汽车产业科技创新与产业创新融合机理与系统性协同

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摘　要：伴随着新一轮科技革命和产业变革向纵深发展，以及产业创新从点状技术突破转向链式生态重构，汽车产业的创新路径和创新成果价值转化正在发生重大改变。在人工智能、新能源技术等颠覆性科技推动汽车产业创新的同时，汽车产业重构引致创新链向系统能力升级跃迁，二者相互赋能、共生演进，形成了以“技术—产业”动态适配为特征的“链式协同”范式。汽车领域科技创新与产业创新的融合机制主要体现为以产业政策和市场择优攻关为指引、多主体联合创新为核心、资本市场为保障的有机架构。对此，通过强化企业创新主体地位、优化创新资源配置与全链条服务保障、构建开放创新生态等的系统性协同，加快推进汽车产业科技创新与产业创新的深度融合。

关键词：产业链；创新链；颠覆性科技；链式协同

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一、引言

当前全球范围内科技领域正在经历快速的技术进步和技术更迭，知识创新和技术演进速度大幅提升，创新环节的边界不断突破与重构，交叉融合趋势日益显著，推动科技创新从量的积累到质的跃升。与此同时，新模式、新业态层出不穷，新的产业形态不断涌现，并呈现出科技创新和产业创新融合发展的趋势。

近年来，我国深入实施创新驱动发展战略，加速推进新兴技术从实验室突破到走向全球市场，在全球科技创新以及产业链创新链中的地位显著提升，形成了全球领先的创新体系和创新生态，特别是在量子计算、人工智能、5G通信、新能源等领域取得突破性进展，成为全球科技创新的重要引擎。国家统计局数据显示，2024年我国全社会研究与试验发展（R&D）经费投入达3.61万亿元，其投入强度（占GDP比重）为2.68%，超过欧盟国家平均水平（2.11%），接近OECD国家平均水平（2.73%）[①]。

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① 资料来源：国家统计局“我国研究与试验发展（R&D）经费投入稳步增长——国家统计局社科文司统计师张启龙解读相关数据”，2025年1月23日，https: //www.stats.gov.cn/xxgk/jd/sjjd2020/202501/t20250123_1958422.html。

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汽车产业作为国民经济的重要支柱产业，一直以来都是技术创新和产业变革的前沿领域。技术创新与产业创新的深度融合，不仅推动汽车产业在关键核心技术领域取得突破，还促进了汽车产业组织形态优化和生态系统完善，从而提升汽车产业竞争力。伴随着全球正在经历的以数字化、智能化、绿色化为特征的产业变革，汽车产业的创新路径和创新成果价值转化形式已发生重大改变，产业间的交叉融合正在加速汽车产业重构。尤其近年来我国汽车产业在新能源技术、智能驾驶技术等前沿领域的科技创新取得了一定的突破，新能源汽车产业创新以及汽车产业链上中下游的协同创新反映了汽车产业创新范式的重大转型。

为了更好理解科技创新和产业创新的概念及内涵，简要回顾经济学中创新理论的形成和演化。熊彼特于1912年首次系统提出创新理论，指出创新是“创造性破坏”的过程，强调创新对经济发展的革命性意义。此后，索洛提出的新古典增长模型（Solow, 1956）将技术进步视为外生变量，认为长期经济增长仅依赖外生技术进步。以罗默的知识溢出模型（Romer, 1986）和卢卡斯的人力资本模型（Lucas, 1988）等为代表的内生增长理论则将知识、技术、人力资本等创新要素内生化，揭示了知识积累以及教育投资的外部性，成为解释长期增长的核心框架。与此同时，技术创新经济学（Enos, 1962；Freeman, 1974）、制度创新理论（North, 1971；Ruttan, 1987）、开放式创新范式（Chesbrough, 2003；von Hippel, 2005）、生态创新系统理论（Edquist, 2001；Chesbrough, 2006）等前沿创新理论相继出现并持续演进。

