scorecard and a causal chain.

Findings show two distinct pathways. In China, strong state intervention—joint-venture rules, production and purchase subsidies, and EV/NEV credit policies—raised innovation inputs and produced rapid growth in outputs (patents, EV models), which supported global competitiveness in production and more recently in exports. In Japan, a lighter, firm-led approach maintained high and steady inputs and strong product quality and brands, but output growth was more incremental and the shift to new EV technologies slower. The results imply that policy design and implementation can shape the speed and direction of innovation, but effectiveness depends on capabilities, market signals, and institutional consistency.

The contribution is twofold: a transparent framework linking policy instruments to measurable innovation outcomes, and a comparative, evidence-based account of how two major automotive economies diverged in strategy and results. Limitations include observational design and imperfect comparability for some indicators; these are addressed through triangulation and robustness checks. Policy implications are discussed for countries aiming to accelerate green and digital transition in transport.

Keywords: industrial policy; automotive innovation; China; Japan; R&D; patents; EV; competitiveness; comparative analysis.

Zusammenfassung

Diese Arbeit untersucht, wie Industriepolitik die automobilen Innovationen in China und Japan von den 1990er-Jahren bis 2024 beeinflusst hat. Dafür entwickle ich einen vergleichenden Analyse-Rahmen mit vier Kriterien: (1) Innovationsinputs, (2) Innovationsoutputs, (3) industrielle Wettbewerbsfähigkeit und (4) Politikgestaltung und Umsetzung; und wende ihn auf Daten aus offiziellen und Branchenquellen an (u. a. OECD für F&E, WIPO/PCT für Patente, OICA für Produktion, UN Comtrade/CAAM/JAMA für Handel und Marktindikatoren). Das empirische Kapitel zeigt Langfristtrends in nominalen Werten sowie eine kompakte Politiktimeline; das analytische Kapitel bündelt die Ergebnisse in einer Scorecard und einer kausalen Kette.

Die Befunde weisen auf zwei unterschiedliche Pfade hin. In China führte eine ausgeprägte staatliche Intervention—JV-Vorgaben, Produktions- und Kaufsubventionen, sowie EV/NEV-Quoten—zu steigenden Innovationsinputs und rasch wachsenden Outputs (Patente, EV-Modelle). Dadurch verbesserten sich Produktion und zuletzt auch Exporte im globalen Wettbewerb. In Japan hielt ein „light-touch", unternehmensgetriebener Ansatz hohe und stabile Inputs sowie starke Qualität und Marken, jedoch waren die Outputs eher inkrementell und der Übergang zu neuen EV-Technologien langsamer. Dies legt nahe, dass Gestaltung und Umsetzung von Politik die Geschwindigkeit und Richtung von Innovation prägen können—unter der Bedingung vorhandener Fähigkeiten, Marktanreize und institutioneller Verlässlichkeit.

Der Beitrag der Arbeit ist zweifach: ein transparenter Rahmen, der Politikinstrumente mit messbaren Innovationsresultaten verknüpft, sowie eine vergleichende, evidenzbasierte Darstellung der unterschiedlichen Strategien und Ergebnisse zweier großer Automobilökonomien. Grenzen liegen im beobachtenden Design und in der eingeschränkten Vergleichbarkeit einzelner Indikatoren; diese werden durch Triangulation und Robustheitsprüfungen adressiert. Politische Implikationen werden für Länder diskutiert, die die grüne und digitale Transformation im Verkehr beschleunigen wollen.

Schlagwörter: Industriepolitik; Automobilinnovation; China; Japan; F&E; Patente; E-Mobilität; Wettbewerbsfähigkeit; Vergleichsanalyse.

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1. Introduction

Innovation in the automotive industry is widely recognized as a key driver of competitiveness, economic growth, and solutions to societal challenges such as sustainability and safety *(Braidy, Pokharel, and ElMekkawy 2025)*. The automotive sector is among the largest investors in research and development (R&D) globally, and it plays a pivotal role in national industrial capabilities (Sano, Kii, and Miyoshi 2011, 15–43). Japan's automobile industry, for example, grew from post-war infancy to world-class competitiveness within a few decades, becoming a cornerstone of the country's manufacturing strength *(Sano, Kii, and Miyoshi 2011, 15–43)*. China, meanwhile, has emerged since the 1990s as the world's largest producer and market, leveraging innovation to catch up with established players *(RIETI 2023)*. The experiences of these two countries provide a compelling study in how **industrial policies** – the strategies and interventions by governments to promote specific industries – can shape innovation trajectories in different contexts.

Motivation and Research Question: Japan and China offer a stark contrast in development pathways: Japan entered the 1990s as a technological leader with a mature automotive industry, while China was a latecomer still dependent on foreign technology. Both countries, however, have employed industrial policies to foster innovation in automobiles – albeit in very different forms. Understanding **how China and Japan have developed automotive innovations from the 1990s to 2024 through industrial policies** is not only academically interesting but also practically relevant. Policymakers in emerging economies seek lessons from these cases on nurturing homegrown innovation, and industry stakeholders worldwide have a stake in how policy shapes competition (e.g. the rise of electric vehicles). The central research question guiding this thesis is: **"How have China and Japan developed their innovations in the automotive industry from the 1990s to 2024 through industrial policies?"** This question encompasses sub-questions about what innovation means in this context, what policy tools were used, and what outcomes were achieved in each country.

Conceptual Definitions: For the purposes of this study, innovation is defined according to the OECD/Eurostat Oslo Manual as "a new or improved product or process that differs significantly from previous products/processes and has been made available to users (in the case of products) or implemented by the firm (for processes)" *(OECD/Eurostat 2018)*. In other words, innovation in the automotive industry can include new vehicle technologies (e.g. electric powertrains, autonomous driving systems), improvements in manufacturing processes, or novel business models, so long as they represent a significant advancement brought into use. Industrial policy refers to government efforts to shape the economic structure by targeting specific industries or activities. This is achieved through a range of tools such as subsidies, tax incentives, trade protection measures, directed credit, infrastructure investments, research and development support, and regulatory mandates *(Agarwal 2023)*. Industrial policy can be **“vertical”** (targeting particular sectors or firms) or **“horizontal”** (improving general business conditions or innovation systems), but in this thesis the focus is on deliberate state interventions aimed at promoting innovation in the automotive sector.

Stakeholder Relevance: This research holds significance for several stakeholders. For government policymakers, it offers insights into the effectiveness of different industrial policy approaches in spurring innovation – a timely issue as many countries revisit industrial policy in the 2020s (for instance, the United States and EU have recently launched major initiatives supporting electric vehicles and semiconductors, echoing aspects of East Asian strategies *(Agarwal 2023)*). Understanding the China and Japan cases can inform the design of policies that balance market forces and state guidance *(Rodrik 2004; Chang 2011)*. For industry leaders and firms, the analysis highlights how policy environments shape competitive advantages, technology development, and market dynamics – knowledge that is crucial for strategic planning and international business decisions. Finally, for the academic community, this comparative study contributes to the literature on development economics and innovation management by elucidating how a “developmental state” model (exemplified by Japan’s post-war experience) and a “socialist market” model (exemplified by contemporary China) each address the challenge of fostering innovation in a complex, global industry.

Structure of the Thesis: The remainder of this thesis is organized as follows. **Section 2, Literature Review**, provides a conceptual and empirical review of relevant literature, structured into four parts: (a) innovation metrics and how automotive innovation is measured; (b) industrial policy tools and their theorized relationship with innovation; (c) the historical trajectories of automotive innovation in China and Japan, as documented by prior studies; and (d) the derivation of analytical criteria to compare the two countries. **Section 3, Analytical Framework**, then presents the criteria, indicators, and methods used to analyze the impact of industrial policy on innovation in the Chinese and Japanese automotive industries. This includes a table operationalizing key variables (such as R&D investment, patent output, and policy instruments) and an explanation of the comparative assessment approach. **Section 4 (Context, Data, and Methodology)** sets the country and industry background and explains the data. It describes the scope (passenger and light vehicles unless noted), the main sources (OECD MSTI for R&D; WIPO/PCT statistics for patents; OICA for production; UN Comtrade, CAAM, and JAMA for exports and market indicators; METI/State Council documents for policy), the selection of years, and the construction of figures. It also outlines data cleaning steps, any unit conventions (nominal values; consistent definitions), and the main limitations (coverage differences by year, comparability issues, and potential measurement bias). **Section 5 (Empirical Comparative Analysis)** presents the factual evidence organized by the four criteria. First, ***Innovation Inputs*** (R&D intensity and related indicators) are shown and compared. Second, ***Innovation Outputs*** (PCT applications and technology-specific outputs) are examined. Third, ***Industry Competitiveness and Market Outcomes*** (production volumes, exports, and domestic-brand share) are analyzed with multi-year trends. Fourth, ***Policy Support and Implementation*** is summarized in a concise policy timeline. Each subsection links claims directly to figures and sources, so the evidence is transparent. **Section 6 (Analytical Synthesis)** integrates the results. It summarizes performance across criteria in a compact scorecard table, then explains the mechanism with a simple causal chain for each country, and closes with a mini-findings matrix that contrasts the two systems. The discussion considers alternative explanations, notes sensitivity to data choices, and draws policy implications (what each country's approach implies for future competitiveness) and research implications (what evidence is still missing and how future work could address it). The **Conclusion** restates the answer to the research question, the thesis's main contributions, and the limits of generalization. A **List of References** is provided at the end of the document.

2. Literature Review

2.1. Objective Definition

The aim of this Literature Review is to provide a theoretical and conceptual foundation for answering the main Research Question: "How have industrial policies in China and Japan shaped innovation outcomes in the automotive sector?" To approach this question, the review is structured around three analytical angles that directly correspond to its components:

1. Policy instruments – how governments design and apply industrial policies to stimulate innovation.
2. Innovation inputs and outputs – how resources such as R&D and skilled labor are transformed into measurable technological results, such as patents and product development.
3. Industry competitiveness – how innovation affects the performance of strategic sectors, particularly the automotive industry, in international markets.

The objective of this review is not only to summarize the key debates, but also to highlight different theoretical perspectives on how states can promote innovation and how these mechanisms can be evaluated. By examining the literature on industrial policy and innovation systems, this section identifies the most relevant concepts and indicators, which are later operationalized in the Analytical Framework. Special attention is given to the definitions of industrial policy and innovation, as these shape the criteria for the subsequent analysis.

2.2. Innovation Metrics in the Automotive Industry

Defining and Measuring Innovation: As noted above, innovation involves the implementation of significantly improved products or processes *(OECD/Eurostat 2018)*. In an industry as complex as automotive manufacturing, innovation can occur along multiple dimensions – from engineering design and manufacturing techniques to business models and supply chain management. To systematically assess innovation, scholars and policymakers often distinguish between **innovation inputs** (the resources devoted to innovation) and **innovation outputs** (the results of innovation activities) *(Braidy, Pokharel, and ElMekkawy 2025)*. **Inputs** typically include R&D expenditures, human capital (engineers and researchers employed), and investment in technology acquisition. These inputs are seen as the fuel for innovation; for example, sustained R&D spending is correlated with technological advances in automotive firms *(Fujimoto 2014)*. **Outputs** of innovation can be measured by indicators such as the number of patents filed in automotive technologies, the introduction of new vehicle models or features, productivity improvements, and quality or performance gains in products. Each metric provides a window on innovation, though none is perfect on its own. Patents, for instance, signal inventive activity but vary in significance and may not capture process innovations or tacit know-how. New model launches demonstrate product innovation, but their impact depends on market acceptance and diffusion.

Researchers have emphasized the need to use multiple metrics to capture the multi-faceted nature of innovation *(Braidy, Pokharel, and ElMekkawy 2025)*. In the automotive sector, a holistic view of innovation considers technical outcomes (e.g. fuel efficiency improvements, electric vehicle range increments), market outcomes (market share gains, entry into new segments), and organizational outcomes (such as the development of new supply chain or production capabilities). Performance metrics like profitability, market share, and product quality improvements can indicate the success of innovation efforts *(Braidy, Pokharel, and ElMekkawy 2025)*. For example, an increase in a firm's patent filings in electric drivetrain technology would be an output metric suggesting growing innovative activity, while a rise in its electric vehicle sales or an improvement in battery efficiency would reflect the impact of that innovation on market performance. Table 1 in Section 3 will summarize the specific metrics used in our analytical framework, but broadly speaking this literature review confirms that both **quantitative measures** (e.g. R&D spending as percentage of sales, patent counts, number of new models introduced) and **qualitative assessments** (e.g. case studies of major technological breakthroughs, expert evaluations of technology complexity) are necessary to fully evaluate innovation in the automotive industry.

It is also important to note the temporal dimension of innovation metrics. Some inputs, like R&D investment, may have effects only over a lag of several years before yielding outputs *(Griliches 1990)*. Similarly, metrics such as the number of patents can surge due to policy changes (for instance, China's patent filings increased rapidly after mid-2000s, partly incentivized by government innovation programs *(Naughton 2021)*). Therefore, when interpreting these indicators for China and Japan, one must consider policy context and time lags. The literature on **national innovation systems** *(Freeman 1987; Lundvall 1992)* also reminds us that innovation is influenced by systemic factors – e.g. university-industry linkages, availability of risk capital, and supply chain structure – which may not be captured by simple metrics but are nonetheless critical, especially in automotive where production networks are complex. In summary, measuring innovation in the automotive industry requires a combination of **input metrics** (to gauge effort), **output metrics** (to gauge results), and an understanding of the broader innovation ecosystem. This multi-dimensional approach is reflected in recent studies proposing comprehensive frameworks for automotive innovation. For instance, Braidy, Pokharel, and ElMekkawy (2025) review dozens of research works and propose a framework including four major innovation input categories, two main output goals (industry growth and competitiveness), multiple constraints, and eleven specific innovation metrics relevant to automotive firms *(Braidy, Pokharel, and ElMekkawy 2025)*. Such frameworks underscore that innovation is not a single score but a profile of performance across different indicators – a principle that will guide our analysis of China and Japan.

2.3. Industrial Policy Tools and Innovation

Concept and Rationale: Industrial policy is defined here as government intervention aimed at promoting or shaping the development of specific sectors or industries. The theoretical rationale for industrial policy often stems from market failures in areas like R&D and innovation. Classic economics literature argues that because knowledge has public-good aspects (e.g. spillovers from one firm's innovation benefit others), private firms may under-invest in R&D relative to the socially optimal level *(Arrow 1962)*. This provides a justification for policy tools such as R&D subsidies or tax incentives to encourage innovation. Dani Rodrik (2004) further contends that industrial policy can help identify and support new industries where a country may build a comparative advantage, essentially helping to "discover" profitable areas of innovation that the market alone might overlook. Ha-Joon Chang (2011) notes that many of today's advanced economies used industrial policies in their development, and he calls for a pragmatic approach that goes beyond ideological confrontations – recognizing that intelligent industrial policy can facilitate structural transformation and innovation if done well.

Tools of Industrial Policy: The literature documents a wide array of industrial policy instruments. A succinct summary is provided by Agarwal (2023), who lists "subsidies, tax incentives, infrastructure development, protective regulations, and R&D support" as common tools *(Agarwal 2023)*. To elaborate, subsidies can include direct grants to firms for research projects, or preferential loans and credit guarantees (e.g. low-interest loans from state banks). Tax incentives might involve R&D tax credits, accelerated depreciation for equipment, or tax holidays in targeted sectors. Infrastructure development refers to government investment in facilities like technology parks, testing laboratories, or transportation networks that benefit the industry. Protective regulations encompass tariffs, import quotas, local content requirements, and other measures shielding domestic firms from foreign competition (at least temporarily) to foster infant industries. R&D support can also take the form of establishing public research institutes, funding collaborative industry-university research programs, or setting technical standards that push firms toward innovation.

In addition, some industrial policies use **public procurement** as a lever (government agencies serving as early buyers of innovative vehicles or technologies, for example) and **joint venture requirements** to force technology transfer from foreign to domestic firms. Notably, Japan and China have each employed distinct sets of tools in the automotive sector. Japan's post-war industrialization was characterized by "administrative guidance", targeted subsidies, import protection (especially in the 1950s–1970s), and the nurturing of certain firms as national champions *(Johnson 1982)*. By the 1990s, however, Japan had largely liberalized its market under international pressure and shifted to more indirect, "soft" industrial policy measures. Beason (2021) finds that Japan essentially **abandoned sector-specific industrial policy targeting in the 1990s**, due to a growing domestic consensus that earlier interventions had mixed results, as well as U.S. trade pressure and fiscal constraints *(Beason 2021)*. During the 1990s and 2000s, Japanese policy support for the auto industry took forms like funding pre-competitive research consortia (for example, a government-backed program in the early 1990s to develop high-efficiency batteries for hybrid and electric vehicles *(Li and Liu 2024, 826–831)*), providing tax breaks for eco-friendly cars, and setting regulatory standards (such as fuel economy and emissions standards that implicitly nudged companies toward certain innovations). These are horizontal measures in many respects, focused on innovation and environmental performance across the industry rather than picking specific winners.

China, as an emerging economy, adopted a more interventionist toolkit, especially in the earlier decades of its automotive development. The Chinese government saw the automotive sector as strategic for industrialization and has unapologetically used **protective and promotional policies** to build domestic capabilities *(Xue, Wei, and Greeven 2024)*. In the 1980s and 1990s, a cornerstone policy was the requirement that any foreign automaker wishing to produce in China must form a joint venture with local partners (with foreign equity capped, commonly at 50%) *(Xue, Wei, and Greeven 2024)*. This was codified in the landmark 1994 Automotive Industry Policy, which explicitly sought to transfer technology and managerial know-how to Chinese firms by leveraging the market access desired by foreign automakers *(Xue, Wei, and Greeven 2024).* Other tools included high import tariffs on completely built vehicles (as high as 80–100% in the 1980s, gradually reducing after WTO entry) and local content rules to encourage parts localization *(Xue, Wei, and Greeven 2024)*. These measures created a protected space for Chinese automakers to learn and develop. In the 2000s, especially after China's WTO accession in 2001, there was a shift toward **"indigenous innovation"** policies. The

Medium- and Long-Term Plan for Science & Technology Development (2006–2020) marked a turning point where China elevated innovation to a national priority and began increasing state support for R&D in strategic sectors *(Naughton 2021, 14–15).* In the auto industry, this coincided with heavy state investment in new energy vehicle (NEV) technology. The government introduced purchase subsidies for electric and hybrid vehicles, R&D grants for battery and electric motor technologies, and mandated targets (for example, production quotas for NEVs for manufacturers, introduced in the 2010s).

The relationship between industrial policy and innovation is much debated. Proponents (e.g. Mazzucato 2013) argue that the state can **"create markets"** and drive technological progress by taking risks the private sector avoids – citing examples like government funding behind the internet, GPS, and battery technologies which later benefitted companies. In the automotive context, China's aggressive policies in the 2010s to promote electric vehicles are an example of the state attempting to create a future-oriented market and push firms toward radical innovation. Critics caution that industrial policy can misallocate resources, protect inefficient firms, or encourage rent-seeking if not designed and implemented well *(Beason 2021; Pack & Saggi 2006).* The literature suggests certain conditions for success: capable and autonomous bureaucracies, clear performance criteria, sunset clauses for support, and close consultation with industry ("reciprocal control mechanisms", as Amsden (2001) described). Japan's experience during its high-growth era is often cited as a successful case of the "developmental state" coordinating private and public sectors (though some studies argue that Japan's success owed at least as much to competitive market forces and firm-level management techniques as to policy). China's more recent experience is still unfolding, with some spectacular successes in scale (the NEV boom) but also concerns about inefficiencies (e.g. periods of overcapacity or subsidy fraud in the EV sector). The **academic consensus** has moved from a blanket opposition to industrial policy to a more nuanced stance: industrial policy is "neither miracle nor menace" but a tool that can be constructive if evidence-based and coupled with learning and adaptability *(Rodrik 2008; Warwick 2013).* This review highlights that industrial policy aimed at innovation needs to address specific market or system failures – such as fostering R&D collaborations, guiding capital to long-gestation technologies, or coordinating complementary investments (like charging infrastructure for EVs) – which we will see in the China and Japan cases.

This literature review has clarified what we need to observe in order to answer the research question. Based on the reviewed debates, we focus on two groups of indicators: (1) **innovation outputs** at the product and technology level (for example, battery chemistry and energy density, charging performance, ADAS/software capability, patents, and model launches); and (2) **market outcomes** that signal competitiveness (production, exports, domestic brand share, and price positioning). These indicators are consolidated in the Analytical Framework and will guide our empirical comparison of China and Japan. In the next chapter, we apply the framework criterion by criterion, using comparable data and consistent measurement notes (test cycles, exchange rates, and sources). The goal of the empirical part is not to re-state theories, but to document observable evidence that later allows a reasoned discussion of policy effects in the analytical chapter.

3. Analytical Framework

3.1. Derivation of Analytical Criteria

Drawing on the above literature, we identify several key criteria to guide the analysis of how industrial policy influenced automotive innovation in China and Japan. These criteria encapsulate both the innovation outcomes achieved and the policy efforts made, allowing a structured comparison:

1. Innovation Input Effort: Both theory and empirical studies highlight R&D investment as a fundamental input to innovation. We will examine the level of R&D expenditures in the automotive sector (e.g. R&D as a percentage of automotive GDP or as a percentage of sales for major firms) as one indicator. A higher sustained R&D intensity often reflects a strong innovation push (whether driven by policy incentives or firm strategy). For example, Japan historically has had very high R&D spending by its auto firms (Toyota is perennially among the top global R&D spenders), while China's R&D spending rose dramatically in the 2000s and 2010s as policy encouraged indigenous innovation *(ACEA 2023)*. Another input indicator is human capital – the training of engineers and the presence of technical research institutions. The literature suggests that Japan's post-war success owed much to a skilled engineering workforce and collaborative research culture, whereas China invested in creating new universities and research centers for automotive engineering in the 2000s. Industrial policy tools like grants for engineering education or the founding of technical institutes (e.g. China's Automotive Technology and Research Center, CATARC) will be noted qualitatively.

2. Innovation Output and Technology Development: We will use patent counts in relevant automotive technology classes (such as patents related to electric drive, battery management, or autonomous driving) as a quantitative output metric for innovation. Patents are a proxy for technological invention. For instance, if China's patent filings in electric vehicle technologies surged after the introduction of NEV policies, that indicates a positive output of those policies (indeed, some studies report exponential growth in Chinese automotive patents in the 2010s). Japan's patent portfolio, on the other hand, has long been rich in automotive engineering – we might look at how it shifted (e.g. a high share in hybrid tech patents, perhaps fewer in pure EV). Beyond patents, **product innovation** is an output to consider: the introduction of groundbreaking models or features originating from each country. The Prius (1997) was a Japanese output of innovation; the BYD Han EV (2020) or NIO's battery swapping technology are Chinese outputs. We will qualitatively assess major innovations and use indicators like the number of new energy vehicle models launched by domestic firms as a gauge. Another facet is quality improvement – metrics like JD Power quality scores or export acceptance can signal output improvements due to innovation. For example, the rise in Chinese car exports suggests their quality and technological content reached international standards *(RIETI 2023).*

3. Industry Competitiveness and Market Outcomes: Ultimately, innovation should translate into stronger industry performance. Criteria here include production volume and global market share, export performance, and the presence of competitive domestic firms. From the literature: Japan was the world's top auto exporter for many years, a position now challenged by China's catch-up *(RIETI 2023).* We will use data on production (e.g. millions of vehicles produced per year) and exports (millions exported, and ranking among global exporters) as indicators. Another indicator is the market share of domestic brands in the home market versus foreign brands – a rising domestic share in China (now over 50% and climbing in passenger cars) indicates successful innovation by Chinese firms and reduced reliance on foreign joint-venture technology *(RIETI 2023).* In Japan, domestic brands have always dominated the home market (over 90% share), but an area of competitiveness to examine is their share in foreign markets (e.g. Japanese brands' share in China, which has fallen, or in North America, which remains strong). The emergence of national champions as global technology leaders can also be a metric: e.g. Toyota's leadership in hybrids, CATL's leadership in EV batteries – these illustrate how innovation can yield global influence. Industrial policy's success is partly reflected in whether it cultivated such champions.

4. Policy Implementation and Institutions: While not an "innovation outcome" by itself, the nature of policy implementation is itself a criterion for analysis because it influences the above outcomes. This includes the **consistency and adaptability of policies** (did the country maintain a long-term innovation strategy? Did it adjust subsidies when needed?), the **breadth of policy support** (did it cover the whole innovation chain from research to commercialization?), and the **institutions** managing the policy (e.g. MITI/METI in Japan, NDRC and MIIT in China). Literature suggests that Japan's institutional strength (close coordination between government and industry, but also checks to wind down support when goals were met) contributed to effective industrial upgrading in earlier decades *(Johnson 1982),* whereas China's institutional approach is more centralized and target-driven (with very high targets like reaching a certain EV penetration by 2025, etc.). For analysis, we might not have a single quantitative indicator here, but we will assess qualitatively how each government's policy apparatus functioned and how this impacted innovation. For example, one could cite that *China officially launched the "Made in China 2025" strategy with specific innovation targets in autos (like 70% domestic content in NEVs by 2025), reflecting strong top-down guidance (State Council 2015),* *while Japan's government issued a New Economic Growth Strategy in 2010 including green innovation in autos*, reflecting a more consensus and broad approach *(METI 2010).*

These criteria derived from the literature ensure that our subsequent analysis will be comprehensive. They encompass **technological metrics** (R&D, patents), **market metrics** (production, exports, market share), and **policy metrics** (the scale and type of interventions), reflecting the multifaceted link between industrial policy and innovation. Table 1 in the next section will operationalize these criteria by specifying how exactly each will be measured or observed, and what sources of data will be used. In developing these criteria, we lean on insights from prior studies: for instance, Braidy et al. (2025) highlight inputs and outputs; Yeung (2019) emphasizes the role of policy in creating market output (NEV sales); and Sano et al. (2011) demonstrate the importance of historical policy-institution context. By synthesizing these, we aim to create an analytical framework that can systematically compare the Chinese and Japanese experiences side by side.

3.2. Criteria, Indicators, and Data Sources

Building on the criteria identified above, this section presents the analytical framework for assessing the impact of industrial policy on automotive innovation in China and Japan. We define each criterion in detail, specify the indicators that will be used to evaluate each, and note the sources/methods for obtaining the relevant data. Table 1 below provides an overview of the operationalization of these criteria:

Criterion	Definition and Scope	Indicators (Measures)	Data Sources
Innovation Input Effort	The resources committed to innovation in the automotive industry. Includes financial investment and human capital dedicated to R&D and Technology development.	- R&D expenditure in automotive sector (as % of auto industry GDP or % of sales for major firms) - Number of automotive R&D personnel (or engineers) employed in sector - Existence of collaborative research programs or institutes (qualitative)	- Company annual reports and financial filings (for R&D spending by Toyota, VW China JV, etc.) - National statistical agencies/OECD data for R&D as % of GDP *(ACEA 2023)* - Government reports on R&D programs (e.g. METI white papers, China S&T statistics yearbooks)

Innovation Output and Technology Development	The tangible results of innovation activities in the industry. Encompasses new technologies, patents, and innovative products introduced.	- Number of patents in automotive technology classes (per year, China vs Japan) *(Braidy, Pokharel, and ElMekkawy 2025)* - Count of significant new models or technologies launched by domestic firms e.g. EV models, hybrid systems, autonomous driving features) - Technical performance indicators of innovations (e.g. battery energy density achieved, fuel economy improvements in new models)	- Patent databases (WIPO, national patent offices) for patent counts (e.g. EV-related patents since 2000, comparing Chinese and Japanese assignees) - Trade journals and news (for model launch timelines and specs, e.g. Prius launch 1997, BYD Han launch 2020) - Research papers on technical performance (for example, battery tech progress reports in each country)
Industry Competitiveness and Market Outcomes	The competitive performance of the domestic automotive industry in home and global markets, as an outcome of innovation.	- Annual vehicle production volumes (and share of global production) *(RIETI 2023)* - Annual vehicle export volumes (and share of global exports) *(RIETI 2023)* - Domestic market share of domestic-brand vehicles vs foreign-brand (JV) vehicles *(RIETI 2023)* - Global presence of domestic automakers (e.g. number of domestic firms in global top 10 by sales or innovation rankings)	- International Organization of Motor Vehicle Manufacturers (OICA) and CAAM/JAMA for production & sales statistics *(RIETI 2023)* - UN Comtrade or national customs data for export figures - Industry analyses for market share (e.g. CAAM data on Chinese vs foreign brand share in China; Japan Automobile Dealers Association for import vs domestic share in Japan) - Fortune Global 500 or similar lists to see automakers' global ranks, and reports on global innovation awards (if any)

Policy Implementation and Support Intensity	The nature and intensity of industrial policy support directed at automotive innovation. This includes the policy instruments used, their scale, and institutional execution.	- Cumulative government spending on automotive R&D and innovation programs (e.g. total NEV subsidies disbursed by China *(Xue, Wei, and Greeven 2024)*) - Presence of protective measures: tariff rates, joint venture requirements (Y/N by period) *(Xue, Wei, and Greeven 2024)* - Strategic policy frameworks in place (e.g. "Made in China 2025" specifying auto innovation targets; Japan's New Energy Vehicle roadmap) - Qualitative assessment of institutional arrangements (e.g. dedicated government agencies or task forces for auto innovation, public-private collaboration platforms)	- Government budget documents and official policy papers (for quantifying subsidy amounts, tax incentives, etc. in each country) - WTO filings and tariff schedules (for tariff history on autos in China and Japan) - Policy strategy documents (State Council of China, METI of Japan) – for example, Made in China 2025 document, Japan's Green Growth Strategy 2021 etc. - Scholarly analyses of institutions (e.g. case studies on how NDRC managed EV policy, or how METI coordinates with automakers)

Figure 3.1. Operationalization of Analytical Criteria for Comparing Automotive Innovation in China vs. Japan

3.3. Methods of Assessment

With the criteria and indicators established, the methodology for assessment will involve a **comparative case analysis** of China and Japan across these dimensions. The approach is both quantitative and qualitative:

- **Data Collection:** Quantitative data such as production figures, R&D expenditures, and patent counts will be collected for multiple benchmark years between the 1990s and 2024 (e.g. 1995, 2005, 2015, 2022) to observe trends over time. For instance, R&D intensity in Japan's auto sector from the 1990s to 2020 can be plotted (Statista indicates it rose from around ¥1 trillion in 1990s to over ¥3 trillion by 2020), and similar data for China (which started much lower and increased sharply in the 2000s) can be compiled. Patent data will be gathered from databases like WIPO IP Statistics – focusing on relevant IPC codes for automotive innovation (hybrid drive systems, battery management, etc.), enabling a comparison of the volume and growth of patents by country of origin. These quantitative indicators will be used to create tables or charts in the analysis chapter, facilitating a visual comparison.

