Blending Tech and Industry: Innovation Synergy in the Automotive Sector

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Abstract: *The automotive sector is experiencing a profound evolution in its innovation and value creation. This transformation, fueled by a technological and industrial revolution, represents a crucial shift from relying on isolated breakthroughs to building an ecosystem-driven approach. This synergy has driven a dynamic partnership and sparked a collaborative model across the value chain in which technology and industry evolve in lockstep. In the automotive sector, the fusion of technological and industrial innovation depends on an organic framework anchored by three forces: collaborative networks of multiple agents, direction set by industrial policies and focused initiatives through market-selected key projects, and support from capital markets. To fast-track this deep integration, seamless coordination is key: empowering businesses as innovation hubs, streamlining resource allocation and end-to-end support, and fostering an open, collaborative innovation ecosystem.*

Keywords: *Industrial chain; Innovation chain; Disruptive technology; Innovation-industrial chain synergy*

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1. Introduction

The global technology landscape continues to race, reshaping industries at breakneck speed with rapid technological iteration. Knowledge creation and technological breakthroughs have accelerated, reshaping and expanding the boundaries of innovation. Cross-disciplinary collaboration as well continues to spark a leap from incremental advances to transformative change. Furthermore, new business models and paradigms have begun to emerge rapidly, driving a powerful trend toward the blending of technological and industrial innovation.

By pursuing an innovation-driven development strategy, China has successfully accelerated the transition of lab breakthroughs to global markets. This progress has significantly elevated the nation's standing across global technology, industry, and innovation networks. From foundational research to real-world applications, China has built a world-class innovation ecosystem. Breakthroughs in quantum computing, artificial intelligence (AI), 5G, and new energy technologies have established China as a pivotal engine for global scientific and technological innovation. In 2024, China's R&D spending hit 3.61 trillion yuan—the second highest in the world—with an R&D intensity of 2.68% of GDP, surpassing the EU's 2.11% and nearing the OECD's 2.73%, according to the National Bureau of Statistics (NBS)[1].

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[1] Source: National Bureau of Statistics, "Steady Growth in China's R&D Expenditure – Statistician Zhang Qilong from the Department of Social, Science and Technology Statistics Interprets Relevant Data," January 23, 2025, https://www.stats.gov.cn/xxgk/jd/sjjd2020/202501/t20250123_1958422.html.

The automotive industry, as a key pillar of China's economy, has been at the forefront of this technological innovation and industrial transformation. Integrating technological and industrial innovation delivers core technology breakthroughs, evolves industrial organization, and solidifies ecosystem, thereby strengthening sector-wide competitiveness. As digitalization, smart technology, and green development redefine global industries, the automotive sector's innovation pathways and value-creation models continue to evolve dramatically. Cross-sector collaboration has accelerated this shift, with China's advances in new energy vehicles (NEVs) and intelligent driving, alongside upstream-to-downstream collaboration in the automotive industry and NEV innovation, signaling a major transition in the sector's innovation paradigm.

To unpack the dynamics of technological and industrial innovation, we revisit the evolution of innovation theory in economics. Joseph Schumpeter first systematically proposed the theory of innovation in 1912, describing innovation as "creative destruction" that drives economic progress. Later, Solow's 1956 neoclassical growth model framed technological progress as an external driver of long-term growth. Endogenous growth theories, such as Romer's knowledge spillover model (1986) and Lucas's human capital model (1988), brought innovation drivers such as knowledge, technology, and human capital into the equation, revealing the externalities of knowledge accumulation and educational investment, and thus becoming the core framework for explaining long-term growth. More recent theories, from technological innovation economics (Enos, 1962; Freeman, 1974) to institutional innovation (North, 1971; Ruttan, 1987), open innovation (Chesbrough, 2003; von Hippel, 2005), and innovation ecosystems (Edquist, 2001; Chesbrough, 2006), have deepened our understanding of innovation's complex dynamics.