结合创新理论，可以认为，科技创新既包括知识积累、认知范式转换带来的原创性科学研究，也涉及将科学发现转化为实际生产能力，通过创造和应用新方法、新技术、新工艺，采用新的生产方式和经营管理模式，对现有的产品和服务进行改造升级，以及创造新的产品和服务。产业创新则是在技术创新驱动下的产业形态变革，通过技术突破、模式变革和生态重构，形成新的产业形态或重塑传统产业格局，推动产业体系向更集约高效、更强竞争力和更可持续方向发展。从相互关系看，科技创新是产业创新的基础和动力，产业创新则为科技创新提供产业化应用场景和市场价值实现，二者互为源流、相互促进，具有天然的融合性。

本文将立足汽车产业创新实践，重点分析科技创新与产业创新相互促进的场景、创新链产业链的双向赋能、驱动融合的体制机制以及深度融合的系统创新，为推进汽车产业体系现代化提供参考。

二、颠覆性科技推动汽车产业持续创新

当前全球产业链创新链加速重构、双向赋能。从基础研究、应用研究以及技术研发的创新供给到产业化、商业化的创新应用，多元创新链条正在持续赋能产业创新；与此同时，产业组织变革和产业生态构建等产业链的调整升级反向诱导技术进步和优化技术路线。由此形成“技术—产业”动态适配机制以及相互联动的“链式协同”范式，通过创新链与产业链之间产生的链式反应，

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推进科技创新和产业创新深度融合。根据巴斯德象限理论(Stokes, 1997),纯应用研究和由应用引发的基础研究是产生知识扩散并促成产业化的科技创新,即爱迪生象限和巴斯德象限。由这类基础研究所引发的通用目的技术,如生成式人工智能、量子科技等,具有较强的渗透性,产生的知识扩散和知识溢出可能突破传统产业链边界,引发诸多行业关键共性技术发生重大变革(李晓华,2025)。本质上,创新的核心是知识创新。通常情况下,创新主体所产生的知识会沿着创新链条线性传递。由于知识活动和创新方式日趋复杂,反馈迭代、跨界融合等机制使得创新模式向非线性和网络化演进。创新链上的知识和技术在与产业的结合中加速渗透转化,促进产业链优化升级。

我国近年来在石墨烯、碳纤维等基础材料,工业软件、高端芯片等核心部件,工业互联网、5G通信等底层技术,以及数字技术、人工智能等通用目的技术领域所取得的一系列关键核心技术突破引致汽车产业深刻变革,特别是一些颠覆性科技在很大程度上决定了汽车产业创新的方向和深度。一方面,颠覆性技术对生产要素的重构会衍生出新的技术创新,如云计算、智能驾驶等,这些新技术组合将以更宽泛更深远的方式影响整个汽车产业链,甚至导致产业链的延伸和断裂。另一方面,颠覆性技术的革命性和渗透性会打破传统产业边界,形成新的业态和产业模式,创造新的产业赛道。随着固态电池量产、高阶智能驾驶系统落地,以及智能座舱从人机交互到情感共生,新能源汽车领域必将再次发生变革和重塑。总的来看,汽车产业的科技创新与产业创新融合,主要集中在动力系统升级带来的产业重塑、绿色技术应用推动的绿色转型、数字技术驱动的智能制造以及智能驾驶技术引领的汽车产业变革等领域,蕴含在多元融合场景之中。

(一)动力电池技术研发和绿色技术应用推动新能源汽车产业变革

新能源领域的颠覆性技术突破催生了新能源汽车产业和动力电池产业,成为全球新能源领域的重要驱动力。动力电池作为新能源汽车的核心部件,是汽车产业技术研发的重点领域,具有万亿元市场规模。据韩国SNE Research统计,2024年全球动力电池装机量排名前十的企业中,6家中国企业的全球市场占有率达67.1%[②]。近年来,我国在固态电池、氢燃料电池等技术路线上的科技研发取得了较大进展,其技术突破直接决定了汽车产业竞争力以及可行的产业创新方向。