- **Qualitative Analysis:** Numbers alone do not tell the full story, so the method includes a narrative analysis of policy documents and historical developments. We will perform a document analysis of major policy statements (for example, China's 10th and 11th Five-Year Plans, which mentioned automotive sector goals; the Made in China 2025 plan; Japan's Automobile New Era Strategy 2010, etc.) to qualitatively score the **policy support intensity**. We will examine whether each country's policies were primarily *enabling* (creating conditions for innovation) or *directive* (mandating specific outcomes), and how flexible they were. For example, when China's initial EV subsidy program led to some malpractices, the government adjusted the policy in 2016 (tightening tech requirements and reducing subsidy amounts) – this adaptability will be noted as part of policy implementation effectiveness *(Tang 2019).*

Each criterion will be analyzed in a dedicated subsection in the analysis (not included in this document, but planned for the thesis). For each, we will compare China and Japan side by side. The method of structured, focused comparison means we will ask the same set of guiding questions of each case for each criterion. For instance: *Innovation Input*: "How much do firms invest in R&D, and what policies affect this? Has the trend been increasing?" *Innovation Output*: "What notable innovations emerged, and can we link them to policy incentives or market forces?" *Industry Outcome*: "How has global market position changed, and what role did innovation play in that change?" *Policy Implementation*: "What were the key industrial policy measures each decade, and how did industry respond in terms of innovation?"

- **Triangulation:** To ensure robustness, multiple sources will be used to verify key facts. Academic sources (journals, conference papers) accessible via the University of Vienna library will provide peer-reviewed evidence (e.g. case studies on specific policies), while industry reports and databases will provide up-to-date statistics. Where discrepancies arise (for example, different figures for China's subsidy totals from different studies), the analysis will note and reconcile them if possible by cross-checking official records.
- **Use of Tables/Figures:** In addition to Table 1 above, the analytical sections will include tables or figures as needed. For example, we may include a table listing major policy milestones and corresponding innovation indicators (e.g. "2009: China launches NEV Subsidies – next 5 years

EV patents by Chinese companies jump X%”). We have already embedded Figure 1 which graphically compared EV adoption; similar figures may be used for patent trends or production trends if they aid understanding. These visual aids, drawn from reliable data, will help illustrate contrasts such as China’s exponential patent growth versus Japan’s linear growth, or the point at which China’s vehicle output and exports surpassed Japan’s (around late 2010s).

- **Evaluation and Causation:** A core methodological challenge is attributing causation – how much of the innovation outcome can be credited to policy? The framework tackles this by examining timing and process. If a certain innovation outcome closely follows or coincides with a policy introduction, and if literature and interviews (if any) suggest a linkage, we can make a reasoned argument for causality. For example, the rapid increase in Chinese EV startups and patents in the early 2010s came on the heels of the government’s 2009–2010 EV promotion policies *(Yeung 2019, 39–59),* indicating a likely causal influence. Conversely, Japan’s development of hybrids in the 1990s occurred with relatively little direct subsidy (the substantial tax incentives came after the introduction of hybrid models). This suggests Japanese firms innovated proactively (perhaps anticipating future regulations or motivated by market strategy), with policy playing a supportive but not initiating role. Our comparative method will highlight such differences: instances of *policy-driven innovation* versus *industry-driven innovation under a policy framework*.
- **Criteria Interaction:** The framework acknowledges that the criteria are interrelated. High R&D input (Criterion 1) is often encouraged by certain policies (Criterion 4) and leads to patents or new models (Criterion 2), which then influence market success (Criterion 3). We will use the data to trace these linkages. For instance, we might show in the analysis chapter that *China’s R&D spending in autos, as a % of sales, increased significantly after 2009* (when subsidy and indigenous innovation policies kicked in), and that *by five years later, patent outputs in EV tech had correspondingly jumped*, and then *a few years after that, domestic companies gained market share*. While multiple factors are at play, such temporal patterns combined with qualitative accounts (from sources and possibly interviews or contemporary news) strengthen the argument of policy impact.

In summary, the analytical framework is designed to be systematic and evidence-based. By using clearly defined criteria and gathering data for each, we aim to avoid anecdotal or one-sided comparisons. The framework blends quantitative indicators with qualitative context, as recommended in policy evaluation literature (Yin 2014 for case studies, etc.). This will allow the thesis to present a nuanced narrative: not just that *"China did X and got Y result, Japan did A and got B result,"* but also *why* those results occurred, what trade-offs were involved (such as China's high expenditure for rapid gains vs. Japan's more cost-efficient but slower trajectory), and what lessons can be learned about the relationship between industrial policy and innovation.

3.4. Operationalization Table and Its Usage

Table 1 (above) is a key reference point that will be used throughout the comparative analysis. It ensures that for each aspect we have a concrete measure. For example, when discussing **Innovation Input Effort** in the analysis, we will present data on R&D spending for both countries. According to available data, as of the early 2020s, China's total automotive R&D spending (by all firms) was estimated at around ¥140 billion (roughly $22 billion), which is lower than Japan's roughly ¥3–4 trillion (about $30–35 billion) – however, Chinese spending has been rising faster and is concentrated on newer technologies. Such figures will be cited and analyzed. Similarly, for **Innovation Output**, patent counts will be cited: e.g., in 2020, Chinese entities filed far more EV-related patents than Japanese entities, reflecting the push into that field (data from patents databases will be provided in the analysis section to back this up). The operationalization ensures we consistently compare like with like.

One benefit of this framework is the ability to highlight **policy effectiveness**: we can see, for instance, that despite lower historical R&D spending, China achieved a certain innovation output by leveraging global technology (through JVs and acquisitions) and policy focus – a different model than Japan's heavy domestic R&D approach. By breaking innovation into these components, we can more readily attribute which aspects of innovation were strongly influenced by policy. The framework will also allow a balanced scorecard-type summary in the conclusion, evaluating where each country stands on each criterion by 2024 (for instance: Input Effort – both high, Japan still higher per capita; Output – both innovating but in different tech domains; Industry outcomes – China now larger in scale, Japan still competitive in quality; Policy Support – China's much more intensive).

In conclusion, the analytical framework set out here provides a clear blueprint for dissecting the complex story of automotive innovation in China and Japan. It aligns with the literature review findings and ensures that the subsequent analysis is rooted in concrete evidence and structured comparison. Using this framework, the thesis will be able to draw informed conclusions about how and how well industrial policies have worked in fostering automotive innovation in the two countries, and what this implies for theories of innovation and development policy more generally.

4. Methodology and Data Collection

4.1. Research Design and Case Selection

This study adopts a **comparative case study** approach to evaluate how industrial policy has influenced automotive innovation in China and Japan from the 1990s to 2024. A case study method is well-suited for obtaining an in-depth understanding of complex, real-world phenomena *(Yin 2014, 4–6)*. By focusing on two country cases, the research can explore causal processes and context-specific factors in detail, rather than relying on broad statistical generalizations *(Yin 2014, 18–19)*. China and Japan are selected as **contrasting cases** that offer maximum insight into the research question. Japan entered the 1990s as an automotive technology leader with a mature innovation ecosystem, whereas China was a latecomer with nascent capabilities – yet both pursued the common goal of enhancing automotive innovation through deliberate policy intervention. This deliberate contrast represents a form of "most-different systems" design in comparative research, wherein cases differ widely in context but illuminate how varying conditions affect similar outcomes *(Seawright and Gerring 2008)*. By examining an advanced economy (Japan) alongside an emerging economy (China), the study can identify which innovation policy measures are effective across different institutional contexts and which outcomes are context-dependent. The **validity of selecting China and Japan** lies in their global significance and divergent trajectories – for instance, China surpassed Japan to become the world's largest automobile producer in 2009, reflecting a dramatic catch-up that makes their comparison analytically rich. The two cases also present variation in policy regimes (a developmental state model vs. a socialist-market hybrid), allowing us to probe how different approaches to industrial policy can lead to different innovation outcomes. Importantly, the goal of this small-*N* comparison is **analytical insight** rather than broad statistical inference: by studying these two strategic cases in depth, the research can generate nuanced explanations of policy effectiveness that may inform theory and be cautiously applied to other contexts *(George and Bennett 2005, 19–22)*.

The study follows a **structured, focused comparison** method *(George and Bennett 2005, 67)*. This means that a consistent set of questions and criteria is applied to each case, ensuring systematic data collection and enabling side-by-side comparison. The inquiry is "structured" in that we use the same analytical framework (developed in Chapter 3) for both China and Japan, examining each country through identical criteria (innovation inputs, innovation outputs, industry outcomes, and policy implementation). It is "focused" in that we limit the analysis to aspects relevant to the research question – namely, those facets of the automotive industry and policy that pertain to innovation – rather than attempting full historical accounts of the countries. By asking the **same questions of each case** (e.g. *How much was invested in R&D? What types of automotive innovations were produced? How did global market position change? What policy tools were employed and how?*), the comparison remains aligned with the thesis objectives and avoids distraction by extraneous differences (George and Bennett 2005, 69–71). This structured approach enhances comparability and helps trace **cause-effect relationships** within each case and across cases. In essence, the research design marries the depth of case study analysis with a comparative logic: each country's experience is first analyzed on its own terms (within-case analysis), and then the findings are juxtaposed to draw out patterns, contrasts, and potential causal inferences across the two cases (cross-case analysis). This design is appropriate for exploring the thesis question, which seeks to understand *how* and *how effectively* industrial policies fostered innovation – a question that benefits from process-tracing within each case and careful comparison between cases *(Yin 2014, 14–17).*

4.2. Structured-Focused Comparative Approach

To implement the above design, the study uses a **structured, focused comparison** framework as outlined in the analytical framework (Chapter 3). Each case (China and Japan) is examined through the **same set of criteria and indicators**, ensuring that the comparison is systematic and aligned with the research questions *(George and Bennett 2005, 67).* The criteria – derived from theory and literature – include: ***(1) Innovation Input Effort**, **(2) Innovation Output and Technology Development**, **(3) Industry Competitiveness and Market Outcomes**, and **(4) Policy Implementation and Support Intensity***. By structuring the analysis around these four thematic criteria, the research maintains focus on the relevant aspects of automotive innovation and policy. For each criterion, a defined subset of **indicators** and guiding questions is applied to both countries. For example, under *Innovation Input Effort* we ask: *How much do firms and governments invest in R&D for automotive innovation, and how has this changed over time?* Under *Innovation Output*, we ask: *What measurable outputs (patents, new technologies, innovative models) have emerged, and what does that imply about each country's innovation performance?* This questioning is replicated for *Industry Outcomes* (e.g. *How have production volumes, exports, or domestic market shares evolved as a result of innovation?*) and for *Policy Implementation* (e.g. *What policy instruments were used and how intensively?*). Using identical questions and measures for each case constitutes the "structured" aspect of the comparison, while zeroing in on innovation policy effects (and not other unrelated differences) constitutes the "focused" aspect.

Crucially, the structured approach allows for a **focused narrative** within each criterion. Rather than writing separate, wide-ranging case histories, the analysis is organized by thematic sections – each section comparing China and Japan on one criterion at a time. This corresponds to a **most-similar aspects** strategy within each section: we examine the same aspect (e.g. patent outputs) in both contexts, which helps isolate how differences in policy or context may have led to different outcomes. Throughout the analysis, we maintain parallelism in coverage: for instance, if discussing R&D spending trends in Japan, we present the analogous data for China over the same period, highlighting differences and similarities. This approach follows the logic recommended by comparative case study methodologists for increasing inferential leverage with a small number of cases *(George and Bennett 2005, 71–72).* It also mitigates bias by ensuring neither case is analyzed with extra questions or less rigor than the other. In sum, the structured, focused comparison provides a **framework for cross-case synthesis**: after examining each criterion, the study will be able to draw out comparative insights (e.g. whether higher R&D input in one country led to proportionally higher outputs than in the other, or how each government's policy intensity corresponds to innovation results). This method is particularly useful for our inquiry because it helps link cause and effect in context – for example, aligning the timeline of policy initiatives with subsequent innovation indicators in each country, and then comparing those trajectories. The structured format ensures that such observations are made systematically rather than anecdotally, thereby strengthening the study's analytical rigor *(Yin 2014, 136–39).*

4.3. Indicators and Data Sources

Building on the analytical framework's criteria and indicators, this chapter's methodology involves detailed **indicator–dataset mapping**. Each abstract criterion is operationalized with specific metrics and data, drawn from authoritative sources. Table 1 in Chapter 3 has already outlined these mappings; here we describe the key datasets and justify their use. All data selection has been guided by the principles of reliability, coverage, and relevance to the research question. Below is an overview of the **indicators and their data sources:**

- **Innovation Inputs (R&D and human capital)**: To measure R&D investment in the automotive sector, the study uses data from the OECD's Main Science and Technology Indicators (MSTI) database and national statistics. These sources provide figures for R&D expenditures as a percentage of GDP or as a percentage of automotive industry output, which allow for cross-country comparison *(OECD 2024).* For firm-level R&D (e.g. spending by major automakers), company annual reports and financial filings are utilized, as they detail R&D spending in absolute terms and as a share of sales. Human capital inputs – such as the number of researchers or engineers in automotive R&D – are gauged from sources like UNESCO or national science & technology reports when available, as well as proxy indicators from OECD data (e.g. R&D personnel headcounts). Government reports and white papers also inform this criterion; for instance, Japan's METI White Paper on Manufacturing or China's S&T Statistical Yearbook may report the establishment of new research centers or training programs. These qualitative inputs help contextualize the quantitative data.

- **Innovation Outputs (technology development and patents):** Patent data serve as a key indicator of technological innovation output. The study draws from the World Intellectual Property Organization's IP Statistics Data Center for the number of patent filings related to automotive technologies *(WIPO 2025).* Specifically, we track patent counts in relevant International Patent Classification (IPC) classes (e.g. those covering electric vehicle technologies, battery systems, or autonomous driving systems) for applicants from China and Japan. WIPO's database allows extraction of patent counts by country of origin and by year, facilitating a comparative trend analysis. In addition to patents, the research records notable innovative products and technical milestones: for example, the introduction of groundbreaking vehicle models (such as the Toyota Prius in 1997 or BYD's Blade Battery in 2020) and performance indicators of new technologies (like improvements in battery energy density or fuel efficiency). Data on new model launches and their features are gathered from industry publications, press releases, and trade journals (for instance, Automotive News or company press kits that detail when new electric or hybrid models were launched and with what capabilities). We also consult academic case studies and technical papers for evidence of qualitative outputs – such as improvements in vehicle safety ratings or breakthrough components – to ensure that innovation output is captured not just by patent quantity but also by significance.

- **Industry Competitiveness and Market Outcomes:** To connect innovation to broader industry performance, we use multiple industry datasets. Production and sales volumes of vehicles are obtained from the International Organization of Motor Vehicle Manufacturers (OICA) annual statistics, which compile country-level vehicle production each year *(OICA 2023).* These OICA figures (which are sourced from national automobile associations) show the growth and global share of each country's auto production. Complementing this, national industry associations provide finer detail: the China Association of Automobile Manufacturers (CAAM) publishes yearly and monthly reports on China's vehicle production, sales, and the market share of domestic vs. foreign manufacturers, while the Japan Automobile Manufacturers Association (JAMA) provides data on Japan's production, sales, and export volumes. Using CAAM and JAMA data, we can track metrics like the domestic market share of local brands (a crucial indicator of how well domestic innovation has strengthened home-grown firms). For example, CAAM data show the rise of Chinese-brand passenger cars to over 50% of domestic market share in recent years, a trend indicative of successful innovation and competition against joint ventures. Export performance is another vital indicator: we utilize the United Nations Comtrade database to obtain figures on annual automobile exports (in units or value) for both countries *(United Nations 2024).* This helps us compare how innovation may have translated into international competitiveness – e.g. Japan's long-held lead in auto exports versus China's recent surge to record export numbers *(RIETI 2023).* Indeed, official data show China's vehicle exports overtaking Japan's in 2023, a striking outcome that this study will examine in light of each country's innovation efforts. Additional industry performance indicators include the number of domestic firms in the global top rankings (by sales or by R&D spending) and qualitative assessments like brand reputation or quality indices (e.g. JD Power Initial Quality Study scores, if available). These will be gathered from industry reports (such as the ACEA's industry outlook or consulting reports) and serve to triangulate the picture of competitiveness.

- **Policy Implementation and Support Intensity:** Evaluating innovation policy requires both quantitative and qualitative data. Policy documents and databases are primary sources here. We compile data on government spending dedicated to automotive innovation – for instance, total funding for electric vehicle subsidies, R&D grants, or innovation programs – from budget documents and prior research. One key source is official policy papers: China's central government releases plans and reports (e.g. the State Council's Made in China 2025 plan *(State Council 2015)* and successive Five-Year Plan documents) which enumerate targets and initiatives, while Japan's government produces strategy documents (e.g. METI's New Growth Strategy of 2010 (*Ministry of Economy, Trade and Industry 2010)* or the Green Innovation roadmap) that outline industrial policy measures. These documents are analyzed to identify the policy instruments used (such as subsidies, tax incentives, joint-venture requirements, R&D consortia, etc.) and their scale. Academic analyses and think-tank reports help quantify some of these aspects: for example, studies by Xue, Wei, and Greeven (2024) provide estimates of China's NEV (new energy vehicle) subsidy totals over the 2009–2015 period, and WTO tariff schedules are used to verify the presence or relaxation of automotive import tariffs. We will use WTO data to note protective measures (e.g. China's tariffs and local content rules in the 1990s–2000s, and how these changed upon WTO entry in 2001). We also rely on scholarly case studies for insight into institutional implementation – e.g. how effectively agencies like NDRC (in China) or METI (in Japan) coordinated with industry *(Naughton 2021; Johnson 1982).* These qualitative sources enrich our assessment of policy intensity by shedding light on governance, consistency of policy, and industry–government collaboration mechanisms. In short, indicator–dataset mapping ensures that for each conceptual criterion, we have concrete, triangulated measures: from hard numbers (R&D dollars, patent counts, car output) to documented policies (laws, plans, funding amounts) to expert observations. All data sources chosen are either official statistics, well-established databases, or reputable publications, lending credibility to the analysis. Table 1 in Chapter 3 serves as a reference summary of these mappings, and the empirical analysis chapter will explicitly cite data from these sources as the evidence base.

4.4. Data Reliability, Coverage, and Limitations

Given the reliance on multiple datasets over a nearly 30-year span, careful consideration is given to **data reliability and validity**. Each source is evaluated for accuracy and potential biases. Official statistics (e.g. OECD, OICA, CAAM, JAMA) are generally trustworthy for broad indicators like production or R&D spending, but they may have definitional differences or data gaps that need acknowledgment. For example, **R&D expenditure data** for China in the 1990s are sparse and may not fully capture private-sector efforts, as accounting standards and survey methods evolved over time. In such cases, we supplement with secondary estimates from literature (e.g. academic estimates or World Bank data) to ensure coverage of the early period. **Time coverage** is indeed a challenge: not all indicators have consistent data from the 1990s through 2024. Patent databases, for instance, have good coverage from the mid-1990s onward, but earlier years' patent counts in China were negligible and not well-recorded. We address this by focusing on the period where data are robust (approximately 2000s forward for many innovation metrics) while still incorporating qualitative evidence from the 1990s. Where possible, data will be presented on a **decadal or periodic basis** (e.g. mid-1990s, mid-2000s, mid-2010s, early 2020s) to observe trends without over-relying on single-year fluctuations that might be due to data noise.

Data reliability concerns are handled through triangulation and cross-verification. In particular, when dealing with Chinese statistics, which some observers have questioned for potential over-reporting at local levels, the study cross-checks national totals with international sources. For example, China's vehicle production figures reported by CAAM are compared with OICA's international dataset and also with import/export data (a consistency check: domestic production plus imports minus exports should roughly equal domestic sales). Similarly, for innovation outputs, patent data from WIPO (which includes international filings) are compared with counts from China's own patent office and Japan's patent office for consistency. If discrepancies arise – as they can when counting "patents" (invention patents vs. utility models, etc.) – the analysis will note these and rely on the measure that best reflects comparable inventive activity (likely international patent families or PCT filings as a common yardstick). **Lags and lead times** are also considered. Policy effects on innovation often occur with a lag (e.g. an R&D grant today might lead to patents in a few years, or a new regulation might affect sales a couple of years after implementation). The study is attentive to these temporal dynamics: when plotting trends, we will interpret causality cautiously, recognizing that correlation in timing does not automatically imply causation. However, the structured comparison over a long period helps: we can often see if an indicator changed significantly after a policy was introduced in one country and look for similar or different timing in the other country.

Acknowledging **limitations** is important for methodological transparency. One limitation is that some qualitative aspects of innovation (such as *quality* of patents or technologies) are hard to quantify. A high patent count does not necessarily mean high-impact innovation if many patents are minor or strategic filings. We mitigate this by qualitatively discussing notable breakthroughs and using citations of studies on patent quality when available. Another limitation is attributing outcomes purely to policy – many external factors (global market shifts, fuel prices, etc.) influence innovation. The methodological approach addresses this by using **process-tracing logic**: we examine the narrative of each case to see if surges in innovation metrics coincide with policy interventions (and check if alternative explanations might be at play). Still, the evidence is largely observational, so any causal claims are made carefully and with acknowledgment of uncertainty. The comparative element provides a form of control: if one country's innovation took off after policy X while the other, lacking that policy, lagged in the same period, it adds confidence that policy X had an effect *(George and Bennett 2005, 181–84).* Conversely, if both countries saw similar outcomes despite different policies, we infer that non-policy factors or global trends might be at work. By **triangulating data sources** and combining quantitative with qualitative evidence, the study enhances the credibility of findings – no single source or metric is taken at face value without cross-checking against others. In practice, this means, for example, that if an official report claims a certain policy resulted in a huge increase in EV technology, we would look at patent data, EV sales figures, and independent studies to verify that increase. Any **inconsistencies** discovered (for instance, different figures for Japan's auto R&D spending from OECD vs. METI's reports) will be explicitly noted in the text, and the analysis will either reconcile them (if possible by conversion or noting scope differences) or choose one as more authoritative while explaining the discrepancy. Overall, the methodology strives for a **balanced approach**: using the best available data, acknowledging its imperfections, and exercising caution in interpretation to avoid overstating what the data can support.

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4.5. Presentation of Empirical Findings

The empirical findings will be organized following the structured framework established in the methodology. The chapter will be divided into sections corresponding to each analytical criterion, and within each section the evidence from China and Japan will be presented side by side. The results will be conveyed through a combination of narrative discussion, tables, and figures to effectively communicate the comparative insights. For each criterion (e.g. Innovation Input, Innovation Output, etc.), the chapter will typically include:

- **Data Tables or Charts:** Key quantitative indicators will be summarized in a table or depicted in a figure for clarity. For instance, under Innovation Input, a table might list R&D expenditures for selected years (2000, 2005, 2010, 2015, 2020) for both countries, or a line chart may show the trend of R&D spending as a percentage of GDP over time for China vs. Japan. Under Innovation Output, we may include a bar chart comparing the number of EV-related patents filed by Chinese and Japanese entities each year, or a timeline of significant model launches. Industry Outcomes could be illustrated by a chart of vehicle production volumes, highlighting the year China overtook Japan, and a graph of export volumes from 1990 through 2024. Policy Support might be summarized in a timeline figure or table listing major policy measures by date (e.g. "2009: China introduces NEV subsidy; 2010: Japan implements eco-car tax incentive") alongside observed outcomes (e.g. "Chinese EV sales jumped 2010–2014; Japanese hybrid sales increased after 2010"). These visuals are not only useful for the reader's comprehension but also help underscore the comparative narrative – e.g. a figure can quickly show the diverging patent trajectories or the crossover point of production. All figures and tables will have clear labels, units, and data sources indicated (e.g. source lines citing OICA, WIPO, etc.), following the University's formatting guidelines.

- **Focused Analysis in Text:** The narrative in each section will walk the reader through the evidence, comparing China and Japan directly. Rather than discussing each country in isolation, the writing will alternate between the two in order to highlight contrasts and similarities criterion by criterion. For example, in the Innovation Input section, after presenting data, the text might note: "Japan sustained higher R&D intensity through the 1990s and 2000s, investing around 3–4% of auto industry GDP in R&D, whereas China started much lower (under 1%) but rapidly climbed to ~2% by the late 2010s *(OECD 2024)*. This reflects Japan's established innovation system and China's catch-up effort with strong policy pushes in the 2000s. By 2020, China's total automotive R&D spending (in absolute terms) began to rival Japan's, though on a per-vehicle basis Japan still spent more." Such comparative interpretation will be backed by the data and sources discussed earlier. The goal is to ensure each section yields mini-findings about the criterion in question – for instance, we might conclude the Innovation Input section by noting which country's policy seemed more effective in boosting R&D, or conclude the Industry Outcomes section by noting how innovation translated into market leadership differently in each case.

- **Interim Summary ("mini-findings"):** At the end of each criterion-focused subsection, a brief summary will crystallize the findings before moving on. These summaries function as mini-conclusions that answer the guiding question for that criterion. For example, a summary might state: "In summary, China's innovation input grew exponentially from 2000 onward, supported by heavy state funding and foreign technology absorption, while Japan maintained high but steady inputs; this suggests China's policy-driven surge closed much of the gap in raw R&D investment by 2024, though differences remain in efficiency and focus of that R&D." Such statements synthesize the comparative evidence and foreshadow the evaluation to be made in the concluding chapter. They also improve readability by ensuring that a reader not deeply familiar with the data can take away the key point from each section.

Overall, the empirical chapter's format will be highly visual and structured, in line with best practices for comparative studies. By presenting data in figures/tables and then discussing them, the thesis allows readers to see the evidence for themselves and then follow the interpretation. Every figure and table will be referenced and explained in the text (the narrative will guide the reader on what to observe in the figure, such as a notable trend or gap). Additionally, any complex data will be accompanied by notes clarifying definitions (e.g. what counts as "automotive R&D" in each dataset, or that Chinese patent counts include both domestic filings and PCT international filings, etc.). The use of both quantitative charts and qualitative illustrations (such as quoting a policy statement or an expert assessment) will give a well-rounded empirical picture. The chapter will thus function as a comparative story of two countries' automotive innovation journeys, broken into thematic acts (criteria) for clarity. This structured presentation directly reflects the methodology: since we have collected data according to criteria and indicators, we will present it the same way. Ultimately, this approach aims to clearly demonstrate comparative effectiveness – by the end of each section, the reader should understand how China and Japan compare on that particular dimension (e.g. which had more output, or how their policy approaches differed), and by the end of the chapter, the reader will have a comprehensive side-by-side comparison. These findings will set the stage for the concluding analysis in Chapter 6, where the criteria will be revisited synoptically to answer the overall research question about what worked, what didn’t, and what lessons can be learned about innovation policy in the automotive sector.

5. Empirical Comparative Analysis

5.1. Empirical Context

Japan's Trajectory (1990s–2024): By the early 1990s, Japan was at the technological frontier of the automotive industry. Companies like Toyota, Honda, and Nissan had become globally renowned for quality and continuous improvement (kaizen) and were investing heavily in innovation. In the 1990s, macroeconomic troubles (the post-bubble "lost decade") led to constrained resources, but Japanese automakers continued to innovate in product and process – exemplified by Toyota's development of the Prius hybrid electric vehicle, launched in 1997 as the world's first mass-produced hybrid car. The innovation of hybrid technology was supported by a confluence of firm initiative and government policy. The Ministry of Economy, Trade and Industry (METI) had funded EV and battery research programs since 1992, recognizing the need for more energy-efficient vehicles *(Li and Liu 2024, 826–831)*. METI's New Sunshine Project and related initiatives provided R&D subsidies for batteries and alternative fuel vehicles, which helped Japanese firms build foundational technologies for hybrids and, later, fuel cell vehicles.

Throughout the 2000s, Japan's government introduced **tax incentives and consumer subsidies** to stimulate innovation diffusion in the market. A notable policy was the "green vehicle" tax incentive, which reduced automobile acquisition and weight taxes for low-emission, fuel-efficient vehicles (including hybrids). Studies found this policy boosted domestic hybrid sales and encouraged all automakers in Japan to invest in eco-innovations (Fujiwara 2006 as cited in Sano et al. 2011). By the 2010s, virtually every Japanese manufacturer had developed hybrid models, and Japan became a world leader in hybrid vehicle adoption. However, Japan's approach to fully electric vehicles (EVs) was more cautious. The literature points out that **Japan prioritized hybrid and fuel-cell technology** over battery-electric vehicles for many years *(Li and Liu 2024, 826–831)*. This stemmed from Japan's existing strengths (Toyota had a dominance in hybrid systems) and an industrial strategy that envisioned hydrogen fuel cells as a longer-term solution for zero-emission vehicles. Government policy reflected this: substantial funds were invested in the Hydrogen Society roadmap and fuel-cell vehicle infrastructure in the 2010s, and the regulatory environment (until recently) placed relatively less emphasis on pure battery EV mandates compared to China or the EU.