In this context, technological innovation encompasses two key aspects: original scientific research rooted in knowledge accumulation and cognitive paradigm shifts, and the translation of such scientific findings into practical production capabilities, including new methods, technologies, processes, operational and management models, as well as product upgrades and new product development. Industrial innovation, driven by technological advances also involves restructuring industries through technological breakthroughs, new business models, and ecosystem redesign, creating or redefining industries for greater efficiency, competitiveness, and sustainability. Technological innovation fuels industrial innovation, and industrial innovation provides the real-world applications and market mechanisms that bring technological advances to life. The two are deeply interconnected, each amplifying the other and possessing a natural propensity for integration.

Drawing on the automotive industry's innovation practices, this paper focuses on four key areas: 1) the scenarios of mutual promotion between technological and industrial innovation; 2) the two-way empowerment of innovation and industrial chains; 3) the institutional mechanisms of these chains' integration; and 4) the systemic innovations required for deeper fusion. Our aim is to offer insights for modernizing the automotive industry system in China.

2. Disruptive Technologies that Fuel Automotive Innovation

Global innovation and industrial chains continue to experience accelerated restructuring, with mutual empowerment between them. From breakthroughs in basic and applied research to the leap from lab to market, diverse innovation chains continually power industrial progress. Simultaneously, adjustments and upgrades within the industrial chain, such as changes in industry structure and ecosystem building, in turn create a reverse feedback effect that induces technological progress and optimizes technical pathways. This process forms a dynamic "tech-industry" adaptation mechanism and an interlinked "chain-style collaboration" paradigm. Through the chain reaction generated between the innovation and industrial chains, technological and industrial innovation naturally fuse.

As derived from Stokes & Pasteur's Quadrant (1997), pure applied research and use-inspired basic research (i.e. the Edison Quadrant and Pasteur Quadrant) are types of technological innovation that drive knowledge diffusion and industrial commercialization. General purpose technologies born from this foundational research, such as generative AI and quantum technology, possess strong permeability. Their resulting knowledge diffusion and spillover effects can thus shatter traditional industrial boundaries, sparking sweeping changes in critical common technologies across numerous sectors (Li, 2025). At its heart, innovation is about new knowledge. Historically, knowledge flowed linearly along the innovation chain. But as knowledge activities and innovation methods grow increasingly complex, mechanisms like feedback, iteration, and cross-sector integration are driving the evolution of innovation models toward nonlinear and networked structures. Knowledge and technology along the innovation chain are accelerating their penetration and conversion through integration with industry, thereby promoting the optimization and upgrading of the industrial chain.

China's breakthroughs in materials, core components, and digital technologies, from graphene and carbon fiber to industrial software, high-end chips, 5G, and artificial intelligence (AI), have begun to fuel a profound transformation in the automotive industry. Disruptive technologies in particular steer both the direction and depth of automotive innovation. These game-changers operate on two fronts. First, the restructuring of production factors by disruptive technologies, think cloud computing and smart driving systems, generates new technological innovations. These new technology combinations ripple through the entire automotive value chain in broader and deeper ways, even leading to its extension or disaggregation. Second, the revolutionary and pervasive nature of disruptive technologies smashes old industry boundaries, giving rise to fresh business models, ecosystems, and competitive arenas. The NEV sector is entering a new phase of transformation, driven by the mass production of solid-state batteries, the rise of advanced intelligent driving systems, and the evolution of smart cockpits from human–machine interaction to emotional symbiosis. Overall, the fusion of technological and industrial innovation in the automotive sector has unfolded across several interconnected scenarios: the industry reshaping driven by powertrain upgrades, the green transformation propelled by green technology applications, the smart manufacturing enabled by digital technologies, and the auto industry transformation led by intelligent driving technologies. Together, these trends showcase the vibrant, multifaceted ways in which technology and industry have merged in this era of disruptive innovation.

2.1 Power Battery Technology and Green Tech in New Energy Vehicles

Disruptive technological breakthroughs in the new energy sector have catalyzed the emergence of the NEV and power battery industries, driving the global transition toward sustainable energy. Power batteries, the heart of NEVs and a hotbed of automotive R&D, have created a trillion-yuan market. In 2024, Chinese companies dominated this arena, with six ranking among the world's top ten in battery installations and claiming a commanding 67.1% of the global market[2], according to SNE Research. China's strides in solid-state batteries and hydrogen fuel cells are particularly critical, as their technological advancements directly determine the automotive industry's competitiveness and the viability of its industrial innovation trajectory.