相较传统锂离子电池,固态电池技术在能量密度、安全性及充放电性能等方面实现了质的提升。目前,宁德时代研发的全固态电池样品实测能量密度达500Wh/kg,是当前主流液态锂电池的2倍以上,有望助推车辆续航突破1000公里,其硫化物固态电解质热稳定性超过400摄氏度,能够从根本上解决传统锂电池的热失控风险[③]。随着固态电解质与电极材料之间界面问题得以解决,

[②] 资料来源:中国工业新闻网“2024年全球动力电池装车量排名出炉:宁德时代蝉联第一 日韩市场份额缩水”,https: //www.cinn.cn/p/375288.html。

[③] 资料来源:今日头条“能量密度 500Wh/kg! 固态电池量产倒计时”,2025年2月24日,https://www.toutiao.com/article/7474773929643622950/。

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以及材料研发取得新突破、制备组装工艺持续优化，固态电池技术的产业化将为新能源汽车在内的诸多领域带来重大技术变革。

绿色技术的持续创新和广泛应用是新能源汽车产业可持续发展的关键，能够显著带动产业链上下游持续创新，而且能够大幅降低碳排放，有助于“双碳”目标的实现。氢能作为零碳二次能源载体，其氢燃料电池技术具有零排放、能量转化效率高等特点。质子交换膜、催化剂及双极板等核心技术领域的系统集成创新，大幅提高了电堆功率密度和电池系统寿命。从电解水制氢到固态储运，再到燃料电池应用，我国氢能产销保持平稳增长。《中国氢能发展报告(2025)》数据显示，截至2024年底，我国累计建成可再生能源电解水制氢项目产能占全球的51%。《2025—2030年中国氢燃料电池车行业项目调研及市场前景预测评估报告》数据显示，截至2024年底，我国累计推广氢燃料电池汽车2.8万辆。

（二）数字技术和工业机器人赋能汽车产业智能制造

制造环节是技术集成的中枢。近年来，在数字技术、工业机器人赋能实体经济趋势下，我国汽车企业通过工艺优化、系统集成、服务创新等方式，大幅提升了产品和服务的创新供给能力。

数字技术加速向汽车制造领域渗透，显著促进了要素优化配置和生产流程再造，汽车产业的生产组织方式出现系统性变革，大规模采用自动化生产线、工业机器人等，实现了生产自动化，并利用数字孪生技术，实时监控和优化生产流程。在新能源汽车制造过程中，应用数字孪生技术，实现生产过程的虚拟建模与优化，能够提前发现并解决其中的潜在问题。这种数字化的生产方式不仅提高了生产效率，而且降低了生产成本和资源消耗。例如，大众汽车通过虚拟仿真技术优化生产线排程，大幅提高设备利用率，单辆车的生产周期明显缩短。赛力斯通过供应链创新模式，构建了从材料研发到整车制造的全链条升级体系，利用数字孪生技术，实现关键工序全部自动化和24小时在线监测。

工业机器人在新能源汽车制造中的应用日益广泛。从零部件加工到整车装配，智能机器人可以完成高精度、高重复性工作，大幅提高了生产效率和产品质量。例如，在车身焊接环节，机器人可以实现精确的焊接路径控制，提高焊接质量和速度。同时，机器人还可以与传感器、视觉系统等结合，实现智能化操作，适应不同的生产任务。

此外，依托工业互联网平台，能够有效整合汽车制造流程，实现产业链各环节的互通互联、数据协同共享，实时获取供应商的生产进度、产品质量等信息，从而更好地进行生产计划和调度。工业互联网平台为汽车制造商和零部件供应商提供了合作平台，促进了产业链的协同创新。同时，汽车供应链应用区块链技术，提高了供应链的效率和可靠性，实现了零部件溯源与供应链金融创新。

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（三）智能驾驶技术引领汽车产业智能化转型

伴随着大数据、人工智能、5G通信技术等前沿技术加速产业赋能，其与汽车技术的深度整合，使得汽车产业转型呈现智能化、网联化的显著特征，“智能移动空间”逐渐成为汽车产品的主流形态，形成了以智能网联新能源汽车为载体的创新技术集群。