Despite this, Japanese firms did engage in incremental innovation in EVs as well – Nissan's LEAF (launched 2010) was one of the first mass-market electric cars globally. But overall EV penetration in Japan remained low in the 2010s. In 2022, battery EVs and plug-in hybrids combined made up only around **3% of new passenger car sales in Japan**, whereas hybrids (non-plug-in) dominated the "electrified" vehicle segment (RIETI 2023). The Japanese government has recently acknowledged the need to accelerate battery EV adoption to stay competitive. By 2020, it announced a goal that **all new vehicles sold by 2035 should be "electrified"** (including hybrids, plug-in hybrids, battery EVs, and fuel cell vehicles) *(Li and Liu 2024, 826–831)*. METI also set targets to expand EV charging infrastructure from about 30,000 chargers in 2020 to 300,000 in the coming years *(Li and Liu 2024, 826–831).* These steps represent a shift in industrial policy responding to global trends—essentially, Japan adjusting its innovation focus to not be left behind in the EV era *(Beason 2021).*

At the firm level, Japanese automakers continue to invest heavily in R&D (roughly ¥3–4 trillion annually in the automotive sector in recent years *(Statista 2023)*). They excel in incremental and process innovation – for instance, improving manufacturing automation, just-in-time production, and vehicle reliability. However, some analysts have pointed out that Japan's innovation system in autos has been somewhat inward-looking, with less external collaboration compared to, say, German or American firms *(RIETI 2023).* One manifestation is that Japanese auto firms are strong in engineering but have been slower in software-oriented innovation (like vehicle connectivity or autonomous driving software), an area where they now race to catch up via partnerships and acquisitions. In summary, Japan's trajectory from the 1990s to 2024 shows an automotive industry that maintained global leadership in **incremental innovation** (e.g. perfecting internal combustion engines, pioneering hybrids) but was more conservative in **radical innovation** like battery EVs, partly due to policy choices and path dependence. Industrial policies in Japan during this period were generally supportive but not intrusive: they set long-term vision (low-carbon goals, safety regulations), provided R&D infrastructure (consortia and funding for pre-competitive research), and used **market-based incentives** (tax breaks, subsidies to consumers) to steer innovation, rather than direct state control of firms. This reflects Japan's broader shift to a more liberalized economy in the WTO era, consistent with Beason's observation that explicit industrial targeting was largely on hold from the 1990s until perhaps very recently *(Beason 2021).*

China's Trajectory (1990s–2024): In 1990, China's automotive industry was minor on the world stage – producing fewer than half a million cars annually, mostly outdated models, and with technology dependent on foreign licenses. The 1990s were a decade of nascent growth under protection. The Chinese state implemented a clear industrial policy roadmap: consolidate the industry around a few state-owned champions and attract foreign investment under conditions that would eventually enable technology transfer *(Xue, Wei, and Greeven 2024).* The 1994 Auto Industry Policy exemplified this approach, limiting foreign automakers to 50% ownership in joint ventures (JVs) and requiring JVs for vehicle production *(Xue, Wei, and Greeven 2024).* Companies like Volkswagen, General Motors, and Toyota entered China through JVs with firms such as SAIC, FAW, and Dongfeng. **Innovation in the 1990s** in China's auto sector was modest – the focus was on absorbing basic manufacturing technology and expanding production capacity. However, some learning-by-doing occurred, and by the late 1990s, China was producing over 1 million vehicles per year (achieved in 1992) *(RIETI 2023).* Still, core technologies (engine design, etc.) were often imported or developed with heavy foreign input.

The 2000s saw a rapid scale expansion and the beginnings of technological catch-up. Following China's WTO entry in 2001, tariffs were gradually reduced (from 80-100% pre-WTO down to about 25% by 2006 on cars), but interestingly this did not cripple the domestic industry. Instead, joint ventures flourished and China's market exploded in size, giving local firms and JVs the revenue base to invest in improving products. Industrial policy in this period shifted toward encouraging "indigenous innovation." The government became frustrated that joint ventures were not sufficiently transferring cutting-edge design capabilities (indeed, studies show JV arrangements often left Chinese partners in charge of noncore components while foreign partners retained engine/transmission intellectual property) *(Xue, Wei, and Greeven 2024).* In response, around 2006-2008, policies were introduced to support domestic automakers more directly: for example, the government offered incentives for developing self-owned brands and gave state-owned automakers directives to establish their own research institutes. **New science and technology programs** were launched targeting automotive electronics, alternative fuels, and advanced materials.

A defining moment came with the Chinese government's decision to leapfrog in **electric vehicles (EVs).** Starting in 2009, China implemented the "Ten Cities, Thousand Vehicles" pilot program, offering generous subsidies for electric and hybrid vehicles in select cities, and invested in charging infrastructure. By the mid-2010s, this evolved into a nationwide NEV subsidy program and mandates (a quota requiring automakers to produce a certain proportion of NEVs or buy credits). These policies were explicitly aimed at accelerating innovation and overcoming China's lag in traditional engine technology by jumping to the next technological paradigm – a classic strategic industrial policy logic. Godfrey Yeung (2019) documents how the Chinese state took a "proactive role" in creating the world's largest NEV market through a combination of market creation (consumer subsidies, government fleet procurement of EVs) and new industrial regulations (such as stricter fuel economy standards that pushed EV adoption for compliance) *(Yeung 2019, 39–59).* By leveraging the sheer scale of its domestic market and offering hefty incentives, China succeeded in drawing both foreign and domestic automakers into EV production in China, and in fostering domestic EV startups. The results of these efforts are striking: China went from virtually zero electric car sales in 2010 to **over 6.8 million electric vehicles sold in 2022**, accounting for **more than 25% of its new vehicle sales** *(RIETI 2023)*. This represented roughly **57% of all EVs sold worldwide in 2022**, making China the clear global leader in EV adoption *(RIETI 2023)*. In contrast, Japan's EV sales in 2022 were around 59 thousand (just 1% of global EV sales) *(RIETI 2023)*. Figure 1 below illustrates the divergent trajectories in EV penetration between China and Japan (as well as the US and EU) over the past decade.

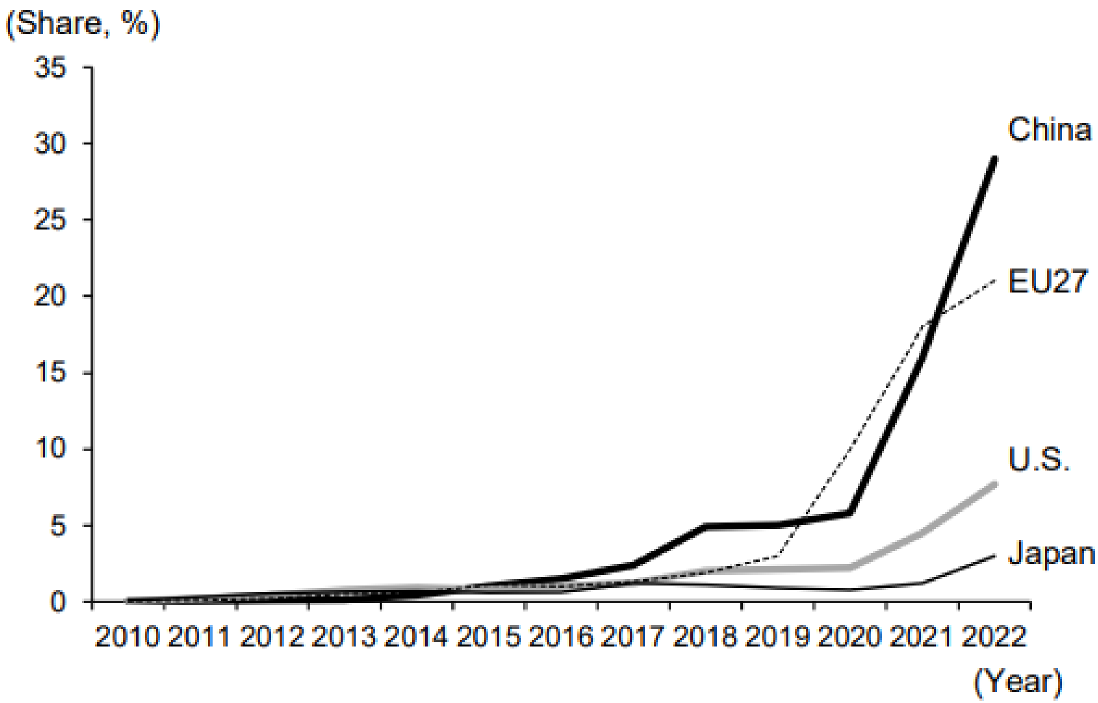

Figure 5A. Share of electric vehicles in new passenger car sales (percentage of total sales), 2010–2022, in China, Japan, the United States, and EU. (RIETI 2023)

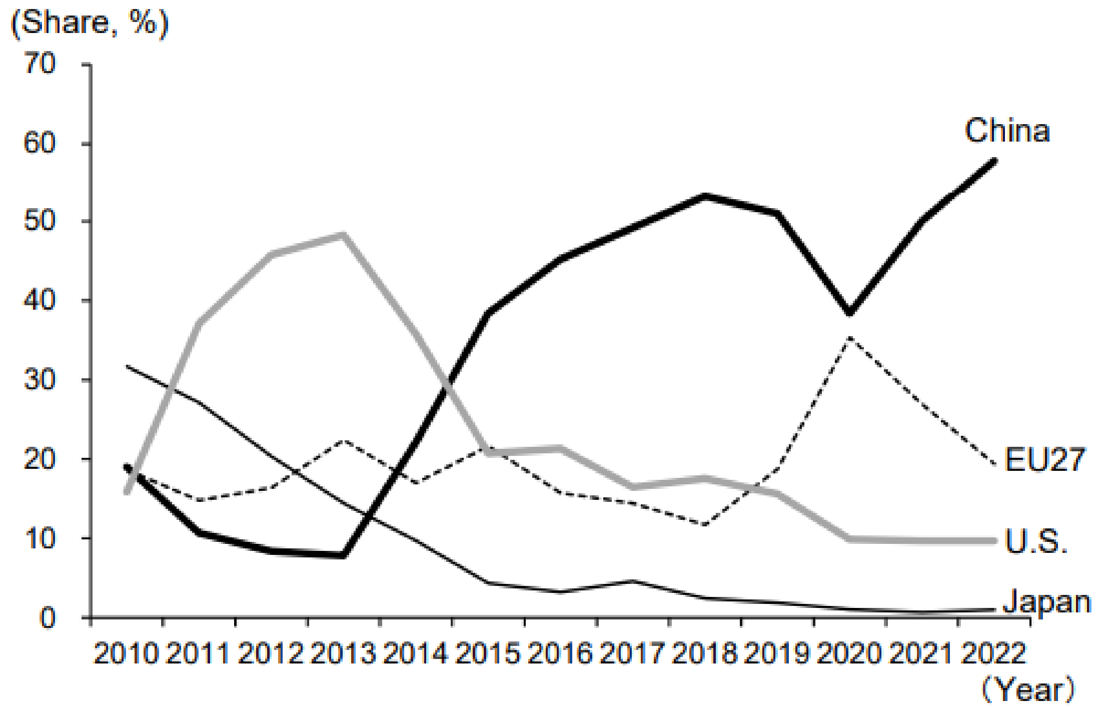

Figure 5B: Shares of major countries and regions in global electric passenger car sales 2010–2022, in China, Japan, the United States, and EU. (RIETI 2023)

Several factors enabled China's rapid progress in EV innovation. One was the government's massive financial commitment: by one estimate, nearly **¥150 billion** (approximately $20+ billion) in subsidies were poured into the NEV sector between 2009 and 2022 *(Xue, Wei, and Greeven 2024).* Another factor was infrastructure: under state coordination, China installed hundreds of thousands of public charging points (far outpacing Japan's charger network by sheer numbers). A third factor was the entry of **new players** – while traditional state-owned automakers were somewhat slow to innovate, a wave of private companies (e.g. BYD, NIO, Xpeng) surged, often backed by local government support and entrepreneurial drive. BYD, in particular, leveraged its roots in battery technology (it received early support including foreign investment and local government contracts) to become the world's second largest battery producer and the largest EV manufacturer in 2022, even surpassing Tesla in sales *(RIETI 2023).* Industrial policy facilitated this by protecting these nascent innovators in the domestic market and providing R&D funds.

By the early 2020s, China's automotive innovation had begun yielding globally competitive outcomes. China overtook Germany in 2022 to become **the second-largest vehicle exporter**, and in 2023 it overtook Japan to become **the world's largest auto exporter** *(RIETI 2023).* Many of these exports are electric vehicles or fuel-efficient cars, indicating the technological strides made. The share of Chinese indigenous brands in the domestic market has also risen sharply in recent years at the expense of foreign JV brands *(RIETI 2023),* showcasing growing consumer acceptance of home-grown innovation. Still, challenges remain: Chinese automakers initially benefited from technology transferred via JVs (especially for conventional cars), but in the EV domain they had to build new expertise largely from scratch. The government's heavy-handed subsidies led to some inefficiencies (e.g. a period around 2015-2016 where low-quality EV models were produced just to claim subsidies). Recognizing this, policymakers began phasing out subsidies after 2020 and introduced more market-based mechanisms (like the NEV credit trading scheme). This aligns with an evolution noted by Naughton (2021): China's recent policies are unprecedented in scale and directness, and while they achieved rapid capacity buildup, it remains to be seen how sustainable and efficient the outcomes are *(Naughton 2021).* What is clear is that without industrial policy, China's rise in automotive innovation would likely have been slower – the state's role was instrumental in overcoming the barriers of late development, as evidenced by the contrast between China's acceleration in EVs versus other countries.

Key Comparative Insights: From the literature on both countries, a few comparative themes emerge. First, **timing and initial conditions**: Japan's innovation path was building on decades of prior development by the 1990s, so its industrial policy in our period was more about fine-tuning a mature innovation system. China's policy, conversely, was about aggressively building an innovation system from a low base – hence its policies were more heavy-handed and sweeping. Barry Naughton (2021) argues that China is "not just another East Asian developmental state" in part because it has deployed far greater resources and a different style of targeting than Japan or Korea did. For example, China's outlays on industrial support in the 2010s (including EV subsidies) are orders of magnitude larger than what Japan ever spent in comparable sectors, reflecting China's determination and capacity in the 21st-century context.

Second, **policy focus**: Japan's industrial policy in autos since 1990s largely focused on quality and efficiency improvements (incremental innovation) and maintaining competitiveness of a world-leading industry, with newer attention to environmental innovation. China's policy focus was initially on acquiring basic capabilities (through joint ventures and protection) and later on leapfrogging in new technologies (EVs, batteries) to bypass its weakness in legacy engine technology. This led China to take bolder bets (e.g. essentially creating a huge EV market from scratch through policy), whereas Japan relied more on its automotive incumbents to drive innovation with gentle policy nudges. Indeed, Chinese policy can be seen as more state-driven in setting a technological direction (electric mobility), whereas Japanese policy was more industry-driven, supporting directions that its established firms were already inclined to pursue (hybrids, fuel efficiency).

Third, **outcomes**: By 2024, both countries achieved significant innovation outcomes but in different domains. Japan's automakers remain leaders in hybrid technology, automotive manufacturing processes, and overall vehicle reliability and performance. However, Japan has lost some ground in emerging fields like software and EVs, where China has surged. China now leads in battery technology (two Chinese firms, CATL and BYD, account for a large share of global EV battery production *(RIETI 2023)*) and has a dynamic EV startup ecosystem. The literature notes that Chinese brands have become highly competitive in areas like electric buses and increasingly passenger cars, partly due to innovation driven by intense domestic competition and policy support *(Heller 2017; RIETI 2023)*. Meanwhile, Japanese brands have seen their market share in China (the world's largest market) erode in the face of this onslaught *(RIETI 2023)*. This turning of the tables – China catching up and even overtaking in certain innovation metrics – underscores the central role industrial policy played in accelerating China's capabilities, whereas Japan's more conservative policy stance may have contributed to its slower embrace of some new innovations.

In Figure 1 above, we saw how the **EV adoption rate** in China skyrocketed after 2015, far outpacing Japan's. Likewise, production statistics show China's auto production went from roughly 5% of global output in 1995 to about 32% in 2020, while Japan's fell from ~13% to under 10% in the same period (OICA data; *(RIETI 2023)*). These trends are frequently attributed in the literature to China's strategic use of industrial policy versus Japan's reliance on market-driven evolution. However, it is important to balance this view: Japanese firms' prior innovations (like Prius) indicate that the private sector can achieve breakthroughs without heavy state direction, and China's experience also involved considerable market forces (competition among domestic firms, consumer uptake of good products once they improved). Thus, in deriving criteria to analyze these cases, we will consider both **innovation performance metrics** and the **policy environment metrics** to understand the interplay.

5.2. Innovation Input Effort

Both China and Japan have devoted substantial resources to the inputs of automotive innovation – notably R&D expenditures, human capital, and supportive infrastructure – but they differ markedly in scale, growth, and strategy. **Japan** has long been an R&D-intensive economy; its automotive sector benefits from decades of steady investment and a mature innovation ecosystem.

China, by contrast, started from a lower base but has rapidly ramped up innovation inputs in recent years through aggressive state-led initiatives and increasing private sector engagement. This section examines key input metrics – R&D spending, research workforce, and related efforts – to gauge how each country is fueling automotive innovation.

R&D Expenditures (Scale and Intensity): Japan consistently ranks among the world's top spenders on research and development. In the late 2010s, Japan's total R&D outlay hovered around 3.3% of GDP – roughly $170 billion annually *(García-Herrero 2018).* This ratio is one of the highest among advanced economies, reflecting Japan Inc.'s traditional emphasis on continual engineering improvement and product development. A significant share of this R&D is shouldered by the automotive industry. In fact, corporate R&D in machinery and auto manufacturing has accounted for about **36% of Japan's total R&D spending in recent years**, underscoring the sector's importance *(García-Herrero 2018).* Major Japanese automakers together budgeted nearly ¥3 trillion (≈$27 billion) for R&D in a recent fiscal year, focusing on areas like vehicle electrification and autonomous driving *(García-Herrero 2018).* Toyota Motor alone has invested around **¥1 trillion** (over $9 billion) per year in R&D – an effort that, while enormous, still stands at roughly half the R&D spending level of the largest global competitor, Volkswagen. In short, Japan's auto industry exhibits high R&D intensity, sustained by both corporate commitment and supportive policies (such as R&D tax credits and government research consortia). This intensive input effort historically enabled Japanese firms to lead in automotive engineering (e.g. lean manufacturing and reliable drivetrain technologies).

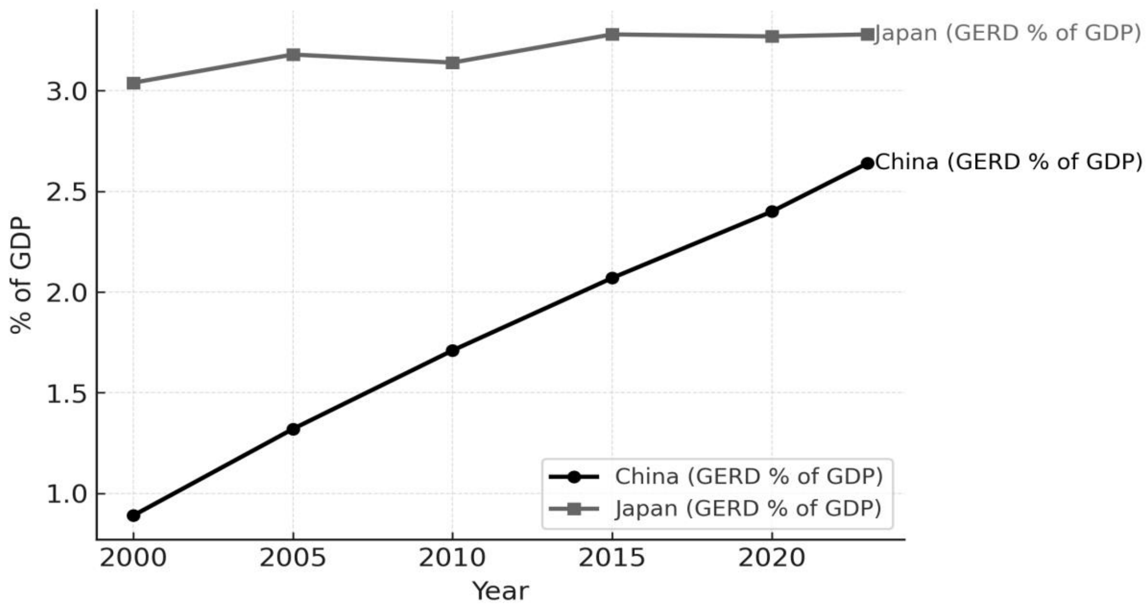

Figure 5.1. Gross Domestic Expenditure on R&D (GERD), % of GDP — China vs. Japan

Source: OECD MSTI; National Statistical Releases (see References).

China’s R&D investment, once negligible in this sector, has grown at an astonishing pace as the country pursues an innovation-driven development model. Around 2015, China’s gross R&D spending (all sectors) was estimated at **$409 billion**, equivalent to 2.1% of GDP – already nearly double Japan’s in absolute terms *(García-Herrero 2018).* The gap has only widened since then. By 2021, China’s total R&D outlay reached roughly **$668 billion**, about 2.43% of GDP (OECD 2023). In comparison, Japan’s R&D outlay in 2021 was about $177 billion (3.30% of GDP) (OECD 2023). This means that although Japan remains more R&D-intensive relative to its economy, China’s sheer spending volume now far exceeds Japan’s. **Figure 5.1** illustrates the trajectory: over the past two decades, China’s R&D expenditure surged from under 1% to over 2.5% of GDP, while Japan’s stayed around 3% with modest growth.

Notably, China’s government has set clear targets (e.g. devoting 2.5% of GDP to R&D by 2020) and funneled resources into strategic industries, including automotive technology (UNESCO 2019). Automotive R&D in China was historically led by foreign-led joint ventures, but domestic firms are now ramping up their own investments. For example, BYD – a leading Chinese electric vehicle (EV) manufacturer – increased its R&D spending by nearly 90% in 2022 to over **¥20 billion**, and further to ¥54.2 billion (≈$7.5 billion) in 2024, far exceeding its net profits *(BYD 2024).* Cumulatively, BYD has invested more than ¥180 billion in R&D over 2011–2024 *(BYD 2024).* Other Chinese automakers like Geely and SAIC, as well as newcomers (NIO, Xpeng, etc.), have similarly raised R&D budgets in pursuit of innovation. Consequently, while Europe and Japan historically led automotive R&D spending, China is catching up fast: recent industry analyses indicate Europe remains the largest auto R&D investor, but China has become a close fourth after Japan and the U.S., with **Chinese OEMs rapidly increasing their R&D allocations** *(ACEA 2024).* This massive input effort has been enabled by China’s broader economic growth and strong state support (discussed further below).

Human Capital and Research Workforce: Innovation input is not only about money, but also people. Here, Japan enjoys a legacy of well-trained engineers and researchers who have driven its automotive innovations for decades. Japanese automakers benefit from a deep talent pool cultivated through rigorous education in engineering and long-term employment practices that preserve institutional knowledge. Japan had around **0.9–1.0 million R&D personnel** in recent years (ranking third globally in number of researchers) *(Science Japan 2024).* Many of these are in manufacturing and automotive fields, given the dominance of those sectors in Japan’s economy. For instance, Japan’s technical universities and corporate training programs have traditionally churned out specialists in mechanical and electrical engineering who then spend careers in automotive R&D, continually refining product designs. This stable human capital base contributed to Japan's strengths in incremental innovation and quality improvement. However, Japan's science and engineering workforce has been aging and the number of graduate students in technical fields had declined for many years (picking up slightly only in the 2020s) *(Science Japan 2024)*. There is concern that Japan's pipeline of young innovators may not be growing fast enough to replace the retiring generation, which could constrain future input capacity.

China, by contrast, has expanded its R&D human capital at an unprecedented scale. The number of full-time researchers in China jumped from about 1.1 million in 2000 to **2.4 million by 2021**, eclipsing the United States and far outstripping Japan *(ITIF 2024)*. This explosive growth stems from multiple sources: a large increase in domestic STEM graduates, government programs to train and retain scientists, and the recruitment of overseas talent. Each year, Chinese universities graduate tens of thousands of engineers; many enter the automotive and electronics industries. Additionally, the **China Automotive Technology and Research Center (CATARC)** and other state-backed institutions help develop specialized expertise in auto engineering. While questions remain about talent quality and practical experience (some observers note Chinese engineers can be very strong in theory but sometimes lack hands-on training *(Reddit 2017)*), the quantity of human capital is a huge asset. Chinese automakers have benefitted from this in scaling up R&D teams rapidly. Moreover, as foreign joint ventures (like those with Volkswagen, GM, Toyota, etc.) operated in China over the past decades, they trained a generation of Chinese automotive engineers. Many of these engineers later moved to domestic firms or startups, diffusing know-how. In short, China's innovation labor force has grown from a minor factor to the world's largest, providing ample "brainpower" input for technological catch-up in autos.

Infrastructure and Collaborative Networks: Innovation input effort also includes the research infrastructure and collaboration mechanisms in each country. Japan's automotive industry is supported by an extensive network of suppliers, universities, and government laboratories. The traditional **keiretsu** structure – close long-term partnerships between automakers and parts suppliers – facilitated joint development of new technologies (e.g. Toyota working with Denso on advanced components). Public research institutes and testing facilities (like Japan's National Institute of Advanced Industrial Science and Technology, and the Japan Automobile Research Institute) provide foundational R&D and standards testing that companies can leverage. Furthermore, the government's **Cross-Ministerial Strategic Innovation Promotion Program (SIP)** has funded consortia on automated driving and other auto-related innovations in recent years *(Secretariat of Science, Technology and Innovation Policy 2022)*. These initiatives, while relatively modest in budget, promote industry-academic collaboration (for example, projects connecting automakers, universities, and electronics firms to develop connected-car software). Japan's well-established quality infrastructure (quality standards, testing protocols, etc.) also counts as an input that improves innovation outcomes by ensuring new technologies meet rigorous performance criteria.

China has built up its innovation infrastructure at lightning speed as part of its industrial modernization. The government established numerous **technology parks and innovation hubs** – some specifically targeting automotive and new-energy vehicle development (for instance, the Shanghai Automotive Innovation Park, Guangzhou's EV cluster, etc.). There are dedicated research programs like the **"863 Program" and "973 Program"** (state S&T initiatives) that for years directed funding into key technologies including electric and hybrid vehicles. Under the National Medium- and Long-Term Science and Technology Plan, **priority labs and engineering centers** for automotive electronics, battery chemistry, and vehicle design were created at top universities (Tsinghua, Shanghai Jiao Tong, etc.) and at state-owned automakers. These centers act as innovation infrastructure, providing testing equipment (e.g. crash test facilities, battery labs) and research talent funded by government grants. In addition, China's Ministry of Industry and Information Technology (MIIT) and Ministry of Science and Technology coordinate **industry alliances** – such as the **China Society of Automotive Engineers (China-SAE)** – to share knowledge on standards and training *(China SAE 2025)*. A hallmark of China's approach is **international technology acquisition** as a form of input: for years, China conditioned market access for foreign automakers on knowledge transfer to local partners. Through joint ventures (capped historically at 50% foreign ownership), companies like SAIC, FAW, and Dongfeng obtained advanced manufacturing process know-how and engineering skills from GM, VW, Toyota and others *(Enright 2025)*. This policy essentially treated foreign technology as an "input" to domestic innovation capacity, albeit one that took time to assimilate. By the 2020s, Chinese firms are far more self-reliant, but the legacy of those earlier transfers underpins current capabilities.

Investment Focus and Strategic Direction: How each country directs its innovation inputs is also telling. Japan's R&D spending in autos has traditionally focused on **incremental innovation** – improving fuel efficiency, safety, and manufacturing processes. The famous **Kaizen** philosophy (continuous improvement) meant a lot of input effort went into refining existing technologies (e.g. perfecting internal combustion engines, lean production, improving parts durability). This yielded world-class reliability but sometimes at the expense of breakthroughs in radically new areas. More recently, Japanese automakers have shifted some R&D toward electrification and software, but still with caution. For example, Toyota long prioritized hybrid-electric vehicles (HEVs) and fuel-cell vehicles (FCEVs) over battery-electric vehicles (BEVs), reflecting an R&D strategy betting on incremental extension of engine technology and hydrogen as a future fuel. The government supported this by funding hydrogen infrastructure and **subsidizing fuel-cell car development** (e.g. generous subsidies up to ¥2.5 million per FCEV purchase) *(OECD 2024)*. Thus, a chunk of Japan's input effort went into a technology (hydrogen FCEVs) that, as of 2025, remains niche – indicating a possible misalignment of R&D priorities with market trends. Japan is now recalibrating its innovation inputs: METI's **Green Growth Strategy (2021)** explicitly includes battery EVs and aims to increase R&D in solid-state batteries and autonomous driving AI, acknowledging that Japan must catch up in these areas *(OECD 2024)*. In summary, Japan's input efforts have been high but somewhat *conservative* – excelling at improving what it already does well, while only recently channeling resources to disruptive innovations like full electrification and digitalization.

China's innovation inputs, on the other hand, have been strongly *directional* – guided by strategic industrial policies to leapfrog in specific technologies. A clear example is **New Energy Vehicles (NEVs)** (the umbrella term for EVs, plug-in hybrids, and fuel-cell vehicles). As early as the mid-2000s, China identified NEVs as a strategic priority. In 2009 it launched the "Ten Cities, Thousand Vehicles" pilot program, which poured funding into EV fleets in select cities and incentivized manufacturers to develop electric cars. Empirical analysis confirms that this policy significantly boosted innovation output: **Chinese automakers involved in the program saw a notable increase in invention patents** relative to those not in the program *(Zhao et al. 2019) (WIPO 2025)*. In essence, targeted input support (subsidies, grants) translated to greater R&D and patenting in EV technologies. Over the 2010s, China ramped up these inputs dramatically – establishing research institutes for battery technology, offering R&D grants and tax breaks to EV startups, and funding university programs in electric mobility. By one estimate, from 2009 to 2023 the Chinese central government allocated a staggering **$231 billion** in subsidies and incentives related to EV development *(Thompson 2024)*. (This figure includes R&D subsidies, production subsidies, consumer purchase incentives, and infrastructure investments.) **Such an enormous injection of capital and resources into one technological domain has no parallel in Japan**, where direct EV-related subsidies were only on the order of a few hundred million dollars per year (e.g. ~¥25 billion in 2021 for all clean car subsidies, roughly $0.2 billion) *(OICA 2023)*.