Compared to traditional lithium-ion batteries, solid-state batteries offer a significant leap in energy

[2] Source: China Industrial News Network "2024 Global Power Battery Installation Ranking Released: CATL Retains Top Spot, Market Share of Japanese and Korean Companies Shrinks," Feb 14, 2025, https://www.cinn.cn/p/375288.html.

density, safety, and charging performance. For instance, CATL's prototype solid-state battery has a capacity of 500 Wh/kg, more than double the energy density of mainstream liquid lithium batteries, potentially enabling vehicles to exceed 1,000 km in range. Crucially, its sulfide-based solid electrolyte is stable above 400°C and fundamentally eliminates the risk of thermal runaway seen in conventional batteries[3]. As researchers overcome challenges at the electrolyte-electrode interface and refine materials and manufacturing processes, the industrialization of solid-state batteries remains poised to unleash major technological change across NEVs and related industries.

Green technologies are the backbone of the NEV industry's sustainable growth. Their continuous innovation and widespread adoption not only drive further innovation across the supply chain but also substantially cut carbon emissions, supporting China's "dual-carbon" goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. Hydrogen energy, as a zero-carbon carrier, and fuel cell technologies deliver high efficiency and zero emissions. Systematic integration innovation in core technical areas like proton exchange membranes, catalysts, and bipolar plates has significantly boosted power density and battery system lifespan. From hydrogen production via water electrolysis to solid-state storage and fuel cell applications, China's hydrogen ecosystem continues to thrive. By late 2024, the country accounted for 51% of global renewable-energy-based hydrogen production capacity, per the *China Hydrogen Energy Development Report* (2025). Furthermore, over 28,000 hydrogen fuel cell vehicles were deployed in China by the end of 2024, according to the *2025-2030 China Hydrogen Fuel Cell Vehicle Industry Report*.

2.2 Digital Tools and Robotics in Smart Automotive Manufacturing

The manufacturing process serves as the central nexus of technological integration. In recent years, Chinese automakers have harnessed the momentum of digital technology and industrial robotics to significantly enhance innovation, primarily by optimizing processes, integrating systems, and enhancing product and service offerings.

Digital technologies are rapidly penetrating automotive manufacturing, significantly contributing to the optimized allocation of factors and the reengineering of production workflows. The sector has undergone a systemic adjustment in production organization, widely adopting automated lines and industrial robots to achieve production automation. Simultaneously, digital twin technology, virtual models of real-world processes, has enabled real-time monitoring and optimization of production. In NEV manufacturing, for instance, digital twins allow companies to simulate and perfect the entire production process, catching potential issues before they arise. This digitized approach not only cuts costs and conserves resources but also boosts overall production efficiency. For example, Volkswagen uses virtual simulations to streamline production line scheduling, significantly increasing equipment utilization and reducing per-vehicle production time. Similarly, SERES has built a fully integrated system from materials R&D to vehicle assembly by using digital twins to achieve full automation of key processes and round-the-clock monitoring.

Industrial robots are now a cornerstone of NEV manufacturing. From precision component machining to final assembly, they excel at high-accuracy, repetitive tasks, elevating both efficiency and quality. In body welding, for example, robots deliver pinpoint accuracy, improving both weld quality and speed. Paired with sensors and vision systems, they adapt to varied tasks to handle the dynamic demands of modern manufacturing.

[3] Source: Toutiao "Energy Density 500Wh/kg! Countdown to Mass Production of Solid-State Batteries," February 24, 2025, https://www.toutiao.com/article/7474773929643622950/.