新能源汽车配备激光雷达、摄像头、毫米波雷达等多种传感器，在芯片研发和算法迭代支持下的多模态大模型能够对实时感知的环境信息进行处理分析并给出决策和控制指令，集中式的电子电器架构使得数据处理和信息交互更加高效，极大地提升了智能驾驶系统的性能，加速实现自动驾驶的高阶目标。例如，蔚来的首款车规级5nm高性能智驾芯片“神玑NX9031”成功流片，拥有超过500亿颗晶体管，预计其算力超过1000TOPS，可支持L4级自动驾驶[④]。小鹏“图灵芯片”实现300亿参数大模型端侧运行，单颗算力相当于当前市场主流芯片的3倍（吕笑颜，2025）。华为等车企加码布局端到端技术，推动辅助驾驶向高阶智能驾驶跨越。

三、汽车产业重构牵引科技创新突破

在全球汽车产业向新能源、智能化转型的关键期，汽车产业链正从传统的“机械主导”向“智能电子融合”深度重构，新能源汽车及智能网联汽车领域已形成较为完善的产业链。产业链不再仅是创新链的应用载体，而是通过市场痛点所牵引的技术需求、产业链主体间的创新网络、从单点突破到系统升级的技术动态迭代等核心机理，构建起全链条创新生态。其中，依托龙头企业的生态组织能力、跨领域主体间的深度协作，以及规模化应用的数据反哺，共同推动创新链从单一技术突破向系统能力升级跃迁。

（一）瞄准汽车市场痛点开展核心技术攻关

汽车产业创新牵引科技创新的主要方式之一，是通过整车厂到供应链的反馈机制，将汽车产业的市场痛点转化为明确的技术目标，形成从消费端到研发端的闭环驱动。

新能源汽车的快速发展以及汽车产业智能化趋势，使得产业焦点从传统机械性能转向自动驾驶、智能座舱等智能化体验，以及续航、补能速度等电动化效率，反向推动汽车产业加速相关领域的关键技术攻关。例如，高阶辅助驾驶的市场需求，促使整车厂与芯片企业联合研发高算力SoC芯片；轻量化与高续航的需求，驱动材料供应商与电池企业协同开发新型铝合金与固态电池技术。

[④] 资料来源：凤凰网“NIO IN 2024创新科技日：蔚来AI原生技术引领未来”，2024年7月27日，https: //auto.ifeng.com/c/8bZBhRoUfUl。

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汽车产业链加强上下游协作，能够有效提升需求传导效率，将分散的市场需求聚合为共性技术目标，提高创新效率并加大产业化应用。例如，整车厂基于用户对低成本、高性能、电驱动的需求，联合电驱供应商与材料企业共同研发定制化产品，并搭载于多款车型实现量产，在降低成本的同时提升效率。这种产业链协同的方式，更有助于驱动科技创新始终围绕市场真实场景发力。

（二）汽车产业链主体间形成创新网络

在汽车产业数字化、智能化转型下，产业链各环节通过龙头企业引领、多主体嵌入的组织方式形成创新共同体，推动技术突破从单一企业向网络化协作跃迁。

汽车龙头企业发挥创新生态主导作用，凭借其技术知识积累和市场地位，扮演着创新链“组织者”角色，不仅提供市场需求与技术标准，更通过技术培训与管理赋能，协助中小供应商提升研发能力，形成“以强带弱、整体跃升”的集群效应。例如，赛力斯通过“1+1+N”供应链集成集聚模式，即1家链主+1家核心供应商+N家上下游配套企业，联合川渝30余家零部件企业，如宁德时代宜宾工厂（动力电池）、成都莲洲科技（模型制作材料）、成都嘉润（车身模块化总成）等，开展协同攻关；与此同时，在产品研发阶段深度融合材料科学、电子电气与整车集成技术，推动轻量化材料、智能座舱模块等关键环节的全链条升级[5]。