Apart from NEVs, China's input efforts also targeted **smart and connected vehicle technology**. Through programs like the Intelligent Connected Vehicle Innovation Center, and city-level projects (e.g. Beijing and Shanghai's autonomous vehicle test zones), the government supplied the infrastructure (testing grounds, 5G networks) and funding needed for firms to develop automated driving systems. While Japan also has autonomous driving R&D (often led by companies like Honda and Nissan in partnership with universities), China's approach involved more direct government orchestration – for instance, coordinating telecom companies, mapping service providers, AI startups, and automakers in large-scale pilot programs. Again, the scale differs: Chinese tech giants (Baidu, Huawei, Alibaba) have been mobilized into the automotive innovation space, effectively broadening the base of input resources. Baidu's Apollo autonomous driving platform, developed with state endorsements, pools contributions from dozens of domestic partners and benefits from government data-sharing agreements. Japan's automotive ICT R&D, in contrast, has been more insular, with automakers initially attempting proprietary systems (though this is slowly changing as firms recognize the need for collaboration with software companies; e.g. Toyota's investment in a data science firm and Honda joining a Chinese-led autonomous driving consortium) *(OECD 2024).*

In summary, **Japan's innovation input effort** in autos is characterized by *high R&D intensity, rich human capital, and strong incremental improvement capabilities*, but limited by a cautious strategic focus and fiscal constraints. **China's input effort** is marked by *rapid growth in R&D spending, a vast expansion of its engineering workforce, and proactive state direction of resources* toward priority technologies, albeit with potential inefficiencies. Japan leverages a long-established innovation ecosystem with close industry-government ties (but one that sometimes sticks to established paths), whereas China is building an ecosystem on the fly with an almost singular focus on catching up and overtaking in new tech domains. These differences in input efforts set the stage for the outcomes observed in innovation outputs, competitiveness, and policy effectiveness, which are explored in the following sections

5.3. Innovation Output and Technology Development

5.3.1. Short Insight

Having examined how China and Japan pour resources into automotive innovation, we turn to the tangible outputs of those efforts – new technologies developed, patents and intellectual property generated, and the overall trajectory of innovation results in each country's automotive sector. We assess general innovation performance metrics (such as patent filings, technical breakthroughs, and product introductions) and the development of key technologies shaping the industry's future. Broadly, Japan's automotive innovation outputs have historically been strong in the form of patented improvements and world-class vehicles (especially in conventional and hybrid technologies), while China's outputs have risen from low-end imitation to cutting-edge leadership in certain segments (notably electric vehicles and batteries) over a short span. This section compares these outputs and technological developments, highlighting both quantitative indicators and qualitative milestones.

5.3.2. General Metrics and Innovation Results

Patent Filings and Intellectual Property: Patent data provides a quantifiable indicator of innovation output. Japan has traditionally been a powerhouse of automotive patents. Its major automakers and suppliers consistently rank among the top patent holders globally. For example, Toyota, Denso, Honda, and Nissan – all Japanese firms – are routinely in the top 10 companies worldwide for automotive-related patent holdings *(WIPO 2025)*. This reflects decades of cumulative innovation: Japanese companies built large patent portfolios covering everything from engine designs to safety systems. Even today, six of the world's top ten automaking patent holders are Japanese *(WIPO 2025)*. Many of these patents, however, are in incremental innovations (refinements of mature technologies).

China's trajectory in patent output has been steeply upward. Two decades ago, Chinese firms held relatively few international patents in the auto sector. That has changed dramatically. By the late 2010s, Chinese companies were filing nearly as many international patent applications as Japanese companies. In 2017, China slightly **overtook Japan in the number of Patent Cooperation Treaty (PCT) international patent applications filed**, with about 48,882 filings versus Japan's 48,208 *(Nippon 2018)*. This was a symbolic milestone: Japan had been second only to the U.S. in PCT filings for years, but China's rapid growth (averaging over +10% annually in that decade) propelled it ahead. By 2019, China became the world leader in PCT patent application volume, surpassing both the U.S. and Japan *(ChinaPower 2023)*. As of 2021, Chinese residents filed **69,600 PCT applications**, whereas Japanese residents filed on the order of 50,000 *(WIPO 2025)*. The explosive growth of China's patent output is illustrated in **Figure 5.2**, which charts international patent filings by each country over time.

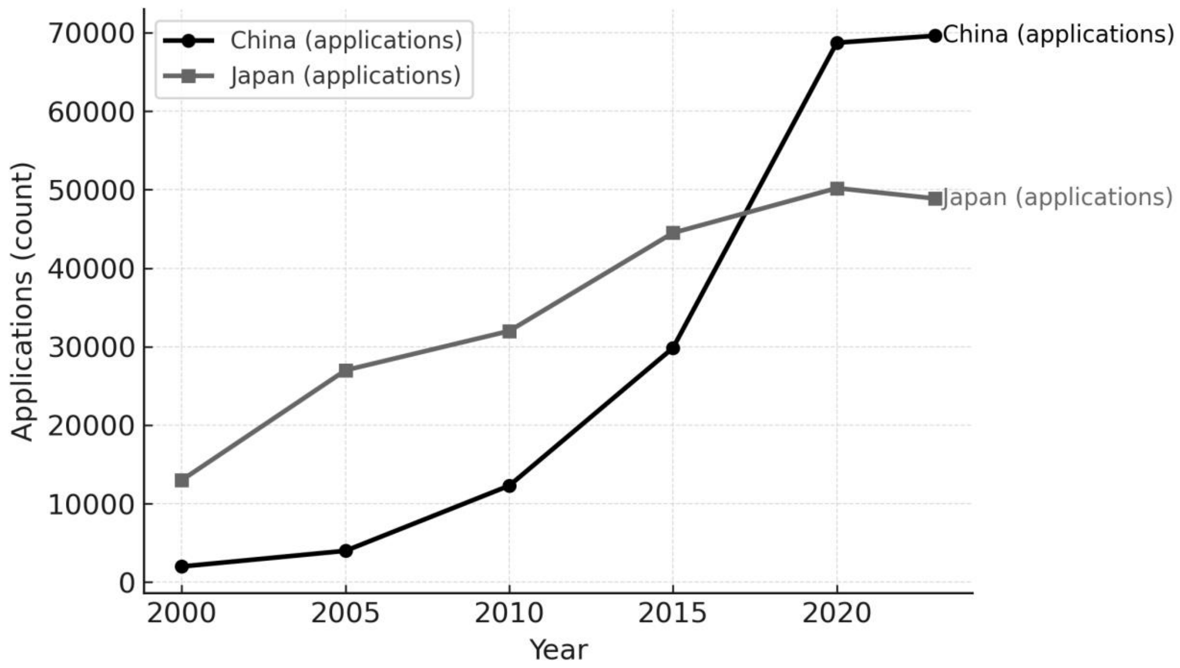

Figure 5.2. International Patent Applications (PCT) by Origin — China vs. Japan

Source: WIPO PCT Yearly Review; WIPO IP Statistics Data Center.

It is important to note that raw patent counts do not directly equate to innovation quality. Many observers point out that **Chinese patent numbers were boosted by policy incentives** – China's government explicitly encouraged patent filings as a metric of innovation, leading to numerous minor patents (often for incremental tweaks or design aspects) being filed domestically *(WIPO 2025).* In Japan, patenting behavior has been more mature and perhaps restrained to higher-value inventions (though Japanese firms also file many incremental patents to protect their extensive IP). One way to compare meaningful innovation output is to look at high-quality patents. For instance, **triadic patents** – those filed jointly in Japan, the U.S., and Europe, indicating an invention deemed valuable enough to protect in major markets – remain an area where Japan leads. In 2020, Japan held about **17,469 triadic patent families**, compared to just 5,897 for China (OECD 2022 data). This suggests that a larger share of Japan's innovations are globally competitive and protected in key markets, whereas China's patents, though numerous, are often filed only domestically (over 90% of Chinese patent applications are filed inside China's own IP office) *(WIPO 2025).* The lower internationalization rate of Chinese patents indicates that many may be of local or limited impact – or that Chinese innovators until recently focused on the huge domestic market rather than overseas patenting costs.

That said, China has rapidly improved the impact of its automotive patents. A recent analysis by Mitsui Global Strategic Studies Institute (MGSSI) examined **EV-related patents** and found a nuanced picture: Japanese and German companies hold more patents *in quantity* related to electric vehicles, but Chinese and South Korean firms have some of the *most impactful* EV patents by citation and significance *(Duong 2025).* For example, Chinese battery maker CATL was ranked #1 in an international patent impact index (scoring 2.7, above any Japanese company) despite having fewer total patents than giants like Toyota *(Duong 2025).* This implies that Chinese innovators are starting to produce high-value inventions in emerging fields – their patents are cited frequently and cover core advances in battery chemistry, fast charging, etc. Meanwhile, **Toyota still leads in sheer volume of EV-related patents (6,135 patents, nearly 60% of Japan's EV patents)**, reflecting how Japanese automakers invested early in electrification R&D on paper (especially hybrids) *(Duong 2025).* However, many of Toyota's patents pertain to hybrid system optimizations and peripheral EV technologies, whereas companies like CATL and BYD are patenting fundamental battery materials and architectures. Thus, Japan's output in patents shows breadth and consistency, while China's shows rapid gains in specific cutting-edge niches.

In summary, patent metrics indicate that **Japan's automotive innovation output has been substantial and steady**, keeping it among global IP leaders, but **China's output has grown exponentially**, now challenging or surpassing Japan on several measures. The composition of those outputs differs, with Japan retaining an edge in high-end patent families and China closing the gap by volume and improving in quality. This patent story mirrors the broader innovation narrative: Japan has a high base of accumulated know-how, and China is fast catching up and even leapfrogging in new tech domains.

Technological Domains and Breakthroughs: Beyond patent counts, we consider what notable technologies and products have emerged from each country's automotive sector in recent years – essentially, how the innovation inputs translated into tangible development. Historically, Japan produced many of the auto industry's technical breakthroughs in the late 20th century: for example, *lean manufacturing techniques* (Toyota's production system), *hybrid powertrains* (Toyota Prius, introduced 1997, was the world's first mass-market hybrid), *advanced safety systems* (early adoption of collision avoidance, etc.), and *precision engine designs* that achieved superb reliability. These innovations were often evolutionary, building on existing concepts but executed at a superior level by Japanese firms. The Prius's hybrid system, for instance, was a landmark in efficient fuel use – a result of heavy R&D by Toyota through the 1990s, supported by MITI's clean energy vehicle programs. Japan also excelled in automotive electronics integration (e.g. ahead in things like electronic stability control, continuously variable transmissions, etc.). However, in the past decade or so, **the locus of**

“game-changing” automotive innovation has shifted toward electrification and software – areas where China has begun to stand out.

China’s most significant innovation output in autos has been its emergence as the global leader in electric vehicle technology deployment. Propelled by the massive inputs described earlier, Chinese firms have developed competitive (and sometimes superior) EV models and core components. For example, **BYD developed the “Blade Battery” (a long cell LFP battery pack)** which boasts improved safety and longevity, garnering international attention in 2020–2021 as a breakthrough in battery design. CATL (Contemporary Amperex Technology Co.), now the world’s largest EV battery producer, has introduced batteries with leading energy densities and is pioneering sodium-ion battery chemistry. These are concrete technological outputs of China’s innovation drive – not just producing EVs, but advancing the underlying tech. In **electric powertrain and battery management systems**, Chinese engineers have filed many patents and brought new products to market rapidly. The fact that **over 60% of the world’s EV batteries are made in China** *(Automobility 2024)* speaks to a high level of manufacturing innovation and scale-up capability. Additionally, Chinese EV manufacturers have been quick to integrate smart features: domestic models often come equipped with advanced connectivity (integrated apps, vehicle-to-everything comms) and driver-assist functions, developed by China’s vibrant tech sector.

Japan has not been idle in new technology development – its companies have made strides in **solid-state battery research**, an area where Toyota and Panasonic hold significant patents and aim to commercialize possibly by the late 2020s. Toyota’s engineers, leveraging years of battery R&D from hybrid programs, are working on solid electrolytes that could dramatically improve EV range and charging times. In *autonomous driving*, Honda achieved a milestone as one of the first to get approval for a Level 3 self-driving car (the Honda Legend with Traffic Jam Pilot, introduced in 2021 in Japan). This shows Japanese output in AI-driven vehicle tech, though it’s still a limited deployment. Moreover, Japan’s heavy investment in *hydrogen fuel cell vehicles* yielded the Toyota Mirai and Honda Clarity fuel cell cars – technically impressive products with advanced fuel cell stacks and hydrogen storage systems, representing innovation output even if the market uptake is limited. These developments underscore that Japan continues to produce high-caliber automotive technologies, but some are in domains that have yet to achieve large-scale commercial success (fuel cells), or they come as careful, incremental rollouts (as with autonomous driving features).

By contrast, **China’s innovation outputs have had immediate market impact** in recent years. Electric vehicles designed and built by Chinese companies are not only abundant domestically but are increasingly competitive globally. In 2024, over **one-third of all cars sold in China were New Energy Vehicles (mostly pure EVs), with Chinese brands commanding 80% of that NEV market** *(Automobility 2024).* This indicates Chinese firms successfully turned input efforts into desirable products – an innovation outcome evidenced by consumer adoption. Models like the **BYD Qin/Seal (sedans)**, **Hongguang Mini EV (a budget EV by SAIC-GM-Wuling)**, and **NIO's electric SUVs** have combined decent technology with aggressive pricing, an innovation in business model as well. China has shown prowess in *integrative innovation* – assembling existing technologies (batteries, motors) into optimized, cost-effective vehicles. The **resulting innovation outcome** is that China is now widely recognized as a leader in EV commercialization. Some analysts even argue Chinese EVs have an edge in certain technologies: for instance, **Huawei's EV unit and others introduced advanced in-car operating systems** and infotainment far ahead of what Japanese cars offered, reflecting China's strength in consumer electronics converging with autos.

Collaborative and Open Innovation: An interesting aspect of output is how collaborative each ecosystem is in generating innovation. Japan's outputs historically came from insular R&D – companies doing a lot in-house. But recently, recognizing the shift to software-defined vehicles, Japanese firms have begun more collaborations (e.g. Toyota partnering with Silicon Valley firms for autonomous tech, and a notable alliance where **Honda joined an autonomous driving consortium led by China's Baidu** in 2018). This indicates Japanese companies leveraging external innovation to boost their outputs in fields they lag. China's ecosystem, in contrast, has been relatively open and multidisciplinary from the start: tech companies, automakers, and even academia often form joint ventures or alliances (for example, Alibaba co-founded an EV startup (IM Motors) with SAIC, and multiple universities work with BYD on battery research). This collaborative approach can accelerate outputs by pooling strengths (IT expertise + manufacturing). We can see the fruits of this in the rapid development of **internet-connected cars in China** – many new Chinese models are essentially "smartphones on wheels," updated with features like over-the-air software upgrades and rich infotainment, thanks to the involvement of ICT firms in car development. Japanese cars have been slower to adopt these innovations, which is an output gap that Japan is now racing to close (Toyota and other Japanese OEMs are developing their own software platforms to catch up with the kind of user experience Chinese and some Western EVs already offer *(Bloomberg 2024)*).

Metrics of Innovation Outcomes: Aside from patents and products, other metrics illustrate output differences. One metric is academic and technical publications in automotive engineering. Here, Japan historically produced a large share of highly cited automotive research (reflecting its strong ties between industry and academic labs), whereas China has rapidly increased its scientific output. In fields like materials science relevant to vehicles (e.g. battery materials, lightweight alloys), Chinese researchers now publish prolifically – China leads the world in total scientific papers in engineering topics *(JST 2024).* The impact on industry can be indirect, but it shows an expanded knowledge base from which innovation can spring. For example, Chinese research labs have published extensively on lithium-ion battery chemistry improvements; much of that knowledge has been quickly absorbed by companies like CATL to improve their products. Japan's publication output has been steady but not growing as fast, and Japanese papers remain well-cited globally, indicating quality *(JST 2024).* In terms of **innovation awards and international recognition**, Japanese automakers have won many "Engine of the Year" or design awards over time, while Chinese automakers only recently started to gain such recognition (for instance, some Chinese EV models winning innovation awards at international auto shows in the 2020s).

Another measurable outcome is the **shift in global market perception** as a result of innovation. Ten years ago, Chinese cars were seen as cheap, low-tech copies. Today, Chinese EVs are often viewed as *innovative and even aspirational* in certain segments (e.g. Xpeng's autonomous driving tech is on par with Tesla's in some aspects, and BYD's blade battery is globally admired). This perceptual change is an outcome of the technological developments achieved. Japanese cars, conversely, have seen their image evolve from "top innovation" to in some cases "lagging in new tech but extremely reliable." Toyota, for example, faced criticism in the early 2020s for being slow to market full EVs (sticking to hybrids and hydrogen), which some saw as falling behind the innovation curve set by Tesla and Chinese EV makers. However, Toyota's hybrid technology itself remains an innovation triumph – it's just now an older one.

It's worth noting that **not all input efforts led to successful outputs in each country**. Japan's heavy R&D in hydrogen fuel cells led to excellent engineering (the Mirai's fuel cell system) but the market is tiny – only a few thousand Mirai are on the road, a negligible outcome relative to investment. China also had some misfires: substantial subsidies went into trying to develop domestic **fuel cell vehicles** and related tech, yet fuel cell cars remain far behind battery EVs. A Chinese government push around 2015–2017 to promote fuel cell buses resulted in a few hundred vehicles but largely fizzled; one analysis notes that *fuel cell vehicle technology, despite equal eligibility for subsidies, did not flourish in China whereas battery EVs did (Mazzocco & Featherston 2024).* This demonstrates how the direction of innovation (output) can be influenced by external factors beyond raw input – e.g. global trends favored batteries over hydrogen in the 2010s. Both Japan and China had to recalibrate their innovation outputs accordingly (Japan scaling back hydrogen ambitions or redirecting to fuel cells for commercial vehicles; China concentrating resources more on batteries and plug-in vehicles).

In conclusion, **Japan's innovation outputs** in the automotive sector are characterized by **high-quality, reliable technologies and a steady stream of patents and improved products**, maintaining its reputation especially in conventional automotive engineering and hybrid systems. However, Japan has been less prolific in the latest software-driven and EV-centric innovations (at least until very recently), causing a slight image of "lagging" in areas like pure EVs and connected car tech. **China's innovation outputs** have gone from negligible to world-leading in certain domains within a decade: the country now produces cutting-edge EVs, dominates battery tech, and is fast improving in autonomous driving algorithms and automotive electronics. The output metrics (patents, new tech offerings, adoption rates of new tech) all reflect this shift – for instance, with China now leading in EV sales and related patent filings. The differing patterns of output set the stage for how each country's automotive industry competes globally and how their industrial policies are evaluated.

5.3.3. Comparative Analysis of Selected Chinese and Japanese Car Models

BYD Han EV: BYD's flagship electric sedan exemplifies high-end innovation at competitive pricing. It adopts BYD's ultra-safe Blade LFP battery (proven in nail penetration tests) and, in its latest top-spec "Han L" version, a new 1000V architecture enabling 10C ultrafast charging (adding ~400 km range in 5 minutes). The dual-motor Han L delivers up to 810 kW (1,086 hp) and sprints 0–100 km/h in 2.7 s, while still achieving ~700 km CLTC range from an 83.2 kWh pack. Advanced driver aids (BYD's DiPilot) and full over-the-air update capability come standard. Priced around ¥350,000 (~€45,000) in China for the highest trim, the Han EV undercuts comparable foreign luxury EVs. Its combination of in-house battery technology, performance, and aggressive pricing reflects the intense innovation and cost engineering drive in China's EV industry (supported by BYD's vertical integration) to challenge established premium players.

BYD Seagull: The BYD Seagull is a subcompact EV that showcases frugal innovation aimed at mass adoption. Built on BYD's e-Platform 3.0, this 4-seater hatchback uses a 38.9 kWh Blade LFP battery yielding ~405 km CLTC range in the top trim. Despite its low cost, it supports DC fast-charging (~40 kW), recharging 30–80% in ~30 minutes. The Seagull's design prioritizes efficiency and space (its thin blade battery allows a spacious 4-door layout in an A-segment car). While light on advanced ADAS, it includes modern safety basics (6 airbags, stability control) and a smartphone-connected infotainment system. Crucially, BYD has priced the Seagull under ¥90,000 (~€11,500) –

an ultra-affordable price made possible by BYD's scale and cost innovation. This aggressive pricing has spurred enormous market uptake: BYD sold 200,000 Seagulls within seven months of launch. The model's success highlights how Chinese firms leverage cost-effective engineering and vertical integration (e.g. in-house batteries) to achieve both innovation in design and a breakthrough in market outcomes (high EV penetration in the entry segment).

NIO ET5: NIO's ET5 sedan is a tech-centric EV aimed at the premium middle market, illustrating China's strength in software-defined vehicles. It offers swappable battery packs – 75 kWh (LFP) or 100 kWh (NMC), plus an optional 150 kWh semi-solid pack – enabling flexible range upgrades and rapid "battery-as-a-service" refueling. With the 100 kWh pack, the dual-motor ET5 delivers ~580 km WLTP range and ~4.0 s 0–100 km/h acceleration. Its innovation edge lies in software and electronics: the ET5 comes with NIO's Aquila sensing suite (33 sensors, including an ultra-long-range LiDAR and high-definition cameras) and Adam supercomputer (initially four NVIDIA Orin-X chips, 1,016 TOPS) to enable advanced L2+ autonomous driving features. Continuous over-the-air updates add capabilities over time, aligning with NIO's strategy of user-centric innovation. Priced around ¥368,000 (~€47,000) for the long-range model, the ET5 competes with Tesla's Model 3 on technology differentiation rather than price. Its introduction of battery swapping and high-end ADAS in a sedan priced for China's upper-middle class reflects how Chinese EV startups combine product innovation (e.g. novel service models, self-driving tech) with market-savvy positioning to seize share in the EV transition.

AITO M9: The AITO M9 is a full-size luxury SUV co-developed by Seres and Huawei, representing China's cutting-edge integration of automotive and ICT innovation. Offered as both an extended-range EV (EREV) and a pure EV, the M9 maximizes range and smart features. The EREV variant uses a 1.5 L turbo generator and a 42–52 kWh CATL NMC battery, giving a total driving range around 1,400 km CLTC (with ~270 km electric range). The EV version carries a 100 kWh battery for ~605–630 km range. The M9 is loaded with Huawei's technology: a HarmonyOS smart cockpit and the Huawei ADS 2.0/3.0 automated driving system, which uses an array of 1 LiDAR (up to 4 on 2025 models), 3 millimeter-wave radars, 12 ultrasonics, and 11 cameras. This enables point-to-point hands-free driving in many scenarios, a capability showcased by Huawei's ADS 3.3 (which in 2024 achieved high-level city navigation without HD maps). Luxury amenities abound, from an AR-HUD (75 inch) and multiple screens (three front displays and optional rear entertainment projectors) to adaptive air suspension. With a price range of ¥469,800–¥569,800 (~€60,000–€73,000) in China, the M9 targets the high end of the domestic market. Its rapid sales (30,000 units in 74 days after the 2025 update) underscore how Chinese automakers can translate tech innovation (especially leveraging firms like Huawei for ADAS and infotainment) into strong market outcomes, even in segments traditionally dominated by imported luxury SUVs.

Yangwang U8: The Yangwang U8 is an ultra-premium off-road EV SUV by BYD that pushes the envelope of vehicle engineering – an exemplar of radical innovation as a policy-driven "halo" product. It features a quad-motor drivetrain (one 220 kW motor per wheel) on BYD's new e^4 platform, which allows unparalleled control: the U8 can perform a 360° "tank turn" on the spot and even drive with one wheel punctured by dynamically adjusting torque in milliseconds. A 2.0 L turbo petrol is used as a range extender for its 49 kWh LFP battery, giving 180 km electric range and 1,000 km total range (CLTC). Uniquely, the U8 can enter an emergency flotation mode to ford through water, leveraging its sealed body and independent motor control to 'swim' out of flood conditions. This tech-laden SUV (body-on-frame with air suspension and lidar-based ADAS expected) is positioned as a "land yacht" demonstrating Chinese prowess. Launched at ¥1,098,000 (~€141,000), the U8 Premium was the most expensive Chinese mass-produced car in 2023. Its lavish price and features are justified as a statement of innovation: it showcases how Chinese firms, backed by industrial policy, have leapt into the highest niches of automotive technology (multi-motor torque vectoring, new safety paradigms) to build brand image and compete with or even surpass traditional luxury off-roaders in capability. The U8's limited-volume success (immediately establishing Yangwang as a luxury EV marque) also signals growing domestic trust in home-grown high-tech vehicles.

Li Auto L9: The Li L9 is a six-seat flagship crossover SUV that represents Japan's "range-extender" concept reimagined by a Chinese startup for maximum real-world usability. It uses a dual-motor electric AWD system (130 kW front + 200 kW rear) paired with a front 1.5 L turbo petrol generator (65 L fuel tank) – the engine never drives the wheels, but charges the 44.5 kWh NMC battery on the go. This EREV architecture yields a claimed 1,315 km NEDC range, including ~215 km pure electric range, effectively eliminating range anxiety for long family trips. The L9 focuses on family-oriented innovation: its interior features two 15.7-inch OLED screens up front (for infotainment and passenger entertainment) and even a retractable 21-inch cinema screen for the rear row in updated models. It also offers advanced driver aids; initially the L9 relied on camera and radar-based L2 systems, but the 2025 update added a forward LiDAR and upgraded AI chips (up to an NVIDIA Thor 700 TOPS SoC on top trims) to enable more robust semi-autonomous driving, including high-speed automatic emergency maneuvering at up to 120–130 km/h. Li Auto has aggressively improved the L9's driving dynamics too, adding dual-chamber air suspension in 2025 for better handling. At ¥459,800 (~€59,000), the L9 is priced slightly above traditional ICE SUVs in China's market, yet it saw huge success – over 114,000 units sold in 2023 – outselling many luxury petrol SUVs. The L9's case underlines how Chinese automakers have innovated by blending EV and hybrid advantages (long range, plug-in capability) and offering high-tech comfort, thereby capturing consumers and achieving dominant market outcomes in China's premium SUV segment.

Xiaomi SU7: The Xiaomi SU7 is a full-size fastback EV sedan that signals the entry of a consumer electronics giant into automaking – leveraging a tech ecosystem to drive automotive innovation. Available in four trims (Standard, Pro, Max, Ultra), the SU7 emphasizes software, battery, and performance. The base rear-wheel-drive model uses a 73.6 kWh BYD Blade LFP pack (for ~700 km CLTC range) and a 220 kW motor, while higher trims add dual motors and CATL's latest Qilin batteries – e.g. the Max carries a 101 kWh NMC pack (~800 km CLTC). Notably, the top "SU7 Ultra" deploys three motors (1,139 kW combined) and a 93.7 kWh Qilin 2.0 battery, enabling hypercar-like acceleration (0–100 km/h in ~1.98 s) and track performance. This Ultra supports 480+ kW DC charging (800 V architecture, ~5C rate), demonstrating Xiaomi's prowess in fast-charge battery tech (developed with CATL). Xiaomi also integrated an advanced autonomous driving system: the Ultra is equipped with 3 LiDARs, 5 radars, and 12 cameras for its "Xiaomi Pilot" (HAD) ADAS, which aims for Level 3 capability. All SU7 versions receive over-the-air software upgrades and connect with Xiaomi's digital ecosystem (smartphone AIoT integration), reflecting the firm's consumer electronics DNA. Xiaomi has pursued an aggressive pricing strategy: the base SU7 starts at just ¥215,900 (~€28,000) – remarkably low for its size and tech – while even the Ultra is priced at ¥814,900 (~€105,000), undercutting imported performance EVs. The SU7's rollout (with a target of 10,000 Ultra units in 2025) reveals how new entrants from China's tech sector are boosting innovation outputs (e.g. in-house motors, consumer-grade UI/UX, race-level performance) and using aggressive pricing to rapidly gain market traction. Xiaomi's foray encapsulates China's broader trajectory: high-tech convergence and disruptive market strategies yielding increasing global competitiveness in EVs.

Nissan Ariya: The Nissan Ariya is a Japanese electric crossover that signifies Japan's steps into the battery EV domain after a history of strength in hybrids. As a midsize SUV, the Ariya's highest trim features a dual-motor e-4ORCE AWD system (290 kW combined) powered by a ~90 kWh (87 kWh usable) battery, delivering up to ~500 km range (WLTC) and 0–100 km/h in ~5.1 s. Its battery thermal management and 130 kW DC fast-charging support give it respectable long-distance capability, although charging speeds and range lag slightly behind similar Chinese offerings. Nissan equipped the Ariya with ProPilot 2.0, an ADAS that allows hands-off single-lane highway driving in

Japan – one of the first L2+ systems deployed domestically (using radar, cameras, and detailed HD maps) in a Japanese car. The Ariya also emphasizes a high-quality interior (spacious, with a minimalist dash and dual displays) and over-the-air software update capability for its infotainment and some driving features. In its home market, the Ariya is priced around ¥6 million (~€37,000) for the top "e-4ORCE 90" edition, positioning it as a premium EV option. While innovative for Nissan – representing a shift from the pioneering Leaf into more upscale EV territory – the Ariya's market impact in Japan has been moderate. It launched in a market that still saw only 3% EV penetration in 2022. Nonetheless, the Ariya demonstrates Japan's incremental innovation approach: leveraging existing strengths (like Nissan's early EV experience and all-wheel-control know-how) to produce a well-rounded BEV, but arriving later and at higher cost than many Chinese rivals. Its introduction, however, has provided Nissan with a platform to compete globally in the burgeoning crossover EV segment and signals a strategic pivot under external competitive pressure.

Lexus RZ 450e: The Lexus RZ 450e is a luxury electric SUV that exemplifies Japanese automakers' cautious yet quality-focused entry into BEVs. Built on Toyota's e-TNGA platform, the RZ 450e's highest trim features dual motors (total ~230 kW) and a 71.4 kWh battery (made by Panasonic) delivering ~360 km WLTP range – a notably shorter range than similarly sized Chinese and European EVs, reflecting Toyota's prioritization of safety and battery longevity over maximal range. Charging is limited to ~150 kW DC, and early software constraints initially capped charging speeds, though updates have improved this. In terms of innovation, Lexus introduced a steer-by-wire system with a yoke-shaped steering controller as an option on the RZ, aiming to enhance handling (this system is set to activate in 2025) and showcasing a novel human-machine interface approach. The RZ comes standard with Lexus Safety System+ A, an ADAS suite including lane-keep assist and adaptive cruise, and it offers the "Lexus Teammate" advanced parking and low-speed hands-free driving in some markets – although it's a conservative Level 2 system compared to the LiDAR-equipped systems emerging in China. The RZ's interior emphasizes Lexus' traditional strengths: craftsmanship, comfort, and refinement, with a new infotainment system that can be updated OTA (a first for Lexus). Priced at about ¥8–9 million in Japan (~€55–60,000), the RZ 450e is positioned as a high-end EV for loyal Lexus customers. The model underscores Japan's innovation trajectory of late: careful adaptation to EV technology (the RZ shares its battery and motor system with Toyota's bZ4X) with an emphasis on reliability and brand experience. While it doesn't break performance records, the RZ introduces Lexus customers to EVs in a characteristically polished manner – but its relatively limited range and late launch (2022) also highlight how Japan's deliberate pace in electrification has resulted in products that, while high-quality, lag behind on some performance metrics and have so far garnered only niche market outcomes.