Furthermore, the industrial Internet platform ties the process together, effectively integrating automotive manufacturing workflows to enable seamless connectivity and data sharing across the value chain. Manufacturers can track suppliers' progress and quality instantly, sharpening production planning and scheduling. This platform also serves as a crucial hub for collaborative innovation, connecting automakers with suppliers to drive ecosystem-wide advancements. Finally, the application of blockchain technology in the automotive supply chain can boost efficiency and trust by enabling component traceability and innovative supply chain financing models.

2.3 Smart Driving Technology and the Automotive Industry's Intelligent Transformation

Cutting-edge technologies like big data, AI, and 5G are fast-tracking the automotive sector's technological upgrade. Their deep integration with vehicle technology has driven the industry's transformation toward distinct intelligent and connected features. The intelligent mobile space is redefining the car—fueling breakthroughs in smart, connected NEVs.

NEVs are equipped with various sensors, such as LiDAR, cameras, and millimeter-wave radars. Supported by chip R&D and algorithm iteration, multimodal large models process and analyze real-time environmental data to issue decisions and control commands. Centralized Electronic/Electrical Architectures (EEAs) streamline data handling and information exchange, greatly enhancing the performance of smart driving systems and accelerating the realization of advanced autonomous driving. For instance, NIO's Shenji NX9031 chip, the company's first automotive-grade 5 nm high-performance smart driving chip, has successfully taped out. It features over 50 billion transistors and may deliver computing power in excess of 1,000 TOPS, enabling Level 4 autonomy[4]. Similarly, Xpeng's Turing chip is capable of running a 30-billion-parameter AI model on the edge, offering three times the computational power of current mainstream chips (Lv, 2025). Furthermore, industry players such as Huawei have also increased their strategic deployment of end-to-end technology, accelerating the shift from advanced driver assistance systems (ADAS) to high-level smart driving.

3. Automotive Industry Restructuring Drives Technological Breakthroughs

The global automotive industrial chain has shifted from a traditional mechanics-focused model to a seamless blend of smart electronics. New energy vehicles (NEVs) and intelligent connected vehicles (ICVs) are leading the charge, with a relatively complete industrial chain already taking shape. The industry's supply chain is more than just a platform for applying new tech; it is now a key driver of innovation itself. The NEV supply chain drives a cohesive innovation network by addressing technology needs that arise from market pain points, building innovation networks among industrial chain players, and enabling dynamic technological iteration from individual breakthroughs to system upgrades. Leading firms leverage their organizational strengths, partner across industries, and use real-world data from widespread adoption to drive innovation from single breakthroughs to comprehensive system upgrades.

3.1 Tackling Core Tech by Addressing Automotive Market Pain Points

A key driver of innovation in automotive is the feedback loop between OEMs and suppliers. This transforms consumer pain points into clear R&D goals, creating a seamless cycle from market demand

[4] Source: Phoenix News "NIO IN 2024 Innovation Technology Day: NIO's AI-Native Technology Leads the Future," July 27, 2024, https://auto.ifeng.com/c/8bZBhRoUfUl.

to innovation.

The rise of NEVs and the push for smarter vehicles have shifted focus from traditional mechanics to user-centric features such as autonomous driving, smart cockpits, and better electric range and charging speed. These demands have spurred faster R&D in critical tech areas. For instance, the call for advanced driver assistance systems has led automakers and chipmakers to team up on high-performance System-on-Chip (SoC) solutions. Likewise, the drive for lighter vehicles with longer ranges has pushed materials suppliers and battery firms to co-develop advanced aluminum alloys and solid-state batteries.

Tighter collaboration across the automotive supply chain, from upstream suppliers to downstream manufacturers, has sharpened the flow of demand, turning scattered market needs into shared tech targets. This has in turn boosted both innovation speed and real-world application. For instance, automakers chasing affordable, high-performance electric drivetrains work with e-drive suppliers and materials firms to create tailored solutions for mass production across multiple models, cutting costs and boosting efficiency. This cross-chain collaboration ensures that tech advances remain grounded in real-world market needs, driving continuous innovation aligned with industry demands.

3.2 Building Collaborative Innovation Networks across the Automotive Supply Chain

As the automotive industry embraces digital and intelligent transformation, companies across the supply chain have begun to organize through major-player leadership and multi-entity embedding to form innovation consortia, shifting technological breakthroughs from single-enterprise efforts to networked collaboration.