随着智能网联汽车技术复杂度不断提升，汽车产业链引入芯片、软件、人工智能等领域的外部创新主体，以跨领域主体深度嵌入推动技术创新。例如，零跑汽车与高通合作，双方从芯片定义阶段就深度协同，推动整车架构设计模式转型。零跑基于自研的“四叶草”中央域控架构（硬件整合SoC系统级芯片与MCU微控制单元双板设计），向高通提出单芯片同时支持智能座舱与辅助驾驶需求；高通则针对车规级场景优化4nm制程的8650芯片，全球首发高通双8797芯片方案，总算力达640TOPS。这种整车厂定义场景、芯片商定制算力、软件商优化算法的跨领域协作，打破了传统汽车产业链从主机厂到一级供应商再到二级供应商的线性结构，构建起以场景为牵引的多维创新网络[6]。

（三）汽车产业应用场景加速技术迭代

颠覆性技术的演化离不开应用场景的支撑，而新兴技术的应用场景具有多样性、规模性、演进性、协同性、不确定性等特征，在其“工程化—商业化—产业化”动态演进过程中发挥着技术验证、需求验证和生态构建的作用（方晓霞、李晓华，2024）。汽车产业的规模化应用与持续反馈，通

[5] 资料来源：重庆发改“赛力斯数智赋能 构建川渝创新链产业链合作生态——加快建设新能源汽车产业主阵地”，2025年4月18日，https://mp.weixin.qq.com/__biz=Mzg3NzcyNTU2OQ。

[6] 资料来源：人民网“汽车智能化时代，中国车企如何重构芯片创新链”，2025年6月30日，https://mp.weixin.qq.com/s?__biz=MjM5NzI3NDg4MA。

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过“应用验证—数据积累—迭代优化”的循环机制，加速技术成熟并催生新的技术需求，形成产业创新与科技创新的正向反馈，持续推动科学技术从实验室走向市场、再由市场进一步激发科技创新的螺旋式演进。

汽车产业链拥有先进的制造能力，同时市场覆盖面广，其规模化应用为技术创新提供“试验田”，有助于加速技术成熟，快速迭代至可商业化落地的状态。与此同时，智能化产品会产生海量用户数据，如驾驶行为、座舱交互偏好等，由此形成数据驱动的创新模式，持续挖掘潜在需求并转化为新的技术攻关目标，为技术升级提供精准指引。例如，零跑汽车的“四叶草”架构通过搭载某系列车型并量产，验证了中央域控架构的工程可行性，并基于用户反馈进一步优化版本，集成度显著提升；通过自研智能座舱系统内置双AI大模型，结合高通8295芯片的算力支持，收集用户语音交互、功能使用频率等数据，反向优化算法响应速度与个性化推荐策略。赛力斯凤凰智慧工厂集成了1000多台机器人协同作业，生产周期缩短约30%，产品不良率降至1%以内，验证了魔方平台兼容纯电、增程、混动三种动力形式的可靠性；通过L3+级辅助驾驶功能的实际道路测试，积累超百万公里行驶数据，为后续高阶智驾系统的功能扩展奠定基础[⑦]。

四、驱动创新融合的体制机制

在汽车产业科技创新与产业创新深度耦合、“链式协同”的范式背后，形成了一套多维联动、协同共生的体制机制，主要由产业政策和市场择优攻关为指引、多主体联合创新为核心、资本市场为保障的系统性框架组成，很好地发挥出制度优势、场景牵引、产学研协同和耐心资本在推动原创性、颠覆性科技创新活动，以及加快产业创新和开拓产业新赛道方面的重要作用。

（一）政策创新为创新融合提供制度保障

近年来，我国针对新能源汽车产业发展实施了大量产业政策。一是以产业规划落实国家战略，包括《汽车产业调整和振兴规划》《节能与新能源汽车产业发展规划（2012—2020年）》《汽车产业中长期发展规划》《新能源汽车产业发展规划（2021—2035年）》等。二是实施“双积分”政策，设定企业平均燃料消耗量积分和新能源汽车积分，促进汽车企业加大新能源汽车的研发投入，推动新能源汽车渗透率从2015年的1%提升至2024年的35%[⑧]，并建立起全球最完善的充电基础设施体系。三是稳步推进试点工作。近几年组织开展公共领域车辆全面电动化先行区试点、换电模式应用试点、新能源汽车与电网融合互动试点、汽车安全沙盒监管试点，以及智能网联汽车准入和