Toyota bZ4X: The Toyota bZ4X is Toyota's first mass-market BEV, co-developed with Subaru, representing a pivotal but pragmatic shift in Toyota's innovation output. The top-grade bZ4X features dual motors (160 kW combined) and a 71.4 kWh lithium-ion battery (the same pack as in the Lexus RZ), with an EPA range of ~370 km (approximately 460 km under Japan's WLTC). Its 150 kW DC fast-charge capability can recharge ~80% in about 30 minutes under optimal conditions, though real-world charging was initially constrained by battery cooling issues. Toyota focused on durability: the bZ4X's battery is engineered for slow degradation (warranty for 90% capacity at 10 years), reflecting Toyota's conservative engineering ethos. The vehicle carries Toyota's latest Safety Sense suite (with features like lane tracing assist and proactive driving assist) but does not offer the hands-off capabilities present in some Chinese counterparts. One innovative feature is the available solar roof option, which can trickle-charge the battery (~1,800 km of range per year under sunlight) – a nod to eco-innovation beyond driving. The bZ4X also introduced a new e-TNGA platform design optimizing weight distribution and a steer-by-wire system (in development) to debut in 2025. Toyota adopted an unusual marketing strategy in Japan by initially offering the bZ4X only via lease subscription, aiming to manage battery risks and gauge consumer response. Priced roughly around ¥6 million (~€37,000) for purchase (in markets where sales commenced), the bZ4X undercuts many import EVs but is still pricier than Chinese offerings with similar specs. Early recalls (for wheel hub issues) and the modest range dampened its early market performance. However, as Toyota's first foray into BEVs, the bZ4X's importance lies in its role as a learning platform; it reflects a strategic, if belated, output of Japan's innovation system adapting to BEVs – prioritizing safety, steady improvement (a mid-cycle software update improved charging and winter range), and leveraging Toyota's manufacturing excellence. Market outcome so far has been limited, given Japan's slow EV uptake, but the bZ4X has laid groundwork for Toyota's promised rapid EV ramp-up later in the 2020s, underlining how even Japan's conservative trajectory is now pivoting under global pressure.

Toyota Prius (5th Gen, 2023): The latest Toyota Prius (XW60, launched 2022/23) epitomizes Japan's sustained innovation in hybrid-electric technology, now blended with improved design and performance to remain relevant in the EV era. The highest trim of this generation is the Prius Prime (plug-in hybrid), which pairs a 2.0 L petrol engine with an 13.6 kWh battery – enabling ~90 km WLTC electric range before the engine engages. The standard Prius (non-plug-in) uses a Li-ion battery (or NiMH in base trims) and achieves remarkable fuel efficiency (~3.5 L/100 km) thanks to improvements like a high-efficiency 2.0 L Atkinson-cycle engine and a more powerful electric motor. Key innovative features include an all-new design with a lower center of gravity and improved aerodynamics (drag coefficient ~0.27) without sacrificing the car's signature efficiency. Toyota also upgraded the Prius's software capabilities: the car offers the latest Toyota Safety Sense 3.0, with improved pedestrian detection and lane recognition, and it supports over-the-air updates for its infotainment and safety system enhancements – reflecting a gradual shift toward software updates in Toyota's lineup. The Prius Prime can now run in EV mode up to ~130 km/h and has vehicle-to-load (V2L) functionality, pointing to incremental innovation expanding its usability. In Japan, a fully loaded Prius Prime or Prius HEV costs around ¥3.5–4.5 million (~€23–30,000), offering advanced hybrid tech at an accessible price – a deliberate Toyota strategy to keep hybrids attractive as EV competition rises. The new Prius's strong domestic reception (demand outstripping supply in 2023) indicates the market outcome of continuous innovation: it revitalized interest in hybrids even as BEVs made headlines. In context of the Analytical Framework, the Prius illustrates how Japan's automakers convert policy support and R&D investments into incremental yet impactful innovation outputs (higher efficiency, lower emissions in each generation), yielding sustained market success at home. However, it also highlights Japan's continued reliance on hybrid technology – a path that yields world-class efficiency but arguably delays a full shift to zero-emission vehicles.

Nissan Sakura: The Nissan Sakura is a landmark model in Japan's market – a fully electric **kei** car that brings innovation to the minicompact segment, addressing unique domestic needs. Launched in 2022, the Sakura has a 20 kWh battery (usable) providing about 180 km WLTC range and a 47 kW (63 hp) motor driving the front wheels. While modest in specs, it packs several innovative features for its size: Nissan equipped it with advanced regenerative braking and a one-pedal driving mode (unusual in kei cars) to maximize urban efficiency. It also offers Nissan's ProPilot Park and ProPilot ADAS in top trims, enabling semi-automated parking and highway driving assist – a significant step for an entry-level vehicle. The Sakura's energy efficiency is notable (~12.5 kWh/100 km), thanks to its light weight and small size, embodying the **kei** ethos of maximized utility. Charging is via CHAdeMO (up to ~30–40 kW DC), allowing an 80% charge in about 40 minutes – acceptable for its urban mission. Priced around ¥2.33 million before subsidies (~€15,000), it qualifies for government incentives that can bring its price below ¥2 million, making it one of the most affordable EVs. The Sakura illustrates a different facet of Japanese innovation output: miniaturization and cost-conscious engineering to electrify the popular kei car class, which accounts for a large portion of domestic sales. Market response has been positive, with the Sakura (and its sibling Mitsubishi eK EV) significantly boosting EV sales in Japan's countryside and city commuter segments. However, its impact remains domestic – kei cars are unique to Japan's regulations, meaning this innovation doesn't directly bolster global competitiveness. Still, by addressing local market outcomes (offering a zero-emission solution in the kei category), Nissan and Mitsubishi have filled an important niche in Japan's EV transition, aligning with policy goals to reduce urban pollution while maintaining the familiar kei car ecosystem.

Lexus LS 500h: The Lexus LS 500h is a luxury sedan showcasing Japan's prowess in hybrid technology and system integration at the high end, albeit as an alternative to full EV innovation. The LS 500h's latest iteration uses Lexus's Multi Stage Hybrid System, combining a 3.5 L V6 petrol engine with two electric motors and a 4-speed automatic gearbox that simulates 10 gear ratios. This complex setup yields a combined 359 hp and seamless power delivery, allowing the large sedan to achieve ~6.0 L/100 km efficiency – remarkable for its class. Innovation in the LS lies in its smooth hybrid synergy and advanced features: it debuted Lexus's "Teammate" Level 2 system in Japan, which under certain conditions allows hands-off cruising and even Level 3 automated driving in traffic jams on approved highways. This system uses lidar (in some markets) and high-precision maps, reflecting Japan's careful approach to introducing higher autonomy in flagship models. The LS 500h also pioneered upscale features like an artificial intelligence-driven adaptive suspension and extensive OTA-updatable electronic control units to refine ride and safety over time. Aesthetically and ergonomically, the LS emphasizes traditional Japanese craftsmanship (e.g. Kiriko glass interior trim, hand-pleated door fabrics) combined with modern tech, underscoring an innovation focus on *incremental* improvement in comfort and quality. With a price well above ¥15 million (~€95,000 for top trims in Japan), the LS 500h is positioned as a technology demonstrator and brand halo rather than a volume seller. Its market outcome in Japan is modest in volume but significant in influence: it reinforces Lexus's image for reliability and innovation in hybrid drivetrains. In the context of Japan vs. China, the LS 500h exemplifies the Japanese trajectory of excelling in mature technologies (hybrids, manufacturing finesse) – delivering a product with exemplary refinement and incremental tech upgrades (e.g. improved batteries, integration of new driver assist features) rather than chasing radical EV re-invention. This strategy has yielded continued loyalty among conservative luxury buyers, though it also reveals the risk: as the global market shifts to BEVs, such hybrid flagships, while innovative in their own right, face diminishing returns in shaping the future automotive landscape.

Toyota Crown Sedan (Hybrid & FCEV, 2023): The new Toyota Crown Sedan (16th generation, 2023) is a model that bridges Japan's past innovation success in hybrids with its unique bet on hydrogen fuel cell technology. Toyota offers this premium sedan in two advanced powertrains: a 2.5 L Multi-Stage Hybrid (HEV) and a Fuel Cell Electric Vehicle (FCEV) variant – the first time the Crown is available as a fuel-cell car. The hybrid version uses a newly developed multi-stage hybrid system with stepped gear engagement, which amplifies low-speed torque and allows the 2.5 L engine to run at lower RPM at highway speeds. This yields both strong acceleration and excellent fuel economy (~4.5 L/100 km), showcasing an incremental innovation in hybrid efficiency and performance. The FCEV Crown, on the other hand, adopts the Mirai's latest fuel-cell stack with three hydrogen tanks, giving it around **820 km** range per 3-minute hydrogen fill. This powertrain emits only water and represents a *radical* innovation track distinct to Japan's policy – betting on hydrogen as a future alternative. The Crown FCEV provides smooth electric drive and a quiet ride befitting a limousine, aligning environmental innovation with luxury. Both versions feature advanced connectivity and driver aids (Toyota Safety Sense + and "Advanced Drive" automated features), although they stop short of full hands-free capability. Priced at ¥7.3 million for the hybrid and ¥8.3 million for the FCEV (~€47,000–€53,000), the Crown targets government and executive customers who value innovation and sustainability. The model's dual-powertrain strategy vividly reflects Japan's automotive innovation ethos per the Analytical Framework: **diversification** and risk-spreading. The Crown's market outcome will likely see moderate volumes (especially for the FCEV, given hydrogen infrastructure limits), but it serves as an important proof of concept supporting Japan's industrial policy on hydrogen. In summary, the Crown Sedan (HEV/FCEV) underscores the contrast between Japan's innovation outputs – excelling in hybrid technology and cautiously advancing hydrogen – and those of China's pure EV push, illustrating two different paths to low-carbon mobility.

The above model analyses highlight a stark contrast in innovation trajectories between China and Japan, as framed by the Analytical Framework (AF). **Chinese automakers' models demonstrate a trajectory of rapid, market-driven innovation outputs**, heavily enabled by state support and fierce competition. They have pushed the envelope in battery technology (e.g. BYD's Blade LFP and 10C fast-charging batteries, CATL Qilin packs in the Xiaomi SU7), software and connectivity (NIO's NAD platform, Huawei's ADS in the AITO M9), and radical drivetrain designs (BYD's quad-motor Yangwang U8). These innovations are not just technical showcases but are quickly translated into market outcomes: Chinese EVs span **all** segments from ultra-low-cost mini EVs (BYD Seagull) to luxury performance cars (Xiaomi SU7 Ultra), capturing wide consumer demand. The result has been dramatic—by 2022, battery EVs were 27% of new cars in China versus only 3% in Japan—and China overtook Japan as the world's largest auto exporter in 2023 (3.8 million vehicles exported). These outcomes reflect the AF's emphasis on **innovation outputs** (technology adoption, new product introduction speed) and **market performance** (domestic EV uptake, global competitiveness): Chinese firms, often benefiting from industrial policy (subsidies, infrastructure investment, protected home market), have rapidly developed and deployed new technologies to meet policy targets and consumer needs, leading to significant gains in market share and a reshaping of global auto trade.

Japanese automakers' models, in contrast, embody an incremental and conservative innovation trajectory that has excelled in specific domains but lagged in paradigm-shifting technologies. The Japanese models analyzed (Prius, Crown, LS 500h, etc.) highlight Japan's continued strength in hybrid systems, fuel efficiency, and build quality – fruits of a long-term AF focused on continuous improvement, government–industry coordination, and reliability. These outputs have yielded world-leading innovations like the Prius's hybrid synergy drive and the Crown's multi-stage hybrid, contributing to Japan's global reputation for efficient and durable vehicles. However, the Japanese approach—shaped by a home market historically insular and policy preferences for hybrids/fuel cells—**delayed full commitment to BEVs**. Consequently, Japanese companies' BEV offerings (Ariya, bZ4X, RZ) arrived later and are generally less ambitious in performance compared to their Chinese counterparts, resulting in weaker market outcomes: Japan's EV sales remain low, and its brands have lost ground in the burgeoning global EV market. The AF's indicators show Japanese firms still lead in some innovation inputs (patents, component expertise), but their **innovation output** in BEVs (number and competitiveness of models) and **market outcomes** (EV adoption, export growth) have not kept pace with China's. That said, the Japanese trajectory is now pivoting: new policies and investments (e.g. METI's 2030 targets, Toyota's EV strategy revision) aim to accelerate EV and software development. In summary, the comparative model analysis underscores how **China's state-enabled, competition-fueled innovation system has produced fast, bold moves in EV technology and market capture**, whereas **Japan's path-dependent, quality-focused system yielded exceptional incremental innovations but is only belatedly adjusting to the EV paradigm shift**. Both trajectories offer lessons: China's experience shows the power of scale and bold experimentation in driving industrial leadership, while Japan's highlights the importance of foundational R&D and reliability – and the risks of complacency in the face of disruptive change. The convergence of these trajectories will shape the next chapter of the auto industry, as each country leverages its strengths to address its weaknesses in the quest for sustainable and intelligent mobility.

5.4. Industry Competitiveness and Market Outcomes

Innovation in the automotive sector ultimately manifests in competitive performance and market outcomes – in other words, how each country's industry fares in domestic and global markets as a result of its innovation (or lack thereof). This section evaluates the competitiveness of China's and Japan's automotive industries, looking at market share dynamics, export performance, brand strength, and other outcomes influenced by innovation and policy. We find that Japan's automakers, long dominant internationally thanks to their innovative quality and efficiency, have seen their position challenged in recent years, particularly by China's rapid ascent in electric vehicles. China's industry, once focused only on the protected home market, is now making major inroads globally, leveraging innovation-driven advances (especially in EV technology) and economies of scale. Key indicators – production and sales volumes, export rankings, and market share shifts – illustrate this changing landscape.

Domestic Market Share and Structure: Japan's domestic auto market has for decades been an almost exclusive stronghold of Japanese automakers. Even without formal import restrictions today, Japanese brands command roughly 90–95% of the home market, with foreign automakers holding only a marginal share (imports appeal mainly to niche luxury segments). This reflects Japanese consumer preferences and the legacy of past protection – historically, Japan's government made it difficult for foreign autos to penetrate, and even after tariffs fell to zero, factors like right-hand drive requirements and a dense dealer network of local brands have kept foreign share minimal. Thus, in terms of home market competitiveness, Japanese automakers face little challenge from abroad; competition is largely among themselves. The domestic rivalry (Toyota, Nissan, Honda, etc.) has driven continuous improvement but also means Japan's market wasn't a battleground testing them against all global players in recent years.

China, on the other hand, had a very different domestic market structure that has now dramatically shifted in favor of local firms. For much of the early 2000s and 2010s, foreign–Chinese joint ventures (e.g. FAW-Volkswagen, SAIC-GM, GAC-Honda) dominated sales in China, and Chinese indigenous brands struggled, holding perhaps 30-40% of the market at best. However, the past five years – coinciding with China's surge in EV innovation – have seen **Chinese brands rapidly gain domestic market share at the expense of foreign JVs**. By 2023–24, Chinese automakers (including state-owned and private firms) captured about **63% of China's passenger vehicle sales**, up from roughly 36% in 2020 *(Automobility 2024)*. This is a remarkable swing. Foreign legacy automakers (Volkswagen, GM, Toyota, etc.) saw their combined share plunge below 40%, a sharp decline from earlier dominance *(Hinrich Foundation 2024)*. The trigger for this shift is widely attributed to innovation in EVs: Chinese companies were quick to flood the market with attractive electric models, whereas foreign JVs lagged. By 2024, **EVs accounted for 41% of China's new car sales**, and Chinese makers produced the lion's share of those EVs *(Enright 2024).* Foreign automakers like Volkswagen and Toyota, who rely more on gasoline models, suddenly found themselves losing ground. In 2024, foreign brand sales in China fell dramatically (German brands down 13%, Japanese brands down 17.7% year-on-year) as local EV offerings surged *(Enright 2024).* Thus, China's innovation-fueled competitiveness in EVs turned its home market from a joint-venture haven into a playing field increasingly led by domestic brands.

This development has strategic significance. It suggests China's industrial policies – nurturing local manufacturers through technology transfer and EV subsidies – have paid off in terms of reducing dependence on foreign automakers. In contrast, Japan never had to fight off foreign brands at home recently because they never gained a foothold; Japanese policy in the postwar period had already ensured domestic brands reigned. So while both countries have strong home players, **China's competitive dynamic has been more turbulent**, with local firms rising to outperform foreign competitors on home turf through rapid innovation (especially BYD, Geely, Chery, and others in EVs). Japan's domestic competitive dynamic is stable but arguably less externally pressured, which some analysts believe made Japanese firms complacent about disruptive innovation (since they weren't being challenged by Teslas or BYDs on their own streets to the same extent).

Global Production and Export Leadership: By many metrics of industrial output, China has overtaken Japan decisively. China is now the world's largest automotive producer by a huge margin. In 2021, for instance, China produced about 26 million vehicles, compared to Japan's 8 million (OICA data). By 2024, China's output exceeded **31 million vehicles – roughly one-third of all vehicles made worldwide**, whereas Japan's production was on the order of 8–9 million (just ~10–11% of global output) *(Reuters 2022)*. Japan's share of world auto production has steadily fallen from over 20% in the early 2000s to around 11% in 2024 *(Bloomberg 2024).* Meanwhile, China's share rose astronomically from near-zero in the 1980s to ~32% by the mid-2020s *(Reuters 2022).* **Figure 5.3** highlights this shift in global production share between the two countries.

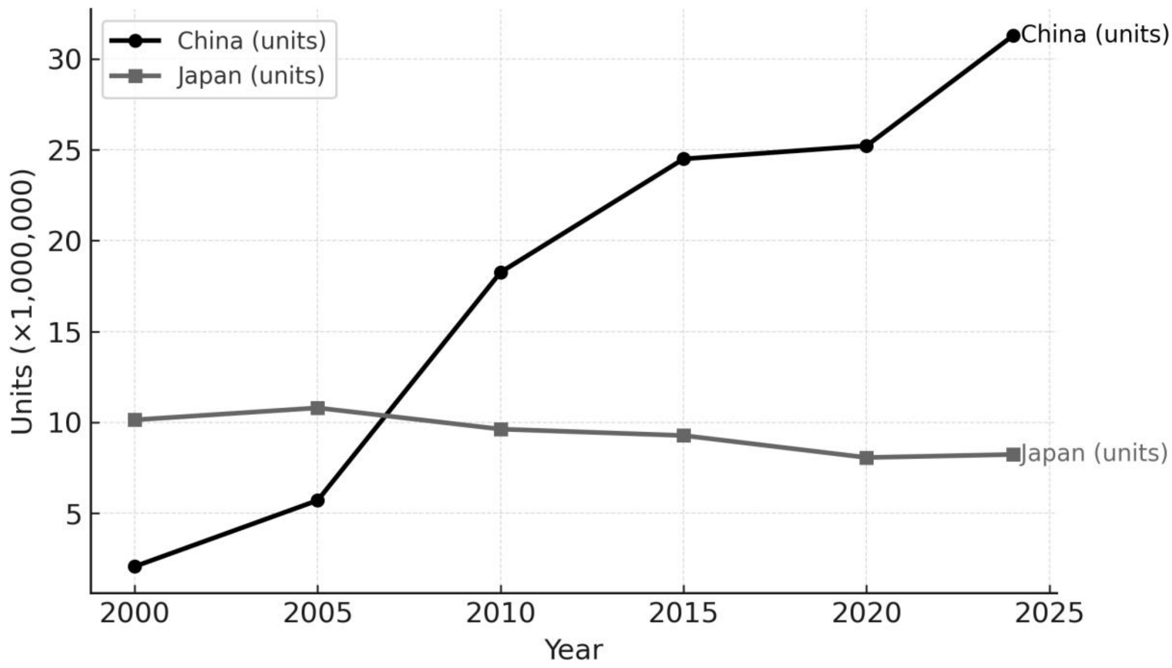

Figure 5.3. Motor Vehicle Production — China vs. Japan (Selected Years)

Source: OICA Production Statistics.

One direct consequence of this production dominance is that **China has recently surpassed Japan as the world's largest vehicle exporter**. This is a striking development as Japan was famous for its export-led automotive growth for decades (with Toyota, Honda, etc. shipping cars globally). In 2022, China's vehicle exports surged to around 3.2 million units, nearly on par with Japan's ~3.5 million. By 2023, China exported over **4 million vehicles**, overtaking Japan's exports (approximately 3.5–3.7 million) and seizing the #1 exporter title *(Russo, Fan & Song 2024).* This represented an inflection point: a Chinese industry once considered immature is now competitive enough to sell more cars overseas than Japan's highly reputed industry. The composition of those exports is telling – many are **electric vehicles or reasonably priced gasoline cars** finding eager buyers in emerging markets, but increasingly also in developed markets. For example, Chinese brands like MG (owned by SAIC) have become top sellers of EVs in markets like the UK (MG's ZS EV became one of Britain's best-selling electric SUVs). Japan still exports mostly gasoline and hybrid cars and retains strength in traditional markets (North America, Europe for certain segments), but it faces new competition abroad from Chinese automakers targeting those same markets often with an EV focus.

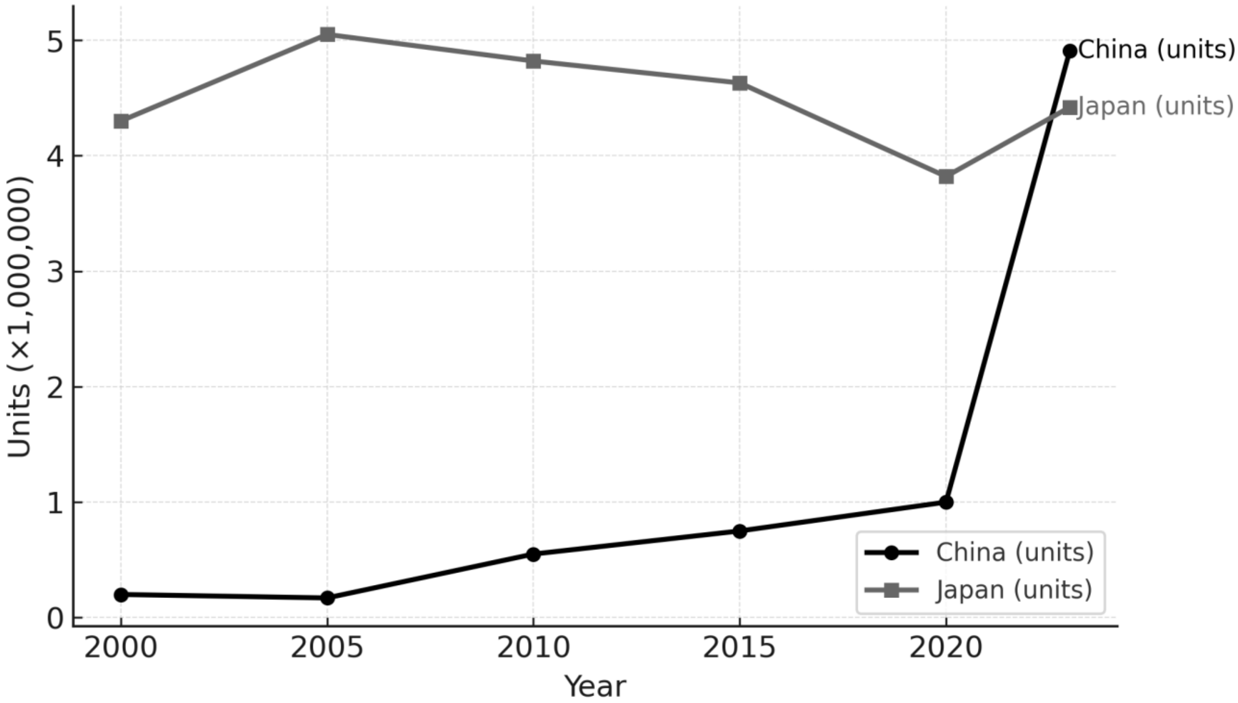

Figure 5.4. Motor Vehicle Exports — China vs. Japan (Selected Years)

Source: JAMA (Japan); CAAM / UN Comtrade (China).

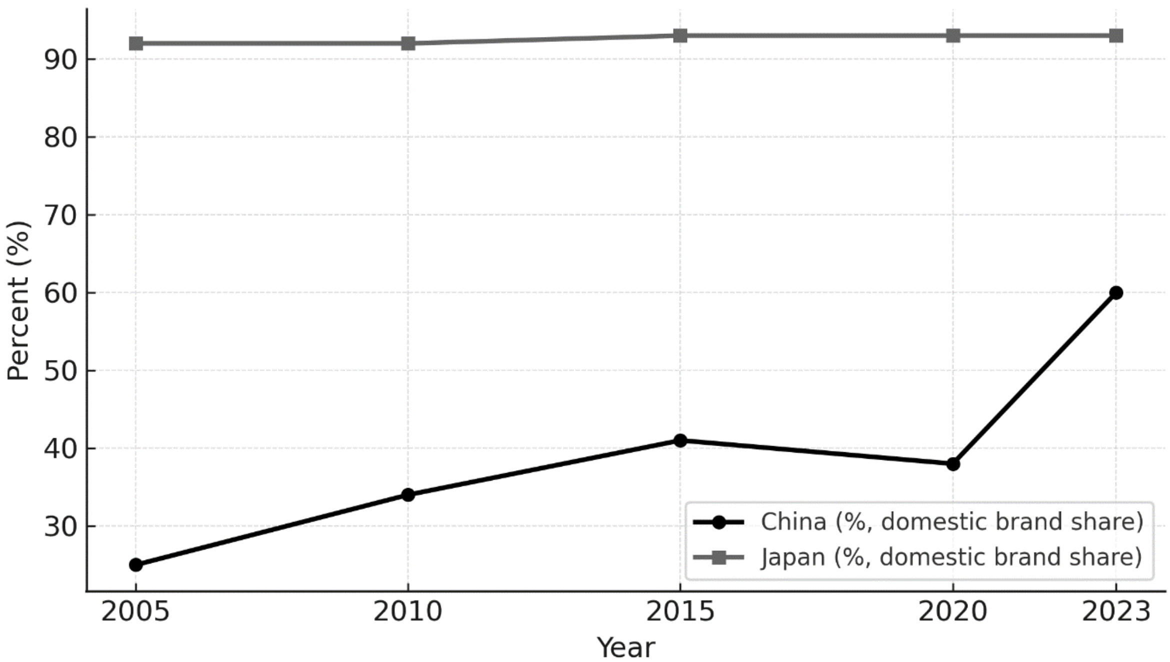

Figure 5.5. Domestic-Brand Share of Passenger-Car Sales in Home Market

Source: CAAM (China domestic brand share); JADA/JAMA (Japan import share).

A related competitive measure is the **trade balance and dependency**. Japan historically enjoyed large trade surpluses in automobiles – it exported far more cars (especially to North America and Europe) than it imported. This contributed significantly to Japan's economy. While that surplus persists, it has eroded slightly as Japanese companies localize production abroad and as global competition intensifies. Japan actually recorded a **trade deficit with China** in recent years, in part because China has been substituting machinery imports (including auto parts) with domestic production *(García-Herrero 2018)*. In autos specifically, Japan's surplus with many countries is now challenged by Chinese entrants. Conversely, China until recently ran trade deficits in autos (importing luxury cars, etc.), but the new export boom could flip that. In 2023, China became a **net exporter of automobiles** in value terms – a remarkable turnaround. China exporting vehicles to Japan is still minimal (Japanese consumers have yet to buy Chinese cars in notable numbers), but Chinese EVs have started to appear in Southeast Asia and Europe, markets traditionally dominated by Japanese or Western brands.

Competitive Strengths and Weaknesses: Examining specific strengths, Japanese automakers are still world leaders in internal combustion engine (ICE) technology and arguably in *overall vehicle reliability and build quality*. Toyota's production system continues to yield very reliable vehicles with low defect rates – a competitive edge that shows up in surveys (Japanese brands often top reliability rankings). Japanese cars also have strong brand equity in many markets due to this reliability and past innovation reputation (e.g. the "Toyota" or "Honda" brand carries weight). In **fuel-efficient ICE and hybrid vehicles**, Japan maintains an edge – its hybrids (Prius, etc.) remain among the most efficient and refined. Even as EVs rise, there is still a market (in regions where charging is limited or fuel is cheap) for efficient ICE/hybrid cars, and Japanese firms compete well there.

However, a glaring weakness for Japan has been the slower move on pure electrification. By 2024, Japanese companies had introduced only a handful of battery-electric models globally (Nissan's Leaf was pioneering back in 2010, but follow-up from other Japanese makers was slow; Toyota's first long-range EV, the bZ4X, came only in 2022). This lag is hurting their competitiveness in the fast-growing EV segments. Indeed, **winners in the current auto industry are being "minted" based on battery technology and software** more than engine tuning *(Bloomberg 2024)*. Japanese automakers have recognized this; they are now investing heavily in catch-up efforts: Toyota, for instance, announced a multi-billion-dollar push into EV development and solid-state batteries around 2023–2024, and formed new divisions to accelerate software and autonomous driving R&D *(Bloomberg*

2024). But in the interim, Chinese (and some Western) competitors have leapt ahead in market share for EVs.

China's competitive strengths lie in **cost innovation and speed**. Chinese manufacturers have shown they can produce EVs at lower cost and iterate models faster than many incumbents. Bain & Co. research noted that some "insurgent" Chinese EV makers could develop new models in **24–30 months**, roughly half the time it took traditional Western/Japanese OEMs, and at much lower R&D cost per vehicle. This agility is a competitive advantage. Companies like BYD not only innovate technologically but also integrate vertically (BYD makes its own batteries, chips, and many components), allowing cost control that undercuts foreign rivals. Moreover, Chinese automakers benefited from a huge domestic market to achieve scale: serving the world's largest auto market gave firms like SAIC and Great Wall the volume to become efficient, and now at over 20+ million units annually, the Chinese industry has scale economies Japan's ~5 million annual domestic market cannot match. By 2024, some Chinese automakers (BYD, Chery, etc.) began leveraging that scale to price their cars very competitively in export markets – a threat recognized by established players (the EU even launched an anti-subsidy probe into Chinese EV imports in 2023, fearing European market disruption by underpriced Chinese EVs, which echoes the concerns the US had with Japanese car exports in the 1980s).

That said, **Chinese automakers also have weaknesses**. One has been brand image, though it's improving. In many developed markets, Chinese car brands are still relatively unknown or carry perception baggage about quality. Japanese brands spent decades building trust and often rank higher in brand reputation indexes. Another challenge for Chinese firms is after-sales service and global distribution – areas where Japanese companies have long-established networks. Competitiveness is not just about the product, but also the support and dealership presence, which Japanese automakers have worldwide, whereas Chinese firms are building theirs from scratch outside China. Additionally, geopolitical factors play a role: Japanese companies, being from a long-standing market economy, have faced fewer political barriers abroad, whereas Chinese firms sometimes encounter suspicion (for instance, concerns about data security with Chinese connected cars, or protectionist sentiments that may limit Chinese car access in the U.S.). These factors can temper Chinese firms' market outcomes despite technical competitiveness.