Leading automakers anchor these ecosystems, acting as organizers of the innovation chain by leveraging their accumulated technical knowledge and market clout. They not only set technical standards and share market insights, but also empower smaller suppliers with technical training and management support, creating a ripple effect where industry giants lift the entire chain toward overall advancement. For instance, SERES has pioneered a “1+1+N” model: one lead company, one core supplier, and multiple supporting firms to build a collaborative network. To do this, SERES has partnered with over 30 parts makers in Sichuan and Chongqing to tackle key technical hurdles, including CATL’s Yibin factory (batteries), Chengdu Lianzhou Technology (prototyping materials), and Chengdu Jiarun (body assemblies). In product R&D, SERES blends materials science, electronics, and vehicle systems to push advancements in key areas such as lightweight materials and smart cockpit technologies across the entire supply chain[5].

As Intelligent Connected Vehicles (ICVs) grow more complex, the automotive industrial chain has begun to integrate external innovation entities, such as those from semiconductors, software, and AI, to drive technical innovation through deep cross-domain embedding. For instance, Leapmotor has teamed up with Qualcomm at the chip definition stage to overhaul vehicle architecture. Leveraging its self-developed “Clover” central domain control system (which integrates SoC and MCU boards), Leapmotor requested a single chip to support both smart cockpits and assisted driving. Qualcomm responded by optimizing its 4 nm 8650 chip for automotive applications and globally launching a dual 8797 chip solution with 640 TOPS of computing power per chip. This cross-sector collaboration moves beyond

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[5] Source: Chongqing Development and Reform “Seres Empowers with Digital Intelligence, Building a Sichuan-Chongqing Innovation and Industrial Chain Cooperation Ecosystem – Accelerating the Construction of a Main Hub for the New Energy Vehicle Industry,” April 18, 2025, https://mp.weixin.qq.com/__biz=Mzg3NzcyNTU2OQ.

the traditional linear supply chain (from OEMs to Tier-1 and Tier-2 suppliers). By uniting carmakers, chipmakers, and software developers around shared scenarios—from computing power to algorithm design—it creates a dynamic innovation network that drives integrated technological progress[6].

3.3 Real-World Use Fast-Tracks Automotive Tech Breakthroughs

The success of new technologies hinges on application scenarios that are characterized by diversity, scalability, synergy, and uncertainty and serve as critical engines for verification and demand validation; they are the crucible where innovations progress through the "engineering-to-industrialization" cycle to build a robust ecosystem (Fang & Li, 2024). In the automotive world, widespread use and constant feedback fuel a powerful cycle of validation, data collection, and optimization that quickly matures technology and sparks new demands. This creates a positive feedback loop between industry and tech, fostering the spiral evolution of science from the lab to the market and back again.

The automotive industrial chain, with its advanced manufacturing capabilities and broad market reach, serves as a robust proving ground for technological innovation. Large-scale deployment accelerates both technological maturation and commercialization. Additionally, smart vehicles generate vast amounts of user data such as driving habits, cockpit preferences, and usage patterns that power data-driven innovation. These insights pinpoint potential consumer needs, providing precise guidance for technological upgrades. Take Leapmotor's "Clover" architecture, rolled out across multiple models for example. It demonstrated the engineering feasibility of the centralized domain control system, with user feedback driving further refinements and boosting integration. Its smart cockpit, powered by dual AI large models and Qualcomm's 8295 chip, uses voice and usage data to optimize algorithm response speed and personalize recommendations. Similarly, SERES' Phoenix Intelligent Factory, with over 1,000 collaborative robots, has slashed production time by 30% and reduced the defect rate to under 1%, an accomplishment that confirmed the "Magic Cube" platform's reliability for pure electric, range-extended, and hybrid systems. On-road tests of L3+ driver-assistance systems have accumulated over 1 million kilometers of driving data, laying the groundwork for expanding the capabilities of future advanced intelligent driving systems[7].