⑦ 资料来源：重庆发改“赛力斯数智赋能 构建川渝创新链产业链合作生态——加快建设新能源汽车产业主阵地”，2025年4月18日，https://mp.weixin.qq.com/__biz=Mzg3NzcyNTU2OQ。

⑧ 资料来源：《中国新能源汽车产业发展报告（2024）》，2024。

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上路通行试点、“车路云一体化”应用试点等(中国汽车技术研究中心等,2024)。例如,2020年9月北京市启动建设以亦庄为核心的高级别自动驾驶示范区,现已建成城市级工程试验平台,旨在探索经济合理的“车路云一体化”解决方案,加快实现L4及以上高级别自动驾驶的规模化运行[⑨]。

(二)市场需求牵引场景开放和技术响应

市场机制是引领科技创新与产业创新及其相互融合的关键机制,其作用不仅表现为需求牵引下场景开放的创新驱动效应,而且在于技术创新迭代下的技术战略合作。例如,当前消费者对出行体验和娱乐场景的需求,引致新能源汽车企业加大智能座舱研发应用,逐渐从“功能堆砌”向“场景化服务”转型,甚至出现“智能化内卷”现象。理想汽车构建了采用自研Task Former神经网络架构的多模态大模型Mind GPT,支持方言自由说、指令自由说、简洁模式以及全时全车免唤醒。我国新能源汽车产销量连续十年全球第一,倒逼产业链上游的锂电材料、智能驾驶等环节实现技术突破。此外,合资品牌为应对市场需求,通过入股自主车企成立合资公司,共同研发智电新产品,借助自主车企的先发优势与本土供应链体系,导入自主车企的智电技术,推出独立的新能源汽车品牌。同时,利用中国较低的生产成本和成熟的供应链,将产品反向出口至海外市场,以促进产品的电动化和智能化转型。

(三)创新主体协同构建创新联合体

有效衔接知识创新和技术创新两大体系是产业创新链的基本功能,相比技术转移和科技创业,产学研协同创新更适合产业创新链的构建(洪银兴,2019)。产学研协同旨在打破知识鸿沟、平台孤岛与场景局限,通过联合研发的方式共享研发资源和技术成果,提高研发效率,降低研发成本及风险。在产业智能化趋势下,即以人工智能为核心驱动的智能经济模式影响下,智能技术和数据要素正加速赋能现有产业发展模式转型和培育新支柱产业。在这一过程中,科技领军企业或产业链链长牵头组建并主导产业创新联合体,以此推进场景化智能技术创新和产业创新融合形成“场景飞轮”(尹西明等,2025)。中国汽车工程学会牵头成立创新联合体,整合了企业、高校及科研机构资源,集中突破固态电池、智能驾驶等关键技术。与此同时,龙头企业之间也在广泛开展战略合作以进行技术攻关和技术输出,创新性地采取跨界联盟的方式整合创新资源。例如,华为通过HI(全栈智能汽车解决方案)、智选车等不同的技术接入模式,与北汽、长安等车企合作,构建并拓展“华为生态联盟”。

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⑨ 资料来源:北京市人民政府网站“‘智能交通’专场活动探讨未来出行”,2024年9月10日,https: //www.beijing.gov.cn/ywdt/gzdt/202409/t20240910_3806365.html。

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（四）“耐心资本”有效降低创新融合风险

科技创新从基础研究到产业化应用，往往需要数年甚至更长周期，特别对于原创性、颠覆性科技创新更是如此；而产业创新及产业结构优化同样存在持续投入和长期回报的问题，整个过程伴随着高风险。对此，培育壮大“耐心资本”，为企业提供全生命周期、接力式融资模式，能够确保从科学探索到产业增值过程的稳定性和可持续性。截至目前，私募股权创投基金参与投资了九成的科创板和北交所上市公司、过半数的创业板上市公司。政府引导基金，如常州新能源产业母基金，引导社会资本投向新能源汽车核心零部件、氢能等领域，推动强链补链。重庆产业投资母基金以“耐心资本”模式支持赛力斯向智能网联新能源汽车转型，推动其电池技术研发及超级工厂建设。