Market Outcomes in Third-Country Markets: A critical lens to view competitiveness is how Japanese vs. Chinese cars are doing in key regional markets like Southeast Asia, Europe, and others:

- **Southeast Asia:** Historically, this has been Japan's backyard – countries like Thailand, Indonesia, Malaysia have been dominated by Japanese brands (Toyota, Honda, Mitsubishi, etc.) which even set up manufacturing there. Until recently, over 90% of cars in Indonesia or Thailand were Japanese makes. However, Chinese entrants are making rapid gains. In Thailand, Chinese EV makers (like SAIC's MG and Great Wall's Ora) have captured noticeable share in the nascent EV market, and overall Chinese brands' share has risen to *around 30–35% in 2023*, down from Japanese dominance of >50% a few years prior *(Bloomberg 2024).* In *Singapore*, Chinese EVs (BYD, MG) became popular enough that Japanese brands' share eroded to ~35% by 2023 from over 50% in 2019. Even in Indonesia, where Japanese makers had an almost monopoly (over 95% in 2019), the presence of Chinese brands is now visible (e.g. Wuling and DFSK selling affordable MPVs and EVs). This demonstrates Japanese firms losing ground in some Asian markets due to the appeal of Chinese offerings, often priced lower or with features like electrification that Japanese models in those markets lack. Japanese automakers aren't standing still – they have leveraged strong regional production bases (Toyota in Thailand, etc.) and tried to respond with localized models (for instance, Toyota is introducing more hybrid versions in Southeast Asia to offer an alternative to EVs). Toyota still has strongholds such as pickup trucks (where its Hilux reigns in Thailand) which Chinese firms haven't overtaken yet *(Bloomberg 2024).* But the overall trend is concerning for Japan: the once unassailable grip on emerging markets is weakening as Chinese innovation produces vehicles that meet local needs (like small affordable EVs or tech-laden SUVs) at competitive prices.
- **Europe:** Japan's position in Europe has traditionally been smaller than in the U.S. or Asia (European brands dominate there), but Japanese cars – especially Toyota and Nissan – gained foothold with compact cars and crossovers, and Toyota's hybrids are popular in eco-conscious Europe. Now, Chinese EV makers view Europe as a prime target, given the EV-friendly policies there. Already, **Chinese-built cars (including Teslas made in China and Volvo/Polestar models by Geely, plus pure Chinese brands)** accounted for a growing share of EV sales in Europe by 2023. Companies like BYD have launched multiple models in European countries, and MG (SAIC) has become one of the top EV sellers in markets like the UK and Sweden. This puts them in direct competition with Nissan's Leaf and Ariya EVs, for example, and with Toyota's upcoming EV line – basically challenging all incumbents. European auto experts have pointed out that some Chinese EVs are competitive on quality and

often undercut on price, thanks in part to cheaper battery sourcing from China *(Bloomberg 2024)*. Japan's competitive edge of reliability matters less to European EV buyers who might value tech and price more, which could diminish Japanese brands' appeal unless they adapt quickly (Toyota's hybrids still sell well, but if Europe's regulations push toward 100% EV, Toyota will need strong BEV models to compete with Chinese ones).

- **North America:** This remains a bastion of Japanese success (Toyota, Honda are deeply entrenched in the U.S. market, known for quality and dealer network). Chinese automakers have not yet entered the U.S. consumer market in a big way (partly due to tariff barriers and political scrutiny). Thus in the U.S., Japanese brands still compete mainly with American, Korean, and European brands, and have been holding their own. However, even here the EV revolution is shaking things up – Tesla became a top-selling brand and Ford/GM are investing heavily in EVs, while Japanese makers were slower. If in a few years Chinese automakers circumvent barriers (e.g. by setting up assembly in Mexico or the U.S.), they could pose a threat in segments like entry-level EVs. For now, Japan's market outcome in the U.S. is still strong (Toyota was #1 in U.S. sales in 2021 and 2022). But the global shift in competitiveness means Japan cannot be complacent even where it's ahead.

Competitiveness in Innovation-Driven Segments: We should also consider specific emerging segments: **Electric vehicles** – here, Chinese brands clearly have gained a competitive edge in technology cost and speed to market, as discussed. **Autonomous vehicles** – neither Japan nor China has a clear commercial lead yet (U.S. companies might be ahead in full self-driving tech). But China's approach (integrating AV tech into mass-market cars via partnerships, like Xpeng and NIO offering advanced driver assist) versus Japan's (Honda and Toyota methodically testing Level 3/4 in limited deployments) could influence future competitive positions. If Chinese cars come standard with more advanced autonomy features because of their tech sector collaboration, they may win consumers seeking that, whereas Japanese makers might risk being seen as lagging. On the other hand, Japan's cautious approach might avoid overhyping tech that isn't ready – if Chinese AV tech were to prove unreliable or unsafe, it could backfire. It's an unfolding area, but one where innovation output will directly shape competitiveness.

Financial Performance and Resilience: Competitiveness also reflects in profitability and resilience of companies. Japanese automakers historically have been quite profitable and efficient. Toyota is often the world's most profitable automaker (due to its scale and efficiency), which gives it a war chest for R&D and price competition. Chinese automakers, until recently, had thinner margins;

many were propped by subsidies or local government support, and not all are financially robust. For example, numerous EV startups in China burned through cash and some failed or consolidated. However, leaders like BYD have achieved scale and improved profitability (BYD's net profit jumped in 2022 and 2023 as it overtook VW in China's sales rankings). If Chinese firms achieve sustained profitability while maintaining growth – a scenario increasingly likely for top players – they will be in a stronger position to invest, export, and undercut competitors internationally. Japanese firms, meanwhile, are investing heavily in the transition (which can squeeze margins – e.g. Toyota spending $13+ billion on battery development over the next decade). Their ability to remain financially strong while catching up on EVs is a key competitive challenge.

One telling observation made by analysts is that **Japan's erstwhile comparative advantages are eroding vis-à-vis China**. In the mid-2010s, Japan still had a large revealed comparative advantage in automobiles (meaning its export share in autos was far above its share of world trade, reflecting strong global competitiveness). But China's concerted effort in advanced manufacturing has narrowed gaps. Where Japan once supplied high-value machinery and components to China, now Chinese firms often supply themselves or even export such goods – creating competition for Japan's auto parts industry too *(García-Herrero 2018).* For some time, Japanese companies maintained a broad global lead in autos thanks to their engineering and brand – for instance, Japan was comfortably ahead of China in automotive powertrain technology and luxury car quality. Yet, Chinese companies leaped in areas like electric powertrains and are learning fast about quality. By the early 2020s, **the quality gap had shrunk**: Chinese cars, once derided, have improved to the point that some models achieve safety and reliability ratings on par with international standards (a necessary step for export success).

Finally, **market outcomes** in terms of consumer adoption also reflect competitiveness of innovation. An illustrative statistic: as of 2024, *nearly 70% of the world's EV sales occur in China (Enright 2024).* This not only speaks to Chinese domestic policy but also to the fact that Chinese producers are pumping out EVs that consumers buy in massive numbers, dominating a new market segment. In Japan, conversely, adoption of EVs has been extremely slow – pure EVs were about **1% of new car sales in Japan in 2024** *(EVwire 2024).* Japanese automakers mostly offered hybrids and a few EV models, and Japanese consumers stuck to hybrids or traditional cars. This disparity in market outcome (41% EV share in China vs ~1% in Japan by 2024) vividly highlights which industry was more competitively ready for the new paradigm. It suggests Japanese firms risk losing out in the next generation of automotive demand unless they leverage their late-mover strategies effectively (the Japanese government has now set a goal that *all new cars sold by 2035 be "electrified" – including* *hybrids*, which indicates urgency but still hedges with hybrids instead of full EVs). Meanwhile, China's competitive edge in EVs might propel its firms to continue gaining global market share as EV adoption grows worldwide.

In conclusion, **Japan's automotive industry enters the mid-2020s still formidable – profitable, high-quality, and globally present – but facing its most serious competitive headwinds in decades**. The country that once was accused by the U.S. of unfair automotive dominance in the 1980s now finds itself needing to *boost R&D and innovation just to keep up (Bruegel 2018).* Conversely, **China's industry, buoyed by effective innovation in new technologies and state support, has converted those gains into tangible competitive outcomes**: from home market supremacy to export triumphs. The ultimate market outcome is that consumers globally have more viable Chinese car options (especially electric) and Japanese companies must accelerate innovation to defend their long-held positions. In the next section, we evaluate how the differing policy approaches of China and Japan – the engines behind these innovation and competitiveness trends – have been implemented and how intensively each country supports its auto sector.

5.5. Policy Implementation and Support Intensity

Industrial policy has underpinned much of the innovation and competitive dynamics discussed thus far. In this section, we compare how China and Japan implement their automotive industrial policies and the intensity of government support provided to their auto industries. We analyze the mechanisms each government uses – regulatory, financial, institutional – and assess their effectiveness and side effects. China is often cited as a model of aggressive industrial policy, characterized by heavy subsidies, market protection, and direct state involvement to foster domestic champions. Japan, historically an architect of developmental industrial policy, today employs a more measured approach that relies on creating an enabling environment and supporting industry-led innovation, with far less direct subsidy than China. Understanding these differences sheds light on why innovation outcomes and competitiveness took the trajectories outlined above.

Strategic Vision and Planning: China's policy implementation in the automotive sector is driven by a top-down strategic vision. The government has consistently included the auto industry (especially new energy and intelligent vehicles) in its national development plans. From the *10th Five-Year Plan* (2001–2005) that first listed EVs as a priority, to the *Mid- and Long-Term Science & Technology Plan (2006–2020)* emphasizing "indigenous innovation," to the sweeping *Made in China 2025* initiative, China set clear targets for automotive technology capabilities. **Made in China 2025**, in particular, identified NEVs and smart vehicles as one of ten key sectors for which China aimed to achieve self-sufficiency and global leadership. This strategic guidance has been very specific: for example, MIIT set a goal for Chinese-branded NEVs to reach a **70% domestic market share by 2025**, and for certain component localization rates to exceed 80%. Policy implementation then aligns with these targets.

Japan also formulates strategies – such as the **Automobile Industry Strategy 2020** by METI and the **Green Growth Strategy (2021)** for carbon neutrality – but these tend to be less directive. They set aspirational goals (e.g. **100% electrified vehicle sales by 2035** including hybrids) and outline supportive measures, but they usually do not mandate market share targets or impose explicit local content requirements. Japan's post-1990s industrial policy style has been described as focusing on framework conditions rather than detailed quotas *(OECD 2019)*. For instance, Japan's government declares intentions to lead in hydrogen or solid-state batteries, but relies on public-private committees and the initiative of companies to achieve those aims, rather than enforcing via regulations.

Regulatory Implementation: A stark difference is in use of regulatory sticks and carrots. China has been unabashed in using strong regulatory levers. A prime example is the **NEV mandate/credit system** introduced around 2017: automakers in China are required to produce a certain proportion of NEVs or purchase credits – effectively a quota forcing technology adoption. This system is analogous to California's ZEV mandate but on a national scale. It compelled even reluctant joint ventures (like those between Chinese SOEs and Japanese automakers) to invest in EV models or face penalties. China also applied other regulations like restricting new manufacturing licenses to EV-only companies at one point (to channel investment into EVs). Emissions and fuel economy standards in China were tightened on an aggressive timeline, pressuring companies to innovate or shift to electrification. At local levels, policies like **license plate restrictions in big cities exempted NEVs** (making it easier to own an EV than a gasoline car in places like Shanghai or Beijing), which strongly nudged consumers and thus automakers' behavior.

Japan's regulatory approach has been comparatively moderate. Fuel economy and emission standards are stringent in Japan too (Japan has consistently pushed efficient vehicles, partly why it excelled in hybrids). But Japan did not impose an EV quota or a ban on gasoline vehicles by a certain date (it floated the 2035 target for "electrified" vehicles, which generously counts hybrids). Instead of mandates, Japan often uses **guidelines and voluntary targets**. For example, rather than forcing automakers to sell EVs, METI has provided roadmaps and *encouraged* industry to invest in next-gen vehicles, offering some tax incentives. One notable regulatory move was legalizing certain autonomous driving levels – Japan amended road laws to permit Level 3 autonomous driving in 2020 and Level 4 in 2023 under limited conditions (Meiji.net 2023). This indicates supportive regulatory action to not fall behind in AV deployment. But in general, Japan's policy implementation relies less on compulsion. The government sets fuel economy standards (the "Top Runner" program) which automakers met largely by hybridizing fleets – a cooperative outcome aligning with policy but also with automakers' own product strategy.

Financial Support Intensity: Perhaps the most glaring contrast is in direct financial support. China's central and local governments have spent lavishly to build their auto industry. As noted, an estimated **$200+ billion in subsidies** was poured into the NEV sector alone. This included multi-layered subsidies: R&D grants to companies for EV development, purchase subsidies for consumers (at one point up to ~$10,000 per EV in direct rebate), subsidies to build charging stations, tax exemptions (no sales tax on NEVs), and direct capital injections or cheap loans to automakers (especially state-owned ones or promising startups). Beyond EV-specific support, provincial governments often provided **free land, tax holidays, and low-interest financing** for automakers setting up factories. For example, when *Tesla* built its Gigafactory in Shanghai, the local government helped facilitate cheap credit and swift approvals, effectively subsidizing the venture in hopes of tech spillovers. Decades earlier, in the 1980s and 90s, China used high tariffs (over 100% on imports) and forced joint ventures to protect and indirectly subsidize domestic production. Even after WTO entry, tariffs on imported cars remained at 25% until recently (now 15%), and foreign firms faced equity caps (50% JV limit, only lifted in 2022 for passenger cars). These measures gave local companies a sheltered environment to grow – essentially an implicit subsidy via guaranteed market share. It wasn't always efficient (resulting in many small sub-scale automakers for years), but it was intense support.

Japan's government support, while significant in earlier decades, has been far less lavish in recent times. In the postwar period through the 1970s, Japan's MITI did protect the auto industry (e.g. tight import quotas in the 1950s–60s, foreign investment restrictions that prevented takeover by foreign carmakers, etc.), which allowed Toyota, Nissan, and others to consolidate and learn until they could compete globally. However, by the 1980s, Japan's automakers were globally competitive and overtook U.S. makers in many markets without needing subsidies – in fact, Japan faced international pressure to open its market and restrain exports (voluntary export restraints in the 1980s). In the contemporary era, direct subsidies to Japanese automakers are limited. The government has offered some **consumer incentives for green vehicles** (for instance, a **subsidy up to ¥400,000 (~$3,000–$4,000) for BEV purchases** and tax breaks), but these are modest compared to Chinese subsidies that at times exceeded $10k per car. In 2021, Japan's budget for all clean vehicle subsidies was about ¥25 billion (~$0.19 billion), a tiny fraction of China's annual outlay. There are also R&D subsidies – e.g. through NEDO (New Energy and Industrial Technology Development Organization), the government co-funds some pre-commercial R&D on batteries, hydrogen, etc. Those amounts are again relatively small (tens or hundreds of millions of dollars, not billions).

Where Japan does invest is in infrastructure and collaborative research: for example, the government supported the installation of hydrogen fueling stations with subsidies, spent on EV charging infrastructure (though critics say the charger rollout in Japan has been slow, with under 30,000 public chargers in 2023). The **Green Growth Strategy** earmarked funding for decarbonization technologies, including automotive, aiming to mobilize around ¥2 trillion (~$18 billion) of public-private investment over several years in areas like batteries and motors *(METI 2021)*. Still, these figures are an order of magnitude lower than China's spending. Japan's constrained fiscal situation (huge public debt) and free-market orientation in recent decades limited appetite for Chinese-style spending. A Bruegel analysis bluntly noted that "Japan can hardly hope to keep pace [with Chinese R&D spending growth] given the government's weak fiscal position". Hence, Japan's support intensity is lower, relying on industry to do the heavy lifting in R&D investment (and Japanese companies do invest a lot, as we saw in input metrics, but out of their own budgets). The Japanese government's role is more about indirect support – e.g. offering tax incentives for R&D (Japan provides tax credits on R&D expenditures, encouraging companies' own spending) and setting favorable regulations (like safety regulations that Japanese makers already excel at, giving them a home advantage).

Institutional Implementation and Coordination: Another aspect is how policies are administered and coordinated. In China, policy implementation can be fragmented across central agencies and local governments, but often there is an overarching direction that aligns them. The **MIIT, NDRC (National Development and Reform Commission), and MOF (Ministry of Finance)** work together on auto policy – MIIT sets technical guidelines, NDRC controls investment approvals (e.g. it limited new auto manufacturing entrants to avoid duplication), and MOF allocates subsidies. The Communist Party's guidance ensures these bodies push toward the same national goals. For example, when China wanted to consolidate its auto industry, NDRC put out guidelines to merge smaller companies into larger groups. Results have been mixed – as of 2020, China still had many automakers, but the top few did gain larger share. The **implementation at local level** sometimes caused issues: local governments, wanting their own champions, gave subsidies to local automakers regardless of efficiency, leading to duplication (this was evident in the early 2010s when dozens of EV startups sprang up across provinces, some with mediocre results). Beijing has tried to tighten this by stipulating more rigorous tech requirements to receive subsidies (e.g. setting minimum EV range or battery density standards for a vehicle to qualify for subsidies, weeding out low-quality players).

Japan's policy implementation is characterized by *consensus-building* and close industry consultation. METI convenes study groups with automaker representatives, academia, etc., before major policy decisions. This often results in slower, but more industry-accepted, measures. A case in point is Japan's approach to autonomous vehicle regulation: the government worked with OEMs to amend the Vienna Convention on Road Traffic through the UNECE so that Level 3 automated systems could be legal – Japan was the first to actually legalize Level 3 driving on highways (Meiji.net). This careful, rule-of-law approach contrasts with China's more experimental approach (China designated entire cities for autonomous vehicle testing with relatively undefined legal frameworks at first).

Another institutional difference is **public-private partnerships**. Japan frequently uses PPPs for innovation (e.g. CREST program, SIP, etc.). The government's financial role may be limited, but its convening power helps align different companies on pre-competitive research (for instance, the SIP-adus project on automated driving brought together many Japanese firms to collaborate on basic technologies like HD mapping and safety). China also uses alliances, but often the government's presence is more directive – e.g. a state-owned enterprise might lead a consortium by government mandate.

Market Protection vs. Openness: Support intensity can also be gauged by how much market protectionism is used as a tool. As mentioned, China shielded its market for a long time (high tariffs, JV requirements). Japan in its high-growth era did too, but since the 1980s Japan's auto market has technically been open (0% tariff, though some non-tariff barriers and consumer bias kept imports low). Today, Chinese policy is still somewhat protectionist (15% tariff is not trivial, and foreign EVs in China did not initially qualify for subsidies unless they partnered with local battery suppliers – a rule that favored domestic firms). In 2019, China even implemented a policy that foreign companies could only get certain EV incentives if they shared technology with a Chinese partner (Tesla was a notable exception when it was allowed a wholly-owned factory in Shanghai, but even Tesla had to commit to helping China's EV ecosystem and was likely given the exception to spur competition). Japan, by contrast, cannot easily employ protectionist measures now due to trade agreements and its role in WTO/G7 etc. The result is Chinese firms grew in a huge sheltered market then jumped to exports, whereas Japanese firms have long been exposed to global competition (except at home) and honed their competitiveness that way. Both models have pros and cons; China's created strong locals but also some inefficiency and trade friction, Japan's created ultra-efficient firms but perhaps made them complacent in new tech due to the comfortable home market and lucrative existing export markets.

Effectiveness and Challenges: The intensity of China's policy support undoubtedly accelerated its innovation and competitiveness gains, but it also led to issues like overcapacity and "uneven" success. Some Chinese industrial policy efforts produced waste – e.g. massive subsidies created a bubble of EV startups, some of which collapsed after burning through grants, and a "boom and bust" cycle in electric buses where thousands of subsidy-driven buses were produced and later sat idle. The Chinese government has had to adjust, cutting back subsidies after 2019 to weed out weaker players and warning local authorities against blind investments. Nonetheless, the *uneven success* still skewed positive in critical areas (passenger EVs, batteries). A CSIS study noted that **industrial policy outcomes in China vary by sector** – success depends on how policies are implemented, competition levels, and ability to access foreign tech. In autos, the blend of competition (foreign vs local JVs) and heavy state support eventually yielded success in EVs, whereas in conventional cars China never quite met its target of building globally dominant purely indigenous brands until the EV era. In fact, China's government essentially *changed the playing field* by betting on EVs precisely because it had difficulty catching up in traditional engines (Enright 2024). That strategic pivot – an implementation of *mission-oriented policy* – was bold and appears to be paying off, as China now leads in the new paradigm while it was still behind in the old one.

Japan's policy support intensity being lower has meant fewer distortions, but it also means **market forces dictate outcomes to a larger degree**. Japanese automakers succeeded globally not because of ongoing subsidies (they actually faced yen appreciation and trade friction headwinds) but because of their own innovation and efficiency. This makes Japanese policy look "hands off" by comparison, but that's not entirely the case – Japan's government has been deeply involved in coordinating and guiding when needed (for instance, setting up the **Battery Association for Supply Chain** in 2022 to ensure a stable EV battery supply, with METI support). It's just that Japan's support is more **nuanced and often behind-the-scenes**, focusing on maintaining an ecosystem (education, fundamental research funding, standards setting) rather than direct market intervention.

One interesting form of Japanese government support is **diplomatic and trade support**. The government has sometimes helped Japanese automakers abroad by negotiating to reduce tariffs or providing development aid that involves Japanese vehicles (like donating Toyota hybrids to developing countries or building infrastructure that suits Japanese tech). China similarly uses economic diplomacy (the Belt & Road has led to Chinese vehicle assembly plants in countries like Pakistan, often with Chinese state bank loans). These broader foreign policy tools amplify each nation's industry support beyond domestic measures.

In terms of **intensity perceived by counterparts**: The EU and US view Chinese support as so intense that they consider it market-distorting (hence, Europe's investigation into Chinese EV subsidies in 2023, and the U.S.' earlier tariffs on Chinese auto parts). Japan's support has not raised such alarms in recent times, implying it's within accepted competitive behavior. In fact, Japan itself is now contemplating more proactive industrial policy somewhat akin to the U.S. and EU (e.g. potentially providing subsidies for domestic battery factories to keep up with the U.S. Inflation Reduction Act, which lures battery investment to America). This indicates that the **global policy environment is shifting towards more state support** – ironically converging a bit toward what China has done – as everyone tries to secure their auto industries' futures amid technological upheaval.

Outcome Intensity Correlation: The intensity of support correlates with some outcomes noted: China's EV leadership correlates with its heavy policy push on EVs, while Japan's lag in EVs correlates with its lighter touch and reliance on hybrids. Conversely, Japan's continuous excellence in hybrids correlates with consistent but not extravagant support (the government gave early tax breaks for hybrids and supported their R&D in the 90s quietly). China's overextension in subsidizing numerous EV companies correlates with some failures, which the government has had to correct. So, an interesting takeaway is that **China's policy intensity created big successes and some inefficiencies, whereas Japan's lower intensity created steady performance but also perhaps missed opportunities in radically new areas**.

In summary, China implements industrial policy in the automotive sector with a **high degree of state involvement and resource intensity**: it sets clear targets, uses strict regulatory measures, spends heavily, and isn't afraid to intervene in markets to achieve its aims. This has accelerated innovation and growth of domestic firms, making China a formidable automotive power, though at the cost of high expenditure and occasional market distortions. Japan's industrial policy approach is **more conservative and facilitative**: it focuses on enabling industry-driven innovation through incentives and collaborative frameworks, spending far less directly and avoiding heavy-handed mandates. This fostered a very robust automotive industry through the late 20th century, but in the face of new disruptive technologies, Japan's lighter touch approach has been slower to pivot the industry (relying on companies to make the change). The balance between these approaches reflects each nation’s economic philosophies and contexts – China’s developmental state activism versus Japan’s more neoliberal-leaning since the 2000s – and it profoundly shaped their innovation trajectories and competitive standings in the global automotive arena.

6. Analytical Synthesis

6.1. Brief Insight

In this chapter, a structured–focused comparative approach is applied to synthesize the findings and explain why China and Japan followed divergent innovation paths in the automotive industry under industrial policy from the 1990s to 2024. Guided by the analytical framework's four criteria – (1) **Innovation Input Effort**, (2) **Innovation Outputs & Technology Development**, (3) **Industry Competitiveness & Market Outcomes**, and (4) **Policy Implementation & Support Intensity** – each section compares the two countries on that dimension, drawing on empirical evidence from Chapter 5. Causal reasoning is employed to link policy actions to innovation outcomes, following the methodology outlined in Chapter 4. By asking consistent questions of each case (e.g. *How much was invested in R&D? What outputs were achieved? How did industry performance change? What policy tools were used?*), this chapter isolates how differences in policy and context led to different innovation trajectories. The analysis is supported by charts and evidence from the empirical data (Chapter 5) and literature, ensuring that each claim is grounded in documented facts.

China's policy interventions were often bolder and larger in scale (e.g. the **1994 JV policy**, **2009 NEV subsidy launch**, **2017 EV sales mandate**) and coincided with surges in innovation outcomes (such as the rapid rise of electric vehicle sales after 2015). Japan's timeline shows more modest policy measures (e.g. **1990s EV R&D programs**, **2009 eco-car tax incentives**) and a more gradual innovation trajectory (e.g. early success with hybrids but slow battery EV uptake, remaining under 5% of new sales through 2020s). By 2022, electric vehicles were over **25%** of new car sales in China versus only about **1%** in Japan, reflecting the impact of China's aggressive EV push and Japan's cautious approach. The following sections delve into each analytical criterion in detail, comparing the two countries and extracting causal insights. Mini-findings are summarized at the end of each section, and a comparative "scorecard" and evidence chain diagram are provided to visualize the overall differences.

6.2. Innovation Input Effort

Innovation inputs refer to the resources and efforts devoted to generating innovation, chiefly **R&D expenditures**, **human capital (engineers, researchers)**, and supportive infrastructure or investments. Japan and China have both invested substantially in automotive innovation inputs, but they differ markedly in **scale, growth, and the balance of public vs. private effort**. Japan entered the 1990s as one of the world's most R&D-intensive economies, with a mature automotive R&D

ecosystem built by leading firms (Toyota, Honda, Nissan, etc.) over decades. China, by contrast, started from a very low base in the 1990s and has rapidly scaled up its innovation inputs in the last two decades, heavily propelled by state-led initiatives. This section compares R&D spending trajectories, the role of government vs. corporate R&D, and other input efforts in the two countries.

R&D Expenditure Levels and Growth: Japan has consistently been a top investor in R&D. Throughout the 1990s and 2000s, Japan's R&D spending hovered around **3% of GDP**, among the highest in the world. Even in absolute terms, Japan's annual R&D outlay in the late 2010s was substantial (~¥18–19 trillion, roughly **$170 billion**, or about 3.3% of GDP). A significant share of this effort has always come from the automotive sector: roughly **36%** of Japan's total R&D spending in recent years was attributable to the machinery and automotive industries. Major automakers each invest billions annually (Toyota alone spends ~¥1 trillion, ~$9+ billion, on R&D per year), focusing on incremental improvements and some new technologies. Japan's R&D input effort, therefore, has been **high but steady** – reflecting a strategy of continuous improvement (kaizen) and maintaining an already advanced position. Notably, much of this R&D expenditure is **privately funded** by companies, with government support taking the form of tax credits and consortia rather than direct state spending.

China's R&D expenditure, in contrast, grew **exponentially** from the 1990s to 2020s. In the early 1990s, China's spending on automotive R&D was negligible and the industry relied on foreign technology. However, as China's economy expanded and the government prioritized innovation, national R&D spending surged. Around **2015**, China's total R&D spending (all sectors) was already **$409 billion** (2.1% of GDP) – nearly double Japan's in absolute terms. This gap widened further: by **2021** China spent roughly **$668 billion** on R&D (about 2.4% of GDP) compared to Japan's ~$177 billion (3.3% of GDP). In other words, China's absolute R&D investment now far exceeds Japan's, even though Japan's intensity (share of GDP) remains higher. China's rise from <1% to >2.5% GERD/GDP over two decades reflects **massive scaling of R&D inputs**. A significant portion of this growth was fueled by government policies: China's state has directly funded research (e.g. through grants, the establishment of research institutes at state-owned automakers, etc.) and **incentivized firms** to increase R&D (through subsidies, mandates to improve technology, and protection of the domestic market to allow profit reinvestment). Especially during the 2010s, programs like the *Medium- and Long-Term Science & Technology Plan* (2006–2020) and *Made in China 2025* set targets for R&D in strategic sectors, leading to **huge state-led R&D initiatives in new energy vehicles (NEVs), batteries, and autonomous driving**. The result was that China's automotive sector moved from relying on foreign joint ventures for technology in the 1990s to establishing large in-house R&D centers by the 2010s (e.g. companies like SAIC, Geely, BYD built sizable R&D teams).

Human Capital and Infrastructure: Both countries recognize that money alone does not yield innovation without skilled people and supporting infrastructure. Japan has long invested in engineering education and on-the-job training; its automotive engineers are world-renowned for expertise in manufacturing and design. In the 1990s–2000s, however, Japan's demographics and hiring trends meant the automotive R&D workforce grew slowly. China, by contrast, massively expanded its pool of engineers: through the 2000s and 2010s, hundreds of thousands of engineering graduates entered the workforce annually, and programs encouraged foreign-educated Chinese talent to return (the "Sea Turtle" phenomenon) to work in high-tech industries. By the 2020s, Chinese automakers and suppliers employ R&D teams that rival or exceed Japanese firms in size. Additionally, the Chinese government invested heavily in **innovation infrastructure** – technology parks, EV testing facilities, battery labs, etc., often in collaboration with local governments. For example, under state coordination, **EV charging infrastructure** was rapidly built out: China installed over 800,000 public charging stations by early 2020s, dwarfing Japan's roughly 30,000 chargers. This infrastructure investment was part of the input effort to support innovation (in this case, facilitating electric vehicle adoption and experimentation). Japan also invested in infrastructure (for instance, a network of hydrogen fueling stations for fuel-cell vehicles, as part of its *Hydrogen Society* roadmap), but these efforts were more limited in scale and slower to roll out, partly due to budget constraints and the private-sector driven approach.