4. Institutional Mechanisms that Drive Integrated Innovation

At the heart of the deep integration between technological and industrial innovation lies a multidimensional and interlinked institutional framework built on a model of chain-wide synergy across the industrial chain. This systemic framework is guided by industrial policy and market-driven selection, centered on multi-stakeholder collaborative innovation, and supported by capital-market mechanisms. Through close cooperation among industry, academia, and research institutions, it harnesses institutional strengths, scenario-driven applications, and "patient" capital to foster original and disruptive technological breakthroughs, drive industrial transformation, and open new frontiers of innovation.

4.1 Policy Innovation: Providing Institutional Support for Innovation Integration

In recent years, China has implemented a comprehensive range of industrial policies to accelerate

[6] Source: People's Daily Online "In the Era of Automotive Intelligence, How Chinese Automakers Are Restructuring the Chip Innovation Chain," June 30, 2025, https://mp.weixin.qq.com/s?__biz=MjM5NzI3NDg4MA.

[7] Source: Chongqing Development and Reform "Seres Empowers with Digital Intelligence, Building a Sichuan-Chongqing Innovation and Industrial Chain Cooperation Ecosystem – Accelerating the Construction of a Main Hub for the New Energy Vehicle Industry," April 18, 2025, https://mp.weixin.qq.com/__biz=Mzg3NzcyNTU2OQ.

the growth of its new energy vehicle (NEV) industry. First, strategic planning has been employed to align industrial development with national objectives. Landmark initiatives such as the *Automobile Industry Adjustment and Revitalization Plan*, the *Energy-Saving and New Energy Vehicle Industry Development Plan (2012-2020)*, the *Medium- and Long-Term Development Plan for the Automobile Industry*, and the *New Energy Vehicle Industry Development Plan (2021-2035)* have collectively charted a clear roadmap for sustainable, long-term progress. Second, China's dual-credit policy sets both corporate average fuel consumption credits and NEV credits, encouraging automakers to strengthen R&D investment and accelerate technological upgrading. As a result, China's NEV market penetration surged from 1% in 2015 to 35% in 2024[8], during which time the country also established the world's most comprehensive charging infrastructure network. Third, a series of pilot initiatives have steadily advanced systemic innovation. These include programs promoting the full electrification of public-sector fleets, battery-swapping pilot projects, NEV-grid integration, automotive safety sandbox regulation, and pilot projects for Intelligent Connected Vehicle (ICV) access and Vehicle-Road-Cloud Integration (China Automotive Technology & Research Center et al., 2024). A striking example is Beijing's High-Level Autonomous Driving Demonstration Zone, launched in Yizhuang in September, 2020. The zone has developed a city-scale test platform designed to explore economically viable vehicle-road-cloud integrated solutions and to accelerate the large-scale deployment of Level-4 and higher autonomous driving systems, setting a benchmark for urban intelligent mobility nationwide[9].

4.2 Market Demand: Unlocking Application Scenarios and Enabling Technological Response

Market forces are a central mechanism that links technological and industrial innovation. They play a dual role: driving innovation through demand-oriented application scenarios and promoting strategic technological collaboration throughout iterative development. For instance, growing consumer demand for advanced mobility and entertainment has pushed NEV makers to ramp up R&D on smart cockpits. The focus has shifted from piling on functions to delivering scenario-based intelligent services, giving rise to what has been described as an "intelligence involution": overly fierce competition in incremental smart upgrades. Li Auto's Mind GPT, a multimodal AI model built on its self-developed Task Former architecture, supports dialect recognition, flexible commands, concise interaction, and always-on, wake-word-free operation. China's position as the world leader in NEV production and sales for ten consecutive years has compelled upstream segments such as battery materials and intelligent driving to achieve technological breakthroughs themselves. Furthermore, joint ventures have reshaped industry dynamics. In response to rising market demand, international automakers have invested in Chinese companies and co-developed smart electric vehicles. Many have formed joint ventures to leverage Chinese partners' first-mover advantages and localized supply networks and to integrate domestic intelligent-electric technologies to launch new NEV brands. Some have even reverse-exported these products to global markets, capitalizing on China's cost efficiencies and mature supply chains. In doing so, international brands have "reverse-leveraged" local enterprises to accelerate their own electrification and intelligent transformation.