五、创新深度融合的系统性协同

推动汽车领域的科技创新与产业创新深度融合，关键需要各类资源、多方主体的系统性协同，从强化企业创新主体地位、优化创新资源配置与全链条服务保障、构建开放创新生态等方面持续发力。

（一）强化企业创新主体地位，发挥多方联合创新效能

企业是技术开发与应用的关键载体，也是市场需求的直接感知者和响应者，能够敏锐把握科技创新的社会需求。其创新能力在很大程度上决定了创新融合的深度，是推动创新融合发展的重要微观主体。因此，科技创新与产业创新深度融合需要充分调动汽车企业、科技企业等的创新积极性，发挥龙头企业创新主体作用。例如，比亚迪开放电池技术标准，引致宁德时代等供应商参与电芯设计，由此形成“技术定义—产业协同—市场验证”的创新路径。一是大力培育汽车相关领域的科技领军企业。例如，据韩国SNE Research统计，宁德时代作为动力电池领域的领军企业，在全球电动汽车电池市场占有率达37.9%，其电池技术创新推动了新能源汽车的发展。华为在车联网、智能驾驶等领域提供全栈式解决方案，一定程度上提升了智能网联汽车的智能化水平。二是壮大汽车产业上下游的专精特新中小企业。加大对开展技术攻关、成果转化等的中小企业给予财政补贴和融资支持。鼓励有能力的民营企业承担人工智能、新能源等重点领域的攻关任务。支持中小企业联合龙头企业组建创新联合体，共同突破动力电池、车规级芯片、智能驾驶等关键技术。

（二）完善科技成果转化服务体系，弥合从实验室到生产线的创新鸿沟

科技创新成果向现实生产力的转化即科技成果产业化，涉及技术攻关、技术转化、技术商业

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化等阶段，依托中试平台、概念验证中心等主要载体，旨在实现从实验室成果到规模化生产技术应用的转换。需要打通堵点、连接断点，构建“技术撮合—联合攻关—产业化落地”的全链条科技成果转化服务体系，覆盖实验室、中试、量产等环节。一是夯实基础研究。加大对新能源汽车基础研究特别是电池材料、智能驾驶算法、电子电气架构等关键领域的投入。鼓励企业联合高校和科研机构开展前沿技术研究，提高我国在新能源汽车技术领域的原始创新能力。二是促进技术融合。积极推动新能源技术、智能驾驶技术、电子电气架构与软件技术等相互深度融合，产生新的功能产品和应用场景。例如，智能驾驶技术与电子电气架构相结合，实现车辆智能化控制和信息交互。三是加快技术产业化。加强产学研合作，推动企业、高校及科研机构共建产业技术基础公共服务平台，加快新能源汽车技术创新成果的产业化。例如，重庆大学与长安汽车共建的智能网联汽车实验室，成功开发L4级自动驾驶系统，关键算法性能指标国际领先。还可以探索建立跨行业跨领域标准协同机制，推进新材料、新工艺、新产品标准制定及国际标准互认。

（三）构建开放创新生态，激发本土应用和全球资源的双重势能

科技创新与产业创新深度融合不应“闭门造车”，而是需要统筹国内国际资源，构建立足本土、面向世界的开放创新生态，通过跨国合作以及技术标准输出提升我国汽车产业创新能力。一是构建产业创新联盟。推动新能源汽车企业与零部件供应商、能源企业、信息通信企业等建立产业创新联盟，加强产业链上下游企业之间的创新合作与协同攻关。二是培育新兴产业生态。积极培育新能源汽车相关的新兴产业生态，如智能网联汽车服务、新能源汽车回收利用、新能源汽车金融等。三是加强科技创新国际合作。积极参与国际产业合作，深入开展与国外新能源汽车企业、高校及科研机构的科技交流与战略合作。

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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*

JEL Classification Codes: O33, L62

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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.

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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

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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.

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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/.

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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.

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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

[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.

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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.

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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.

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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

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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,

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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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