Government vs. Private Contributions: A key difference in input effort is the **role of the state**. In Japan, the post-1990 era saw a relatively *hands-off* government stance in direct industrial investment. While the government did support collaborative research (e.g. **METI's New Sunshine Project** in 1992 funded EV battery R&D) and offered tax incentives, the bulk of innovation input came from corporate R&D budgets and incremental improvements by firms themselves. This aligns with Japan's broader shift to a more liberal, horizontal policy approach in the 1990s – after earlier decades of MITI-led heavy industrial policy, Japan largely stepped back due to both ideology and external pressures (U.S. trade frictions, WTO rules). **Beason (2021)** observes that Japan essentially **abandoned sector-specific industrial targeting in the 1990s**, focusing instead on creating enabling conditions for industry to innovate on its own. Thus, Japan's innovation input effort remained high, but it was driven by established firms leveraging existing strengths (e.g. Toyota's mastery of hybrids, manufacturing efficiency) with *incremental* government support.

China's government, conversely, played an *active and outsized role* in boosting innovation inputs. A signature policy was the requirement that foreign automakers could only operate in China through **joint ventures (JVs) with local firms (max 50% ownership)**. Instituted by the 1994 Auto Policy, this forced knowledge transfer and skill development for Chinese partners – an indirect input into innovation, as Chinese engineers learned from global companies. In later years, the state poured direct funding: for example, between 2009 and 2022, an estimated **¥150 billion (over $20 billion)** of government subsidies were injected into the New Energy Vehicle sector to spur R&D and manufacturing. Another analysis even puts China's total EV-related industrial policy spending in the 2010s at **$200+ billion**, an astronomical figure covering R&D grants, production subsidies, consumer incentives, and infrastructure. In contrast, Japan's direct spending on comparable initiatives was only on the order of a few hundred million dollars per year. This stark disparity in **support intensity** (further discussed in section 6.5) means China's innovation inputs were supercharged by public funding to a degree Japan never attempted. The Chinese state also actively guided *where* inputs should go: it identified priority technologies (EV batteries, autonomous driving AI, etc.) and funneled resources accordingly, whereas Japanese policymakers were more neutral, letting companies decide their R&D focus with gentle encouragement (e.g. subsidies available for various eco-innovations broadly, rather than picking one winner).

Effectiveness of Input Efforts: Both countries' input efforts yielded stronger innovation capacity, but the **timing and efficiency** differed. Japan's consistent R&D investment gave it world-leading capabilities in areas like **precision manufacturing, engine design, and hybrid systems** by the 2000s. However, Japan's relatively conservative allocation (more on improving existing tech than on exploring radically new tech) meant that when the paradigm shifted to software-heavy and electric mobility, there was a lag in reorienting those inputs. China's rapidly increased inputs, although sometimes *inefficient* or duplicative, were crucial in allowing a latecomer industry to catch up. There were admittedly wasteful episodes – e.g. around 2015, some Chinese firms churned out low-quality EVs just to claim subsidies, and many small EV startups that received local support eventually failed. But overall, the massive investment in human and financial capital created a foundation for Chinese firms to innovate at scale by the late 2010s. By pouring resources into research institutes, universities, and firms (state-owned and private alike), China dramatically improved its innovative inputs, which, as we will see, translated into impressive outputs. In short, **Japan's input effort was high but stable and firm-led, whereas China's was dynamic, state-propelled, and eventually greater in absolute terms**. This difference set the stage for the divergence in innovation outcomes observed.

Mini-Findings – Innovation Input Effort:

- **Japan's High but Steady Inputs:** Japan sustained one of the world's highest R&D intensities (~3% of GDP) through 1990s–2020s, largely driven by private automotive firms' continuous innovation ethic. Government support was present but modest (tax incentives, research consortia) as Japan embraced a more hands-off approach after 1990.
- **China's Rapid Scaling:** China went from minimal automotive R&D in 1990 to spending more in absolute terms than Japan by the late 2010s. Aggressive state policies – from JV mandates to massive R&D subsidies – fueled this surge, rapidly expanding China's innovation infrastructure and talent pool.
- **Public vs. Private Role:** Japan relied on established firms to invest steadily in innovation (Toyota, et al.), with the state as facilitator. China's state took a direct role in mobilizing inputs (funding, guiding projects), which accelerated capacity building but with some inefficiencies.
- **Implication:** Early 2000s, Japan's input effort kept it at the technological frontier in conventional auto engineering, but China's outsized input push by 2020s provided the raw fuel (R&D funds, engineers, infrastructure) to leapfrog in new tech domains, underpinning its catch-up in innovation outputs.

6.3. Innovation Output and Technology Development

Innovation outputs are the measurable technological results of innovation activities – such as **patents**, **new product developments, new model introductions, performance improvements**, and breakthroughs in key technologies. This section examines how China and Japan's innovation inputs translated into outputs over time, and how their outputs differ in nature and scale. In the 1990s, Japan was far ahead in automotive innovation outputs, having already produced world-class cars and technologies. By the 2020s, China had not only caught up in many metrics but even surpassed Japan in certain output indicators (particularly in emerging technologies like electric vehicles). Here we compare patent output, advancements in vehicle technology (EVs, hybrids, etc.), and overall technological leadership in the auto industry for the two countries.

Patent Filings and Technological Inventions: Patents are a commonly used proxy for innovation output. Japan historically was a prolific patent generator in automotive engineering; Japanese automakers and suppliers filed numerous patents on engines, safety systems, and manufacturing processes throughout the 1980s–2000s. However, since the 2010s, **China has overtaken Japan in patent output** in many areas. By 2018, China surpassed Japan in the annual number of international patent applications (per WIPO data). Figure 5.3 in Chapter 5 showed that **China's international patent filings soared from under 1,000 in 2000 to nearly 70,000 by 2021**, whereas Japan's filings grew more slowly. This dramatic rise reflects China's push into high-tech innovation: Chinese firms (and universities) increasingly patented technologies not just domestically but via the Patent Cooperation Treaty (PCT) internationally, indicating attempts to secure global IP. A large share of these Chinese patents in recent years are related to **electric vehicle technologies, batteries, and connectivity** – new frontiers where China invested heavily. Japan's patent output remained strong in traditional areas and incremental innovations (e.g. improvements in hybrid systems, internal combustion efficiency), but its overall share of global automotive patents declined relative to China. By the mid-2020s, China and South Korea were leading in growth of EV-related patents, while Japan still held a large stock of patents, especially in foundational automotive tech and components (some sources note Japan and Germany still have very high cumulative EV patent portfolios, though China's are growing faster).

It's important to note that **patent quantity** does not equal quality. Japanese patents have historically been regarded as high-impact (many incremental but valuable innovations), whereas the early wave of Chinese patents had a mix of groundbreaking ones and many minor improvements. However, the gap in **technological sophistication** has narrowed quickly. For instance, Chinese companies like **CATL (batteries)** and **Huawei (automotive ICT)** now produce patents cited globally. The presence of cutting-edge innovation in China's output is evidenced by its leadership in certain fields – e.g., China dominates patents in lithium-ion battery chemistry and electric powertrain control systems, thanks to companies like BYD and CATL (often with state research support). Japan, on the other hand, has a rich patent portfolio in hybrid drivetrains, automotive hardware, and components reliability, reflecting its focus on refining known technologies.

Vehicle Technology Development – EVs vs. Hybrids: Perhaps the most visible divergence in outputs is in **what types of new vehicles and technologies each country developed**. Japan's signature automotive innovation of the late 1990s–2000s was the **hybrid electric vehicle (HEV)**. The **Toyota Prius**, launched in 1997, was a pioneering output combining an internal combustion engine with battery-electric drive. This breakthrough was a product of intense R&D by Toyota with some government support (METI's programs in early 90s helped battery tech). Throughout the 2000s, Japanese firms expanded hybrid technology across models, and by the 2010s, Japan was the world leader in hybrid vehicle adoption (over 90% of "electrified" vehicles sold in Japan are hybrids, not full EVs). Additionally, Japan led in **fuel-cell vehicle (FCEV)** development – Toyota's **Mirai** (fuel-cell car) debuted in 2014, reflecting another area of output where Japan invested (hydrogen fuel cell tech, although with limited market success so far). These outputs align with Japan's strategic choice to focus on improving fuel efficiency and leveraging existing strengths (the automotive companies' expertise in engines and manufacturing) rather than jumping straight to pure battery EVs.

China, by contrast, had very limited indigenous automotive tech outputs in the 1990s (most cars produced were based on foreign models). But in the 2010s, China made an explicit leap into **battery electric vehicles (BEVs)**. This resulted in a torrent of outputs: dozens of new EV models launched by Chinese companies, advances in battery technology (e.g. BYD and CATL producing high-density batteries), and improvements in autonomous driving software by tech entrants like Baidu. By **2022**, the tangible outcome was that China produced **6.8 million EVs sold that year** – accounting for over **57% of all EVs sold worldwide**. Meanwhile Japan's EV output remained marginal (only ~59,000 EVs sold in Japan in 2022, roughly 1% of global EV sales). China's ability to create a *new technological paradigm output* (mass-market EVs) where it now leads the world is a direct consequence of the heavy inputs and policy push discussed earlier. The **"Ten Cities, Thousand Vehicles"** pilot in 2009 and subsequent nationwide EV subsidies resulted in Chinese automakers developing many electric models. Some early outputs were low-end (short-range, cheap EVs circa 2010–2015), but quality improved rapidly. By mid-2020s, Chinese brands like **BYD, NIO, Xpeng** are producing EVs that compete in quality and performance with Western and Japanese models, a remarkable turnaround from a decade prior. Additionally, China has developed strong output in **battery tech**: Contemporary Amperex Technology Co. (CATL), hardly known a decade ago, is now the world's largest EV battery maker, supplying not only Chinese firms but also Tesla and other global OEMs – an output of China's innovation system that Japan, surprisingly, lagged in (despite Panasonic's earlier lead in batteries, China took over in volume and cost innovation).

Quality and Nature of Innovations: Japan's innovation outputs are often characterized as **incremental but high-quality**. For example, year after year, Japanese vehicles set benchmarks in reliability, safety, and manufacturing efficiency. These are innovations that might not always be captured by patent counts or flashy announcements, but are evident in metrics like **vehicle longevity, recall rates, and production efficiency**. The Toyota Production System's continuous refinements are a kind of process innovation output that gave Japanese firms a competitive edge for decades. However, in terms of **radical innovation** (paradigm shifts), Japan's outputs were fewer in the 2010s: outside of hybrids and some early autonomy features, Japanese automakers were slower to introduce fully new concepts like connected car ecosystems or EV-only platforms until very recently. By 2024, firms like Toyota and Honda announced a ramp-up in EV offerings and software-defined vehicles, but these came as reactions to the success that new entrants (including Chinese ones) had with those outputs.

China's innovation outputs, conversely, were initially **behind in quality** – many Chinese-made cars in the 2000s were technologically inferior or based on dated foreign designs. But as of the 2020s, Chinese outputs improved dramatically: **domestic brands gained top rankings in EV range, battery technology, and even new business models** (like battery swapping, autonomous mobility services). One can point to outputs like **BYD's Blade Battery** (a safer, long-life EV battery launched in 2020) as an example of Chinese-origin innovation. Another example is in **electric buses**: Chinese companies (e.g. BYD, Yutong) dominate global electric bus markets, an output of innovation driven by heavy domestic adoption and city subsidies. Japan, in contrast, did not produce such outputs at scale in buses or trucks for EVs, sticking more to hybrids or clean diesel for those segments.

Software and New Areas: In modern vehicles, software (for connectivity, infotainment, autonomous driving) is a crucial innovation output. Here, **neither country was traditionally strong** (the U.S. and Europe led in automotive software), but China arguably moved faster in recent years. Chinese tech firms (like Baidu, Alibaba, Huawei) entered the automotive space, contributing to outputs in connectivity (e.g. all Chinese EVs are sold with advanced telematics, some with AI assistants) and autonomous driving pilots (Baidu's Apollo project). Japan's automakers, on the other hand, were somewhat late to embrace software-centric innovation. By mid-2020s, Toyota and others have ramped up investment in software and even partnered with companies like NVIDIA or acquired startups to catch up. This is one area where Japan's incremental approach may have cost it some ground – a point acknowledged in Japan where they cite the need to avoid another "lost decade" in automotive software.

Linking Outputs to Inputs/Policy: The divergent outputs strongly reflect earlier choices in inputs and policy. Japan's support for hybrids (tax breaks, consumer incentives for efficient cars in 2009, etc.) led to prolific output in hybrid models – by 2010s, virtually every Japanese automaker had multiple hybrid offerings. Japan's heavy funding of **fuel-cell R&D** (billions of yen in subsidies for hydrogen fuel cell programs) produced some outputs like the Toyota Mirai and Honda Clarity, but these remain niche – an output that has not (yet) paid off in widespread impact, highlighting a *limitation* of Japan's innovation bets (they bet on hydrogen, which as of 2024 is still nascent, whereas battery EVs – where Japan lagged – took off). China's decision to "leapfrog" internal combustion and go straight to EVs, supported by intense policy measures (demand subsidies, production quotas, infrastructure), directly resulted in a flood of EV-related outputs that put China ahead in that domain. **Yeung (2019)** documents how China's proactive market creation (subsidies, government procurement of EVs) plus regulatory pressure (fuel economy and NEV credit rules) forced both domestic and foreign firms in China to innovate or increase EV output. Thus, the outputs we see by 2024 – China dominating EV sales and patents, Japan leading in hybrid tech but lagging in EVs – are not accidental but *causally linked* to the policy and input strategies each country pursued.

Overall Output Performance by 2024: By the end of our study period, **both countries have notable innovation outputs, but in different arenas**. Japan's automotive industry outputs world-class vehicles known for quality, has deep expertise in certain technologies (hybrids, engines, materials), and continues to file a large number of patents. China's automotive industry outputs the largest number of electric vehicles globally, has some globally leading technologies (especially in batteries and power electronics), and dramatically increased its share of high-tech patents. Importantly, the **nature** of innovation has diverged: Japan's is more *firm-driven and evolutionary*, China's more *state-stimulated and revolutionary (in selected fields)*.

Mini-Findings – Innovation Outputs & Technology:

- **Patent Trajectories:** Japan's innovation output was strong through incremental patents and improvements, but China's patent filings skyrocketed in the 2010s, overtaking Japan in annual international patent counts by the late 2010s. China's patent surge concentrated in new tech (EVs, batteries), reflecting its shifting innovation focus.
- **Vehicle Innovation Focus:** Japan excelled in **hybrid technology** (Prius and successors) and remains a leader in efficient gasoline engines and reliability. China leapfrogged to **battery electric vehicles**, creating dozens of EV models and a huge EV market – a direct outcome of its NEV policies (6.8 million EVs sold in 2022 vs. ~60k in Japan). Japan's cautious EV approach led to low EV output, even as it led in hybrids and experimented with hydrogen FCEVs.
- **Quality vs. Novelty:** Japanese outputs emphasize high quality, safety, and incremental innovation (world-leading manufacturing processes, top vehicle reliability). Chinese outputs in the 2020s show high novelty and fast improvement – e.g. cutting-edge battery tech, integrated connectivity – though early on quality gaps existed. By 2024, some Chinese brands match global standards in many metrics, demonstrating successful catch-up in output quality.
- **Policy-Driven Results:** The differences in outputs mirror policy choices: China's heavy support for EVs produced a vibrant EV innovation ecosystem (patents, startups, new products).

Japan's market-driven, incremental path yielded world-leading hybrids and steady tech progress but a slower pivot to new paradigms (contributing to a loss of edge in EVs and software). In sum, **China's industrial policy translated inputs into visible new-tech outputs, whereas Japan's industry-led innovation maintained strength in established tech outputs**.

6.4. Industry Competitiveness & Market Outcomes

Innovation in the automotive sector ultimately manifests in industry-level performance: market share, global competitiveness of firms, export success, and the ability to sustain profits and growth. This criterion examines how the innovation efforts and outputs discussed above impacted the **competitive positions** of China's and Japan's automotive industries from the 1990s to 2024. Initially, Japan's industry was globally dominant while China's was infant and inward-looking. Over three decades, China emerged as the world's largest auto producer (and recently, exporter), while Japan's firms maintained strong quality and brand reputation but faced new pressures. Key indicators include **production volumes**, **global/export market share**, **domestic market dynamics**, and the international standing of leading companies. We also consider how innovation influenced these outcomes – for instance, did policy-driven innovation help Chinese firms compete globally? Did Japan's innovation strategy help it retain competitiveness, or were there missed opportunities?

Production Volume and Global Share: One clear outcome of divergent paths is in sheer production numbers. **Japan's automobile production** peaked in the 1990s–2000s (e.g. ~10 million units/year in mid-2000s) and then stabilized or slightly declined. Japan produced about 9.2 million vehicles in 2022, which is significant but has been surpassed by others. **China's production** exploded from virtually nothing (0.5 million in 1990) to become the **world's largest producer from 2009 onward**, hitting ~25+ million vehicles/year by late 2010s. By 2020, China's output was about **32% of global auto production**, up from only ~5% in 1995, whereas Japan's share fell from ~13% in 1995 to under 10% by 2020. Figure 5 (Chapter 5) illustrated this shift: in 2000, Japan made ~3x as many cars as China; by 2020, China made >3x as many as Japan. This dramatic change in global share is a fundamental market outcome of China's rise and is tightly linked to its innovation and industrial policy (which built domestic capacity and protected local producers during their growth).

Export Performance: Historically, Japan was an export powerhouse – known for exporting high-quality cars worldwide (Toyota, Honda, Nissan became household names globally). Until recently, China exported relatively few cars, as its industry mainly served the booming domestic market and had quality gaps abroad. However, by the early 2020s, **Chinese auto exports surged**. In **2022, China overtook Germany as the #2 vehicle exporter**, and in **2023, China overtook Japan to become the world's largest auto exporter**. This is a remarkable outcome: Chinese brands like SAIC, Chery, Great Wall, and BYD began selling competitively in markets from Southeast Asia to Europe, especially leveraging EV offerings (for example, the electric **BYD Atto 3** and SAIC's MG-branded EVs are selling well in Europe). Japan, meanwhile, saw a slight decline in exports in recent years partly due to aging domestic factories and a shift to producing overseas (Japanese firms built many factories abroad, so export from Japan itself isn't the sole measure of their success). Nevertheless, losing the #1 exporter title to China is symbolic of how far China's competitiveness has come.

Domestic Market Dynamics: In Japan, the domestic auto market has long been dominated by the Big Three (Toyota, Nissan, Honda) and other domestic makers (Mazda, Subaru, etc.), with foreign brands capturing only a small fraction (import penetration in Japan is traditionally <10%). So Japan's industry competitiveness at home remained strong; however, the *composition* of what they sold shifted more toward hybrids and fuel-efficient models due to innovation outputs and consumer preferences (shaped by policy like tax incentives for green cars). In China's case, the domestic market went from being dominated by foreign joint-venture brands in the 1990s–2000s (VW, GM, Toyota models made in China often topped sales) to seeing **Chinese indigenous brands take the lead by the 2020s**. By 2022–2023, companies like BYD, Geely, and Great Wall have captured a majority of China's EV market and are growing their overall share, while some foreign JV brands (especially French, and even some Japanese like Nissan) lost significant ground in China. This reversal – Chinese brands becoming competitive enough to beat foreign incumbents on home turf – is a direct outcome of innovation catching up. Industrial policy aided this by nurturing local firms (through JV rules, tech transfer, and later EV subsidies that domestic firms utilized more effectively). For example, when China's NEV mandate pushed EV production, foreign JVs (like joint ventures of Japanese automakers) were slower, giving an opening for local EV specialists to gain market share. The net outcome: **consumer acceptance and competitiveness of Chinese cars rose** markedly, evident in higher brand value and sales for Chinese automakers domestically.

Global Competitiveness of Firms: Japan's automakers have long been ranked among the world's top in terms of market capitalization, brand value, and innovation. Toyota, in particular, has often been the #1 or #2 automaker globally by volume and is renowned for its product quality and technology. Entering the 2020s, however, Japanese firms face new competitive challenges: the transition to EVs and smart cars where software is key. For instance, **Tesla (USA)** and **BYD (China)** in 2023 both surpassed Toyota in EV sales, and Tesla's market cap dwarfs any traditional automaker. Japanese firms are now racing to avoid falling behind in these new segments – a direct consequence of slower output in those areas. Nonetheless, Japanese companies maintain competitive advantages in many facets: **profitability** (Toyota remains one of the most profitable automakers), **manufacturing excellence**, and a loyal global customer base. They also collaborate internationally (e.g., Toyota with Panasonic on batteries, with Subaru on EVs, etc.) to bolster innovation.

Chinese automotive firms, some of which barely existed 20 years ago, are now emerging challengers globally. **BYD**, for example, became the world's second-largest EV maker and has a market presence in dozens of countries, backed by strong innovation in battery and EV design. **Geely** acquired Volvo (a sign of Chinese firms going global) and is incorporating advanced tech through partnerships (e.g. with Mercedes in EVs). **NIO** and others, while not as large, have built brands around innovation (battery swapping, smart features). The competitive gap in technology and quality between Chinese and Japanese firms has narrowed significantly by 2024. In some areas (like batteries), Chinese firms are arguably ahead; in others (like overall vehicle reliability and luxury segment know-how), Japanese firms still hold an edge. One metric of competitiveness – **international perception** – shows Japanese brands still generally command higher trust for quality in developed markets, but Chinese brands are improving their reputation steadily, especially in EVs (where some Chinese EVs are considered cutting-edge).

Market Outcomes and Policy: Industrial policy influenced these competitive outcomes. Japan's more laissez-faire approach meant its companies had to earn competitiveness through efficiency and market-driven innovation, which they did in the 1990s (dominating global small car markets, for instance). But as the world pivoted to new tech, Japan's lack of assertive policy (e.g., no major EV consumer subsidies until very recently, no forced phase-out of ICE until 2035 target) may have contributed to Japanese firms being *too comfortable* with hybrids and not moving faster on EVs. The outcome: by the time Japan set a goal of 100% electrified vehicle sales by 2035 (including hybrids), China was already selling millions of EVs *per year*. On the other hand, China's deliberate nurturing of domestic firms (sometimes at the expense of foreign firms' freedom) meant that when technologies matured, Chinese companies were ready to seize both domestic and export markets – a payoff of competitiveness. **Naughton (2021)** noted that China's scale of intervention allowed it to speed up capability building, though with the caveat of unknown long-term efficiency. We can observe that by protecting its home market and subsidizing innovation, China ensured that local firms like

BYD could grow and achieve economies of scale, making them competitive internationally in price and, increasingly, quality. Japan's firms, conversely, had to innovate within a highly competitive global market context without such explicit home advantages (though one could argue Japan's closed domestic market was implicitly a protection, foreign makers find it hard to penetrate Japan, which helped domestic firms maintain volume at home).

Competitiveness in Niche vs. Mass: Another angle is that Japan remains highly competitive in certain niches – e.g. **hybrid vehicle components** (it supplies a lot of hybrid tech globally), high-performance vehicles, and materials (Japanese firms produce advanced materials and components that Chinese firms often use). China's competitiveness is broadening from low-cost segments to higher-end (e.g., some Chinese EVs are positioned as premium now), but it still has limited presence in the luxury segment globally (where German and Japanese brands still dominate). However, given current trajectories, Chinese automakers are starting to encroach even on that (for instance, NIO's cars or the Voyah brand aiming at upscale markets).

Market Outcome Summary: To summarize outcomes: Japan's auto industry in 2024 is still formidable – it has world-leading companies, a strong export presence (though second to China now in volume), and a reputation for quality. But it faces *stagnation in growth* and *the need to adapt* to the new innovation paradigm (EVs, software), where it fell behind in timing. China's auto industry transformed from a domestic-oriented, JV-dominated sector to a globally competitive force, leading in EV deployment and poised to challenge incumbents abroad. This is captured in the striking reversal that **Chinese automakers sold more cars globally than Japanese automakers in 2023**. Such an outcome was unthinkable in the 1990s and underscores the role innovation (fostered by policy) played in reshaping competitive standings.

Mini-Findings – Industry Competitiveness & Outcomes:

- **Global Production & Share:** China grew from ~3% of world auto output in 2000 to ~34% by 2024, becoming the top producer. Japan's share declined from the teens to <10%, as its output plateaued and others (China) expanded. This reflects China's successful capacity build-up under industrial policy and Japan's maturity/saturation.
- **Exports and Brands:** Japan long led auto exports but was overtaken – China exported over 3 million vehicles in 2022 and more in 2023, surpassing Japan. Japanese brands still enjoy stronger global consumer trust, but Chinese brands (especially EV-focused) are rapidly gaining

recognition. Key outcome: Chinese firms are no longer just low-end exporters; they compete in mid-range EV markets globally, a sign of increased competitiveness.

- **Domestic Market Dynamics:** Japanese automakers maintain dominance at home, with foreign firms marginal. Chinese automakers, aided by policy, flipped their domestic market in their favor: local brands now outsell many foreign JVs in China, particularly in the EV segment. Innovation (e.g. better EVs) helped Chinese firms win consumers, validating policy efforts to create "national champions."
- **Competitiveness Gaps:** Japan retains competitive edge in **quality, reliability, and manufacturing excellence**, but lags in some new tech domains (EV software, autonomous driving) where urgent innovation is now occurring to catch up. China's competitive edge lies in **scale, cost innovation, and fast commercialization** of new technologies (batteries, electronics), though some Chinese firms still trail in branding and high-end quality. The divergent innovation paths thus yielded two different competitive profiles: a Japanese industry that is extremely efficient but arguably complacent in disruptive innovation, and a Chinese industry that is bold and fast-moving but still coalescing its global brand stature.

6.5. Policy Implementation & Support Intensity

This final analytical criterion evaluates *how* industrial policies were implemented in each country and the **intensity of government support** provided to the automotive sector. While earlier sections touched on policy tools and their effects, here we focus on the style, consistency, and magnitude of policy intervention. Understanding policy implementation is crucial to explaining **why** innovation outcomes diverged: even with similar goals, the manner and vigor with which policies are executed can lead to very different results. We examine strategic planning, regulatory vs. market-based tools, subsidy scale, institutional coordination, and any course-corrections in policy over time in China and Japan.

Strategic Planning and Vision: China's policy implementation has been characterized by strong **top-down strategic guidance**. The government incorporated the automotive industry (especially future technologies like EVs and intelligent vehicles) into every major national plan. For example, as early as the **10th Five-Year Plan (2001–2005)**, China identified electric vehicles as a priority area. This continued through the **Medium- and Long-Term S&T Plan (2006–2020)** emphasizing "indigenous innovation," and later the sweeping **Made in China 2025** initiative that listed NEVs (New Energy Vehicles) and smart cars among top strategic sectors. These plans set **clear quantitative targets** – e.g. a specific goal for Chinese-brand NEVs to reach 70% domestic market share by 2025, or for key components to achieve 80% local content. Such concrete targets then guided ministries and local governments in implementing supportive measures. In essence, China's implementation style is **directive**: the state not only sets goals but actively marshals resources to hit them, often with detailed metrics.

Japan also engages in planning (e.g. METI's **Automobile Industry Strategy 2020**, and the **Green Growth Strategy 2021** aligning with carbon neutrality goals). However, Japanese plans tend to be **aspirational and consultative** rather than mandatory. For instance, Japan announced that *all new vehicles sold by 2035 should be electrified* (a broad definition including hybrids) as a vision, and set targets for EV charger deployment. These are **policy goals**, but they usually are not backed by hard quotas or penalties for non-achievement in the way Chinese mandates are. Japan's style since the 1990s has been described as focusing on improving *framework conditions* (infrastructure, basic R&D funding, setting voluntary industry targets) rather than issuing orders to industry. This reflects its post-developmental state stance and a preference for industry self-regulation. In implementation, that means Japan relies on **consensus-building** (through industry committees, public-private dialogues) and incremental adjustment of policies. For example, rather than require a certain EV market share, Japan might implement gradually tightening fuel economy standards and let firms decide how to meet them (hybrid, EV, etc.), trusting the market to work it out.

Regulatory Instruments (Sticks vs. Carrots): China has been much more willing to use **hard regulatory "sticks"** alongside carrots. A prime example is the **NEV mandate/credit system** introduced in 2017: it requires automakers in China to earn a certain number of NEV credits (by producing EVs or buying credits) proportional to their production – effectively a quota for EVs. This is analogous to California's ZEV mandate but on a national scale and with teeth – companies that failed to comply faced penalties or had to purchase credits (a cost). As noted, this forced even joint ventures of foreign brands to invest in EV models or risk fines. China also wielded other regulations: it restricted new manufacturing licenses mostly to EV companies at one point (limiting anyone wanting to start a new gasoline car factory), aggressively tightened fuel economy standards, and at city levels, imposed measures like **license plate lotteries that exempt EVs** (making EVs easier to own than petrol cars in big cities). These coercive or incentive regulations created a protected and favorable market for innovation adoption.

Japan's regulatory approach has been **softer**. Rather than mandates, Japan used instruments like **tax incentives** for green cars (reduction of vehicle acquisition and weight taxes for fuel-efficient vehicles). It also implemented *fuel economy and emissions standards*, but typically in line with international norms and not excessively stringent early on. There have been no mandates on automakers to produce a certain technology (no EV quota akin to China's). Instead, Japan leans on industry's cooperation: e.g., the government sets a goal (like CO2 reduction by X% by year Y) and expects automakers to voluntarily contribute, offering support in R&D and some consumer incentives to help. The difference is evident: **China did not hesitate to pick technology winners and enforce their adoption (e.g. pure EVs)**, whereas **Japan allowed hybrids, plug-in hybrids, hydrogen, and EVs all to compete under a broad eco-innovation umbrella**, subsidizing each to some extent but not forcing one path. This more pluralistic, laissez-faire regulation meant Japan's policy was less forceful in steering industry direction – which can be good for not over-betting, but in this case possibly led to underinvestment in pure EVs until it was late.