4.3 Collaborative Innovation among Core Stakeholders: Building Industrial Consortia

The core function of the industrial innovation chain is to connect two key systems, knowledge

[8] Source: China Automotive Technology & Research Center et al. *China New Energy Vehicle Industry Development Report* (2024), 2024.
[9] Source: Beijing Municipal People's Government Website "Smart Transportation Event Explores Future Mobility," September 10, 2024, https://www.beijing.gov.cn/ywdt/gzdt/202409/t20240910_3806365.html.

creation and technological innovation. Compared to isolated technology transfer or start-up activities, Industry-University-Research (I-U-R) collaboration is better suited to building a resilient and integrated innovation chain (Hong, 2019) because such collaboration seeks to bridge knowledge gaps, dismantle platform silos, and overcome scenario constraints. Through joint R&D, participants share resources and outcomes, enhancing efficiency while reducing costs and risks. With the rise of industrial intelligence driven by artificial intelligence and the expanding smart economy, advanced technologies and data have accelerated the transformation of existing industrial models and nurtured new pillar sectors. In this context, leading technology firms or "chain leaders" within industrial ecosystems have taken the initiative in forming and steering innovation consortia. These alliances advance the integration of intelligent technologies with industry through scenario-based applications, generating a self-reinforcing "scenario flywheel" of innovation, in which real-world applications continuously feed data back into technological progress (Yin et al., 2025). For instance, the China Society of Automotive Engineers has led the establishment of an innovation consortium that unites enterprises, universities, and research institutes to achieve breakthroughs in key fields such as solid-state batteries and intelligent driving. Furthermore, major industry players have deepened strategic collaboration for both technological problem-solving and technology diffusion and adopted cross-sector alliances to integrate innovation resources. Huawei, for example, has expanded its "Huawei Ecosystem Alliance" through various technology access models, including its HI (Full-Stack Intelligent Vehicle Solution) and the Harmony Intelligent Mobility Alliance (HIMA), in partnership with automakers such as BAIC and Changan.

4.4 Patient Capital: Reducing Risks in Innovation Integration

Technological innovation, especially of an original or disruptive nature, often requires years, sometimes decades, to progress from basic research to industrial application. Similarly, industrial transformation and structural upgrade demand sustained investment and entail long, uncertain payback periods, making the entire process inherently high-risk. The cultivation and growth of patient capital, defined as long-term, risk-tolerant investment, are therefore essential. Such capital provides enterprises with full-lifecycle and relay-style financing, ensuring stability and sustainability throughout the journey from scientific exploration to industrial value creation. To date, private equity and venture capital have invested in around 90% of companies listed on the STAR Market and the Beijing Stock Exchange, and in more than half of those on the ChiNext Market. Government-guided funds play an equally crucial role in China. For example, the Changzhou New Energy Industry Fund of Funds directs private capital toward key fields such as NEV core components and hydrogen energy, strengthening and extending supply chains. Likewise, the Chongqing Industrial Investment Fund of Funds has applied a patient capital model to support SERES in its transition to smart, connected vehicles, advancing battery R&D and the construction of its super factory.

5. Systemic Synergy Recommendations to Drive Deep Innovation Integration

Promoting the deep integration of technological and industrial innovation in the automotive sector requires systemic synergy among diverse resources and stakeholders. Efforts should concentrate on three fronts: empowering enterprises as innovation leaders, optimizing the allocation of innovation resources and full-cycle service support, and fostering an open and collaborative innovation ecosystem.