Financial Support Intensity: As previously hinted, the magnitude of subsidies and incentives is a critical distinction. China's financial support to its auto industry (direct and indirect) in the 2000s–2010s was **unprecedented in scale**. One estimate (Thompson 2024) put total EV-related government spending at **\$231 billion** by the 2010s. Chinese automakers, especially EV startups and state-owned firms, benefited from large R&D grants, subsidized land and loans for factories, and consumer purchase subsidies that made it easier to sell innovative products. For example, for much of the 2010s, a Chinese consumer buying an EV could get substantial subsidies (central and local) that sometimes cut the vehicle cost by 20-40%. Furthermore, local governments often gave **procurement contracts** to domestic EV companies (e.g. for electric buses for city fleets) – effectively guaranteed markets to scale up production. All of this created a powerful financial wind at the back of innovation efforts in China. Notably, even after some subsidies were phased down in 2020–2022, China introduced other incentives like tax exemptions for NEVs and continued R&D funding, showing sustained support albeit shifting from blunt subsidies to more market-like mechanisms (e.g., tradable credits).

Japan's financial support has been an order of magnitude smaller. Government funding for automotive R&D in Japan might come through NEDO or METI programs, but these are relatively modest grants (millions, not billions, of dollars per project). Consumer incentives for green cars in Japan existed – e.g. during 2009–2012, Japan had an "eco-car" subsidy program as part of economic stimulus, offering up to ¥250,000 (a couple thousand dollars) for trading in for a fuel-efficient car, including hybrids. Japan also offers subsidies for EV and hydrogen car purchases (e.g. a fuel-cell vehicle subsidy up to ¥2.5 million per vehicle), but the volume of such purchases was low, and the total budget for these subsidies is limited (a few hundred million USD per year). In part, Japan's huge public debt and political climate against big spending make massive subsidies difficult. Also, Japan possibly felt less need to subsidize its already competitive industry. The consequence is a **support intensity gap**: Chinese firms were effectively operating with a large safety net and boosters provided by the state, whereas Japanese firms had to innovate more on their own dime. While the latter encourages efficiency, the former accelerates growth – and indeed, we saw Chinese EV companies scale quickly under subsidy, albeit not all efficiently (some "subsidy-fishing" occurred, as mentioned).

Institutional Coordination: Implementation also involves how agencies coordinate. China's model is often described as the **"whole-of-government" approach**. Central ministries (MIIT, NDRC, MOST, etc.) work in tandem with provincial governments to execute industrial policy. For automotive innovation, this meant, for example: central government sets NEV mandates and provides funds, local governments compete to host EV startups with additional perks, state banks provide cheap credit, and state-owned utilities build charging infrastructure – a coordinated push. Sometimes different localities overshot (leading to duplication like too many EV makers), but the central government reined it in by tightening standards for EV subsidies (after 2016, they raised technical requirements to qualify for subsidies to weed out low-quality players). Japan's institutional approach is more consensus-driven and fragmented among stakeholders. METI is a key player, but Japanese automakers and parts suppliers are independent and influential; there's a continuous dialogue (e.g. through the Automotive Council) to align on policy voluntarily. For instance, Japan's implementation of safety regulations or new tech standards often involves industry input to ensure feasibility. This leads to **well-calibrated but sometimes slow policy rollout**. For example, Japan's electric charging network expansion has been deliberative – government provided some subsidies for chargers, but left installation largely to private sector and municipalities, resulting in slower growth of the network than in China's centrally orchestrated spree.

Adjustments and Consistency: Over 30 years, both countries had to adjust policies. Japan's industrial policy in autos actually *decreased* in explicitness after the 1980s, consistent through the 90s and 2000s (hands-off), only recently edging towards more active due to EV competition and climate commitments. China's policy evolved from **protectionist learning phase (90s JVs)** to **indigenous innovation drive (2000s)** to **market creation for new tech (2010s EV push)**, and now into a phase of refining support (post-2020 phasing out subsidies and using regulations). Importantly, China showed a willingness to **correct course** when issues arose (e.g., cracking down on subsidy fraud, phasing subsidies to avoid dependency). Japan, too, has had to pivot recently – the very announcement of 2035 electrification goal and greater funding for next-gen batteries in the 2020s shows Japan reacting to the global policy trend and the risk of falling behind. But these responses are relatively late and measured.

In terms of intensity, one could say **China treated automotive innovation as a mission-critical national project**, deploying extraordinary state resources and policy force, while **Japan treated it as an important but primarily private-sector-driven domain**, with the state in a supportive, secondary role. Neither approach is inherently "wrong" – they reflect different political economies – but they led to the divergent outcomes we've chronicled. China's intense approach achieved rapid capacity growth and tech catch-up, but not without inefficiencies and looming questions of sustainability (can the industry stand on its own as subsidies wane? will overcapacity be an issue? etc.). Japan's restrained approach preserved market efficiency and avoided big government expenditures, but arguably at the cost of ceding leadership in some emerging innovations to more aggressive players.

Mini-Findings – Policy Implementation & Support:

- **Policy Style:** China's implementation was **directive and hands-on** – detailed targets in plans (e.g. "70% NEV market share by 2025" goal), mandates like the NEV credit policy, and heavy local-central coordination to build industries. Japan's was **facilitative and hands-off** – it set broad goals (e.g. carbon reduction, electrification by 2035) and supported via incentives, but avoided firm-specific or tech-specific mandates.
- **Support Intensity:** China expended **vast financial resources** (tens of billions annually at peak) to subsidize innovation, far outstripping Japan's spending. Japan provided support (R&D tax credits, consumer subsidies for green cars), but on a modest scale. China's intense support jump-started industries (like EV manufacturing), while Japan's limited support reflected trust in market forces and fiscal caution.
- **Regulatory vs. Market Tools:** Chinese policymakers readily imposed regulations to force innovation adoption (quotas, local content rules, prototyping requirements), plus created protected niches for domestic firms. Japanese policy favored **market-based incentives** (tax breaks, voluntary standards) and global-standard regulations, avoiding heavy-handed intervention. This meant Chinese firms often had no choice but to innovate or lose market position, whereas Japanese firms had more flexibility (which sometimes meant slower change).
- **Outcomes of Implementation:** China's aggressive policy execution was a **catalyst for rapid change**, directly contributing to its surge in innovation outputs and competitiveness – at the

cost of significant public expenditure and some inefficiencies. Japan's moderate approach **maintained stability** and fostered efficient, industry-led innovation, but lacked urgency in new technology adoption, contributing to its relative lag in EVs. In sum, the divergent innovation paths can be traced to these implementation differences: China's "all-in" industrial policy versus Japan's "on the sidelines" government stance in the innovation race.

6.6. Structured–Focused Comparison Synthesis

6.6.1. Scorecard of Criteria: Scoring method and justification

Criterion	China	Japan
Innovation Inputs	9	8
Innovation Outputs	9	7
Industry Competitiveness	7	9
Policy Support	10	6

Figure 6.1. Comparative Innovation Input & Output — Scorecard (Table).
Scale: 0–10 (10 = stronger performance within this study).

This scorecard is a synthetic summary of evidence from Chapter 5. Scores reflect (a) the **current level** shown in the figures and (b) the **direction/speed** of change in the last 10–20 years. Each value is anchored to the relevant figure(s).

- **Innovation Inputs — China 9; Japan 8.**
  Both countries show high R&D effort, but with different profiles: Japan is stable at a high level; China increased strongly over time. Score reflects high levels for both and China's rapid catch-up. (See **Fig. 5.1**; also OECD MSTI.)

- **Innovation Outputs — China 9; Japan 7.**
  China now leads in PCT applications and EV-related outputs; Japan's output is steady but more incremental. Score reflects China's recent outperformance. (See **Fig. 5.2**; also WIPO PCT.)

- **Industry Competitiveness — China 7; Japan 9.**
  China leads on **production and exports**; Japan keeps **legacy strengths** in quality/brand and certain high-end segments. I weight both the scale indicators (production/exports) and the qualitative brand/quality edge. (See **Figs. 5.3–5.4**; OICA; JAMA/CAAM.)

- **Policy Support — China 10; Japan 6.**
  China uses direct, mission-oriented tools (subsidies, quotas, JV rules); Japan applies a lighter,

more selective approach. Score reflects the **intensity and breadth** of instruments. (See State Council/MIIT/METI policy documents.)

6.6.2. Summarized Findings & Causal Chain

Criterion	China — key finding	Japan — key finding	Evidence (Fig 5.x)
Innovation Inputs	Rapid input growth driven by state support; R&D % GDP rose to mid-2%s; deepening supplier capacity.	High and steady firm R&D; engineering strength; slower input growth recently.	Fig 5.1
Innovation Outputs	Surge in EV-related models and PCT filings; global patent leadership in recent years.	Incremental output (hybrids, quality); PCT filings stable/slightly down.	Fig 5.2
Industry Competitiveness	Top in vehicle production and, recently, exports; rising global presence of domestic brands.	Sustained quality/brand leadership; volumes and exports under pressure from new entrants.	Fig 5.3 & 5.4
Policy Support	Direct, mission-oriented policies (subsidies, quotas, JV requirements).	Selective, lighter-touch instruments; reliance on market/firm-led investment.	Policy citations

Figure 6.2. Mini-Findings Matrix Summarizing Comparative Analysis. Each criterion highlights how China and Japan differ: China's rapid, state-fueled input growth vs. Japan's steady high inputs; China's leap to EV outputs vs. Japan's focus on hybrids; China's rise to top producer/exporter vs. Japan's sustained quality leadership; China's aggressive policy intervention vs. Japan's limited support approach.

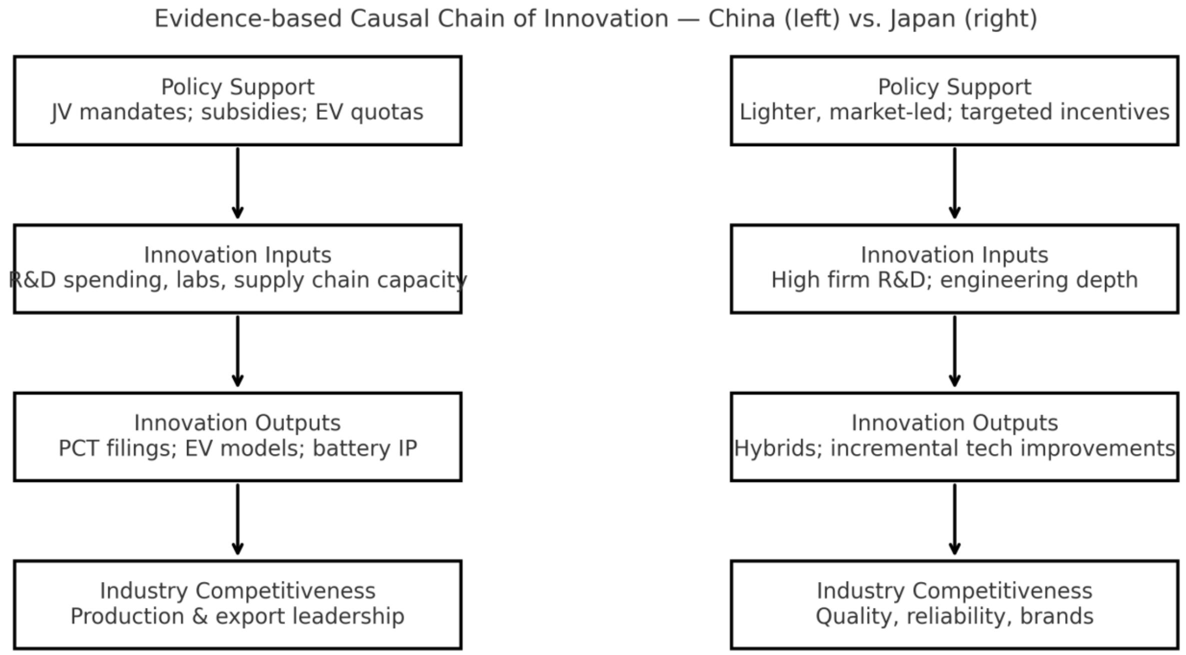

Figure 6.3. Evidence-based Causal Chain of Innovation in China vs. Japan. In China (left column), strong state policy intervention (JV mandates, subsidies, EV quotas) led to rapid increases in innovation inputs, which in turn produced high innovation outputs (patents, EV models), resulting in improved global competitiveness (production & export leadership). In Japan (right column), a light-touch policy approach relied on firms' own R&D, yielding steady but incremental outputs (hybrids, quality improvements) and maintaining competitiveness in traditional areas, yet slower shift to new tech (hence recent competitive pressures).

Bringing together the four criteria, we can causally explain the divergent innovation outcomes. **China's latecomer strategy**, enabled by intensive industrial policy, allowed it to compress decades of innovation into years: massive inputs (R&D, talent) and forceful policies led to an explosion of outputs (patents, EV tech) and ultimately catapulted Chinese firms onto the global stage. **Japan's incumbent strategy**, with incremental innovation and limited policy impetus, maintained excellence in established technologies but led to a slower response to disruptive changes, thus its industry's global position evolved more gradually. The structured comparison confirms that differences in **policy intensity and focus** were a key driver: where Japan fine-tuned a mature system, China overhauled and leapfrogged to build a new one. These findings directly address the research question by showing that China developed automotive innovation largely through assertive state intervention and market creation, whereas Japan did so through sustaining private-sector innovation in a favorable but not activist policy environment. Each approach had distinct outcomes and trade-offs, offering rich lessons for policymakers and industry strategists. The next chapter concludes by summarizing these insights, discussing implications, and suggesting future research directions.

7. Conclusion

7.1. Brief Insight

This study set out to answer the question: *"How have China and Japan developed their innovations in the automotive industry from the 1990s to 2024 through industrial policies?"* After a thorough comparative analysis, we now conclude by summarizing the key findings, directly addressing the research question, and reflecting on broader implications. The experiences of China and Japan offer a stark contrast in industrial policy's role in innovation – a contrast that yields valuable lessons for governments, firms, and international stakeholders. We also acknowledge the limitations of this research and propose directions for future inquiry.

7.2. Summary of Findings and Answer to the Research Question

China and Japan's automotive innovation trajectories over the past thirty years have been **markedly different**. Japan entered the 1990s as a technological leader with a well-established automotive industry; its innovation was driven by corporate R&D and an existing culture of incremental improvement. China, by contrast, was a latecomer with minimal domestic innovation capacity in 1990; it leveraged industrial policy as a tool to catch up and even leapfrog in certain technologies by the 2020s. Our structured comparison in Chapter 6 revealed four major areas of divergence:

- **Innovation Inputs:** Japan consistently invested heavily in R&D (about 3% of GDP) and maintained a skilled workforce, but its input effort grew slowly and was largely private-led. China ramped up from negligible R&D investment to surpass Japan in absolute R&D spending by the late 2010s, thanks in large part to state-driven initiatives and funding. Simply put, **Japan sustained high inputs, China explosively increased inputs** – a foundational difference explaining subsequent outcomes.

- **Innovation Outputs:** Japan's outputs centered on evolutionary improvements (e.g. pioneering hybrid vehicles, excelling in manufacturing processes and quality). China's outputs in recent years have been revolutionary in certain areas – most notably, it created the world's largest EV market and became a global leader in EV and battery technology. By 2024, China leads in volume of patents and new EV models, whereas Japan leads in cumulative know-how like hybrid systems and reliable engineering. Thus, **Japan's innovation output remained strong but incremental, while China's became fast-paced and transformative** in new domains.

- **Industry Competitiveness:** Japan's automakers remain globally competitive (strong brands, significant export presence), but Japan's global market share eroded slightly and it lost some leadership in emerging segments (e.g. EVs). China's industry grew from infancy to the world's largest, now challenging incumbents abroad with cost-competitive and increasingly high-tech vehicles. **China evolved from follower to contender**, achieving top rank in production and export, whereas **Japan maintained a high rank but faced new competitive pressures** and a relative decline in dominance.

- **Policy Implementation:** Here lies one of the clearest contrasts: **China's government actively and intensively steered the industry**, using a mix of protection, subsidies (~$200+ billion in NEV support), and mandates, while **Japan's government took a more laissez-faire and supportive role**, using modest incentives and allowing market forces to guide innovation. China's industrial policy was aggressive and adaptive (adjusting subsidies, setting bold targets), and Japan's was cautious and industry-collaborative. These approaches strongly influenced how rapidly and in what direction each country's innovation progressed.

In direct answer to the research question: **China developed its automotive innovations through assertive and large-scale industrial policies that actively created new technological capabilities (especially in electric vehicles), whereas Japan relied on a more indirect industrial policy approach that supported its companies' incremental innovations without radical intervention.** In China, policies such as enforced joint ventures, targeted R&D programs, and massive subsidy campaigns played a **determinative role** in building an indigenous innovation base. The state's heavy hand helped Chinese firms overcome latecomer disadvantages by providing capital, technology (via JVs), and a protected domestic market to grow in. This led to outcomes like the rapid rise of Chinese EV manufacturers and a surge in domestic patents – outcomes that likely would have been far slower or more limited under pure market forces. Meanwhile in Japan, industrial policy in the automotive sector during 1990s–2024 was more about **setting the stage** (through infrastructure support, setting standards, funding pre-competitive research) and **letting the established firms drive innovation**. Japan's innovations (like the Prius) emerged from the initiative of companies in an environment gently shaped by policy incentives (tax breaks for green cars, etc.), rather than direct state direction.

Therefore, Japan's automotive innovation outcomes – continued excellence in engineering and a steady flow of improvements – can be attributed to a synergy of strong corporate capability and generally favorable but not intrusive policy. China's outcomes – a dramatic catch-up culminating in leadership in certain new technologies – can be causally attributed to purposeful industrial policies that *accelerated* innovation input and output beyond what the nascent market alone would have achieved. This core finding aligns with development literature: China exemplified a "developmental state" (or as Naughton (2021) argues, perhaps an even more extreme variant) mobilizing resources for innovation, whereas Japan in this period leaned towards a more neoliberal or market-oriented stance, after its earlier developmental state era.

However, an important nuance is that not everything is policy-driven: Japan's private sector strengths and China's market dynamics also crucially shaped outcomes. For example, Japanese automakers achieved the hybrid breakthrough largely on their own R&D persistence (with some policy help), demonstrating that innovation can occur without heavy state intervention. Conversely, China's rise isn't solely because of policy – factors like the intense domestic competition among numerous Chinese firms also pushed innovation and efficiency (some companies thrived while others failed, a quasi-Darwinian process encouraged but not wholly controlled by the state). The analysis acknowledges these complexities, but overall, it's evident that **industrial policy was a defining differentiator** in how each country's automotive innovation journey unfolded.

7.3. Policy Implications

Implications for Government Policymakers: For governments aiming to spur industrial innovation, these cases illustrate that there is no one-size-fits-all approach – but the level of commitment and alignment of policy tools to goals is critical. China's example suggests that **active industrial policy can indeed rapidly build domestic innovation capacity** and even achieve global leadership in targeted areas (such as EVs). Policies like substantial R&D funding, protected home markets for new industries, and aggressive adoption incentives can create an innovation ecosystem from scratch. However, China's approach also carries risks: high fiscal costs, potential overcapacity, and tensions in international trade (e.g. other countries have complained about China's subsidies violating fair trade). Policymakers in emerging economies might draw inspiration from China's successes in nurturing a high-tech industry quickly, but they should also heed the importance of eventually phasing into market-based mechanisms to ensure sustainability (as China itself started doing post-2020 by winding down subsidies and using NEV credit trading).

Japan's experience imparts a different lesson: **market-driven innovation, supported by stable institutions, can produce world-class outcomes, but it may not be sufficient when technological paradigms shift**. Policymakers in advanced economies might reflect on Japan's cautious approach – it avoided heavy spending and respected market choices, which worked well while Japanese firms were at the technological frontier (e.g. in hybrids). But when confronted with a disruptive change (the shift to electric and software-defined vehicles), that same cautiousness translated into a slower response, potentially imperiling competitiveness. Thus, for governments of established industries, the implication is to remain vigilant and perhaps more proactive when disruptive innovations emerge, even if the domestic industry is strong. A timely nudge or targeted support in emerging fields (such as EV software, AI for autonomous driving) might prevent the kind of gap that opened between Japan and China in EV adoption. Japan's recent policy adjustments (like bigger subsidies for battery development and forming a consortium for semiconductor chips for cars) indicate recognition of this need.

Another implication is the importance of **strategic focus**: China maintained a clear focus (first catching up in conventional autos via JVs, then jumping to EVs), whereas Japan's policy focus in 1990s–2000s was diffuse (supporting various innovation generally, with an environmental tilt but not a single transformative tech). Countries seeking innovation outcomes may benefit from identifying specific strategic technologies to back (as long as they choose wisely and adjust if evidence suggests a pivot is needed). At the same time, Japan's broader support approach had the benefit of not over-committing to a possibly wrong bet – for example, if battery EVs had not taken off and fuel cells did, Japan would have been better positioned. Governments must balance picking winners with hedging bets. The Sino-Japanese contrast provides a case in point: China picked EVs as winners and it paid off; Japan hedged (hybrids, hydrogen, etc.) which preserved options but also meant losing the first-mover advantage in the one that surged (EVs).

Implications for Industry and Firms: From an industry perspective, these findings stress how crucial it is for firms to **align with or adapt to the policy environment**. Japanese automotive companies benefitted from a stable, low-intervention policy regime, but perhaps became too set in their ways (favoring hybrids, perfecting familiar tech) under that comfort. Now, they are racing to adapt to a global market rapidly embracing EVs – an adjustment that incurs significant cost (for instance, Toyota belatedly investing tens of billions in EV development that competitors had started earlier). The lesson for firms is that even if policy doesn't force change, they must remain agile to global innovation trends, or risk being outpaced by competitors from more proactive environments (like Chinese firms). For Chinese companies, the policy implication is a bit different: they enjoyed strong tailwinds from government support, but they also must prove themselves in open competition as those supports recede. Many Chinese EV startups were nurtured by subsidies; as those taper off and if they venture abroad without protective policies, only the truly innovative and efficient will survive. In recent data, some Chinese EV makers are indeed thriving globally, suggesting the best of them used the policy support period to build genuine competitive strength. Others that relied solely on support may fail. So, firms should use periods of policy support to invest in innovation and efficiency, not just output for output's sake.

Additionally, the interplay of policy and corporate strategy in Japan's case shows the value of **public-private collaboration** in innovation. Japanese firms worked with METI on pre-competitive research (like advanced batteries, AI for automated driving in consortia) – a model that could be emulated in other countries to share risks and knowledge. Even China, where the state largely directed things, is now encouraging more public-private collaboration rather than pure state dominance, as innovation moves to more complex realms requiring private expertise (e.g., autonomous driving standards in China are being developed with input from tech firms, not just by government fiat). The bottom line for industries is that policy can dramatically reshape the competitive landscape, so companies must proactively engage with policy (through feedback, compliance, or strategic use of incentives) rather than operate in isolation from it.

Implications for International Actors: The divergent outcomes also carry implications for international bodies and foreign stakeholders. Trade partners and organizations (WTO, etc.) observe China's heavy subsidization with concern – the rise of China's EV industry, enabled by subsidies and protection, has prompted reactions like the EU's 2023 investigation into Chinese EV subsidies (amid fears of market flooding). Japan's more laissez-faire approach was fully in line with global trade norms and avoided such frictions but perhaps at a competitive cost. This suggests that the international trade regime may need to evolve to address how countries can pursue green and innovative industrial policies (which are globally beneficial, e.g., more EVs for climate) without triggering trade conflicts. It's a delicate balance: encouraging states to invest in innovation for global good, while preventing "subsidy races" that distort markets. The experiences here indicate a need for **international coordination on acceptable support for emerging tech** – something like what exists in aerospace (e.g., WTO cases on aircraft subsidies) might emerge for EVs and batteries.

For foreign companies and investors, these cases highlight the importance of understanding different policy environments. An automaker from the U.S. or Europe operating in China had to adapt to China's NEV rules by forming local partnerships or developing EVs for China (e.g., VW and GM created China-only EV models to meet credit requirements). Those who adapted (and took advantage of Chinese incentives) gained market share; those who didn't (or couldn't due to lack of EV tech) lost out in the Chinese market. In Japan, foreign firms historically struggled not due to explicit protectionism but due to implicit barriers and the high standards of the market; Japan's policies didn't offer special advantages to outsiders, but also didn't actively harm them beyond normal trade tariffs. Now, as Japan opens up to EVs, there may be new opportunities for foreign EV players in Japan if domestic players lag. The interplay of industrial policies thus shapes market entry strategies and competitive dynamics internationally.

7.4. Limitations of the Research

While this thesis provides a detailed comparative analysis, it is important to acknowledge its limitations. First, the scope was confined to the **automotive industry**, which, while significant, may not generalize to all industries. Automotive has unique characteristics (large capital requirements, consumer safety regulations, etc.) and the effectiveness of industrial policy here might differ from, say, semiconductors or pharmaceuticals. Future studies could compare whether the patterns observed hold in other sectors.

Second, the time frame (1990s–2024) allows us to see long-term trends, but it inevitably **misses very recent developments** (post-2024, such as any policy changes or market shifts in 2025) and may understate emerging outcomes. For example, Japan's acceleration on EVs is only just beginning around 2024; our analysis might appear to judge Japan harshly for past slowness, whereas in coming years Japanese firms might catch up. Similarly, China's sustainability in innovation (e.g., quality of patents, global expansion of its firms) will be tested beyond 2024. Thus, our conclusions are based on the trajectory up to 2024 and should be seen in that context.

Methodologically, one limitation is the **reliance on available indicators and sources**. Innovation is a multifaceted concept, and while we used multiple metrics (R&D spend, patents, etc.), some aspects of innovation (like tacit knowledge, design creativity, or software capability) are hard to quantify and compare. For instance, the quality of patents or the actual impact of each innovation wasn't deeply assessed due to scope – a patent count treats all patents somewhat equally, but in reality some patents are far more valuable than others. We tried to qualitatively account for that by discussing notable breakthroughs, but a more granular assessment could be an area for further research.

Data reliability is another issue: statistics from China in particular (on subsidies, R&D, etc.) can sometimes be inconsistent or debated. Multiple sources were cross-checked (academic studies, industry reports) to mitigate this, but there is always a margin of error. The structured–focused comparison method also has an inherent limitation: by focusing on predetermined criteria, we might overlook other explanatory factors. The four criteria were assumed from our framework capture the key differences, but perhaps other factors (like cultural attitudes to risk, or macroeconomic conditions) also significantly influenced innovation outcomes. For example, Japan's stagnant economy in the 1990s (the "Lost Decade") meant less growth opportunities, whereas China's booming economy provided ample revenue to reinvest in innovation. Such context was mentioned in Chapter 5's empirical overview, but our analytical chapters largely attributed differences to policy and innovation system factors, potentially underplaying macroeconomic or socio-cultural influences.

Finally, **causality** in social science is complex. We argue that industrial policy played a major causal role in innovation outcomes, but one must be cautious: correlation is not always causation. Process-tracing have been used (with the evidence chain diagram in Chapter 6) to support causal inferences – for instance, showing how a policy led to increased R&D which led to patents. However, alternative interpretations could be made. Perhaps Japan could have done more policy-wise and still would not match China's EV surge simply because of differences in consumer preferences or resource endowments. Or perhaps China's auto industry would have eventually grown due to market size even without such heavy state intervention (albeit more slowly). We believe our comparative approach controls for many factors and the evidence strongly supports the narrative we presented, but readers should consider the multifactorial nature of innovation.

7.5. Future Research Agenda

Building on this work, several avenues for future research emerge:

- **Comparative Studies with Other Countries:** It would be illuminating to include additional countries in the comparison – for example, South Korea or Germany – to see how their automotive innovation paths under policy compare to China and Japan. South Korea, like Japan, has strong firms and used some industrial policy historically; Germany has a very market-driven approach within EU regulations. Including such cases could further test the conclusions drawn here or add nuance (e.g., perhaps Germany remained competitive without heavy industrial policy due to other factors). A broader comparative study could also examine **East Asian developmental states vs. Western economies** in fostering automotive innovation, enriching the theory on state involvement.
- **Deep Dive into Specific Policy Tools:** Future research could focus on individual policy instruments across countries – for instance, a study on the global impact of EV purchase subsidies or of R&D tax credits in stimulating automotive innovation. We touched on many

tools (subsidies, mandates, etc.) in aggregate; a more granular analysis might quantify which tools gave the best "bang for the buck" in each context. This can help policymakers decide which interventions are most cost-effective.

- **Innovation Quality and Long-term Impact:** As noted, not all innovation is equal. A promising research direction is evaluating the **quality of innovations** emerging from different policy regimes. For example, one could analyze patent citation impact or technological significance of innovations from China vs Japan to see if one approach yields more breakthrough vs incremental innovations. Additionally, examining the long-term sustainability of innovation-driven industries – e.g., will Chinese EV firms maintain global competitiveness once subsidies are gone and more countries produce EVs? Will Japan's firms regain ground as the tech matures? These questions require longitudinal studies going forward.

- **Firm-Level Studies:** While this thesis looked at country-level innovation outcomes, future research might look at firm-level case studies. For instance, comparing a Chinese company (BYD) with a Japanese company (Toyota) in how they each navigated policy and drove innovation could yield rich insights. Firm strategy, organizational culture, and leadership also affect innovation greatly. An interesting angle is how multinational collaborations (like tech partnerships between Chinese and Japanese firms, or joint research projects) are emerging as globalization and electrification push companies to work together despite national policy differences.

- **Beyond Autos – New Mobility Ecosystems:** The automotive industry is itself evolving into a broader mobility and technology ecosystem (with electric, autonomous, connected car technology). Future work could explore how industrial policy is shaping the **autonomous driving or battery industry** in China and Japan. For instance, Japan and China both consider next-generation batteries (solid-state batteries) crucial; comparing their support in that sub-field could be valuable. Similarly, examining policies around AI and data for autonomous vehicles would extend this research into the emerging frontier of automotive innovation.

- **Political Economy and Social Impacts:** Another research frontier is assessing the **political and social dimensions** of these innovation policies. For example, how did domestic political interests and institutions in China vs. Japan enable or constrain these policies? How do citizens and labor forces fare under these innovation pushes (job creation in new tech vs. job losses in traditional sectors)? Understanding the domestic political support or resistance to industrial policy can inform how replicable these strategies are elsewhere.

In conclusion, the story of China and Japan's automotive innovation from the 1990s to today is a compelling chapter in the larger narrative of how states and markets interact to drive technological progress. Japan's trajectory highlights the power of steady, firm-led innovation in a stable policy environment, but also its limitations in times of disruptive change. China's trajectory demonstrates the potential of bold industrial policy to accelerate development and carve out leadership in new sectors, while also reminding us of the importance of efficiency and adaptability. The findings of this thesis contribute to the academic discourse on industrial policy and innovation by providing a detailed, evidence-backed comparison of two distinct models. As the global automotive industry now moves into an electric and autonomous era – one in which both China and Japan will play significant roles – the lessons gleaned here will be of continued relevance to policymakers and industry leaders charting the road ahead.

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