5.1 Empowering Enterprises as Core Innovators and Enhancing Collaborative Innovation

Enterprises are the primary drivers of innovation since they are the most capable of rapidly sensing market demand and translating technological potential into real-world applications. Their innovative capacity largely determines the depth of integration, making them key micro-level actors in the innovation process. Achieving deep integration between technology and industry therefore requires fully mobilizing the innovative potential of both automotive and technology enterprises while also strengthening the leadership role of industry pioneers. For instance, BYD has opened its battery technology standards, inviting suppliers such as CATL to participate in cell design, creating an innovation pathway characterized by "technology definition, industrial collaboration, and market validation". First, efforts should focus on cultivating leading technology enterprises in automotive-related fields. According to South Korea's SNE Research, CATL, a global leader in power batteries, holds a 37.9% share of the world's electric vehicle battery market, with its technological innovations driving the expansion of the NEV sector. In other progress, Huawei has enhanced the intelligence of connected vehicles through its full-stack solutions in vehicle networking and smart driving. Second, it is vital to strengthen specialized, refined, distinctive, and innovative SMEs across the automotive industry's value chain. Specific policy measures should include expanding fiscal incentives and financing support for SMEs engaged in technological breakthroughs and commercialization, encouraging capable private firms to undertake key R&D tasks in areas such as artificial intelligence and new energy, and supporting SMEs in forming innovation consortia with industry leaders to jointly tackle critical technologies such as power batteries, automotive-grade chips, and intelligent driving systems.

5.2 Strengthening Technology Commercialization to Bridge the Lab-to-Production Gap

The transformation of scientific innovation into productive capacity, commonly referred to as technology commercialization, spans multiple stages, including technological breakthroughs, technology transfer, and market deployment. This process relies on key intermediaries such as pilot testing platforms and proof-of-concept centers to translate laboratory research into scalable industrial applications. To bridge existing bottlenecks and disconnects, it is essential to build a full-chain service system for technology commercialization that links "technology brokerage and matching, joint R&D, and industrial implementation" across laboratory, pilot, and mass-production stages. First, efforts should focus on reinforcing basic research. Policymakers and industry leaders need to increase investment significantly in fundamental studies related to NEVs, particularly in critical areas such as battery materials, intelligent driving algorithms, and electronic–electrical architectures. Collaborative initiatives between enterprises, universities, and research institutes are vital to strengthening China's capacity for original innovation in NEV technologies. Second, greater emphasis must be placed on technological integration. Stakeholders across the automotive and technology sectors should advance the deep convergence of new energy systems, intelligent driving, electronic architectures, and software technologies to create new functional products and application scenarios. For instance, integrating intelligent driving systems with advanced electronic architectures can enable more sophisticated vehicle control and real-time information exchange. Third, the pace of industrialization should be accelerated. Governments at all levels, enterprises, and research institutions should deepen cooperation by jointly establishing public service platforms for industrial technology development, thereby expediting the commercialization of NEV innovations. One notable example of this already in place is the Intelligent and Connected Vehicle Laboratory jointly established by Chongqing University and Changan Automobile, which has successfully developed an L4-level autonomous driving system whose key algorithmic performance indicators rank among the world's best. In addition, policymakers should promote cross-industry and cross-sector standard coordination to advance the formulation of new standards for materials, processes, and products, as well as the mutual recognition of international standards.

5.3 Fostering an Open Innovation Ecosystem to Leverage Local and Global Potential

The deep integration of technological and industrial innovation must avoid "closed-door development" and instead coordinate domestic and international resources. By establishing an open innovation ecosystem rooted locally and globally oriented, China can enhance its automotive innovation capacity through cross-border collaboration and the export of technical standards. First, industrial innovation alliances should be established. Automakers should partner with component suppliers, energy companies, and information and communication technology (ICT) firms to form collaborative consortia. These alliances strengthen cooperation and facilitate joint R&D across upstream and downstream enterprises along the value chain. Second, emerging industrial ecosystems should be cultivated. Policymakers and industry leaders should actively foster new sectors related to NEVs, such as intelligent connected vehicle services, NEV recycling and reuse, and specialized NEV financial services. These complementary ecosystems amplify innovation and support sustainable industry growth. Third, international technology collaboration should be deepened. By engaging in global industrial partnerships, China can strengthen scientific and technological exchanges and strategic cooperation with overseas NEV manufacturers, universities, and research institutes. By integrating more deeply into global networks, China is poised to play a greater role in shaping international standards for advanced automotive technologies.

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