中国电动汽车产业协同融合发展:途径及政策启示

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摘 要：中国电动汽车产业在过去十年中实现了快速发展，拥有先进的技术和成熟的国内市场。中国电动汽车产业的发展具有明显的产业链协同融合特征。本文对中国电动汽车产业的融合发展进行了系统分析，并构建了产业链协同融合促进产业发展的分析框架，重点探讨了产业链协同融合对发挥各环节比较优势、提升整体国际竞争力的关键作用。最后，本文提出了通过产业协同融合促进其他战略性新兴产业高质量发展的路径和政策建议。

关键词：电动汽车产业　产业协同融合　战略性新兴产业

JEL 分类号：O14, E65

一、引言

近年来,中国战略性新兴产业的崛起推动了技术进步和整体产业发展。其中,电动汽车(EV)行业目前处于国际产业竞争的前沿,对于实现道路运输部门脱碳、促进汽车行业发展和实现国家能源安全目标至关重要。在过去短短二十年的时间里,中国已成为世界主要电动汽车生产国之一,其电动汽车自有品牌制造商(OBM)在销售增长、市场渗透率和生产技术方面已经超越了传统的全球汽车领导者。截至 2023 年,中国电动汽车的总销量占全球电动汽车市场的 50% 以上,而且电动汽车的质量和性能都逐步接近或超越国际标准,生产成本及平均价格也明显低于国外同行(IEA,2024)。此外,中国电动汽车生产商的成功并非是孤立发生的,而是与电动汽车各个供应链环节中具有创新和全球竞争力的本土企业的出现相伴相生。由此引出以下问题:中国电动汽车产业链协同与融合是否推动了整体电动汽车产业的快速发展？其关键驱动力是什么？

既有研究考察了美国、欧洲、日本等国电动汽车产业的融合水平,包括电动汽车与其他产业的局部集聚和集成创新网络,分析了中国相关产业链与创新网络的构成和网络结构的差异(左世权等,2020;肖凡等,2022)。在产业链上下游融合发展方面,一些研究通过构建专利引证网络,勾

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勒出中国新能源产业创新融合的总体结构与协同发展的主体特征（郭燕青、何地，2014；苏屹、曹铮，2022）。生产性服务业与电动汽车或其他制造业的融合对于提高服务效率、实现规模经济和专业化至关重要，电动汽车行业必须拥抱技术和产品创新才能实现高质量发展（吴艳、贺正楚，2016；刘国巍、邵云飞，2020）。然而，既有研究较少关注电动汽车供应链融合的发展模式和性质以及与其他新兴行业的协同作用等问题。

本文从供应链、集群和网络的角度系统分析了中国电动汽车行业的发展。考察了中国电动汽车供应链上游、中游和下游行业的发展经验，以全面了解不同环节之间的协同融合。通过探索这些环节如何相互作用和协同，我们强调了推动该行业快速增长和在全球舞台上形成比较优势的途径。这一分析为探讨跨供应链战略融合如何提高效率、创新能力和市场响应能力提供了思路。此外，我们还为其他新兴产业提供了政策建议，强调了培育协同的供应链管理方法对推动可持续增长和技术进步的重要性。我们的研究结果为促进产业体系和技术发展的协同融合提供了路线图。

本文余下部分安排如下：第二部分考察中国电动汽车产业链的发展经验，以及上中下游行业如何根据禀赋结构和产业技术地位发挥其比较优势。第三部分分析了协同融合促进产业发展的路径，重点关注产业的关键特征。最后提出了政策建议。

二、中国电动汽车行业的协同融合发展

随着经济全球化和企业间分工的不断深化，产业链已成为产业发展过程中的关键因素。具体而言，产业链是涵盖上下游企业之间原材料、技术、中间产品和服务相互交换的供需关系，本质是形成产品内生产分工的链条或网状结构（邵昶、李健，2007）。产业链的协同发展强调不同企业之间在资源（如资金、技术、人才、信息等）上的共享和整合，以提高资源利用效率和降低成本。而产业链的融合则是指各个生产与服务环节的深入互动和协作形成的边界模糊化和一体化等现象，进而引发产业范围内不同领域的相互渗透交叉，促进各环节逐步形成新的生产互动生态的动态过程。产业链上各环节的融通，促进了资源、信息和技术在产业内的有效流动和汇聚，企业可以更加有效地整合资源，形成技术创新合力，推动产业的技术进步和升级（赵新华，2014）。在中国电动汽车产业的发展过程中，禀赋结构与上中下游环节的技术进步共同促进了其产业链的协同融合发展，是这一产业发挥潜在比较优势、形成国际竞争优势的重要驱动力。

（一）中国电动汽车产业链的发展历程

过去20年间，中国的电动汽车产业不仅在整体产销规模和技术水平上取得了世界领先地位，并且在产业链的各环节均涌现出多家具有国际竞争力的自主创新企业。电动汽车的产业链包括

上游的矿产资源和正负极等原材料制造，中游的电池、电机、电控等核心零部件的研发与生产，以及下游的整车制造、智能化软硬件以及充电换电、智能电网等配套设施的建设与运营（见图1）。回顾过去20年的高速发展，中国的电动汽车在产业链上游率先起步并逐渐达到国际前沿，产业链下游的电动汽车整车制造行业取得了世界瞩目的增速；同时在需求的进一步带动下，中游的核心零部件厂商在数年内从规模生产、成本控制、技术积累三方面均取得了世界领先水平，下游的充电设施配套行业也实现了快速进步。

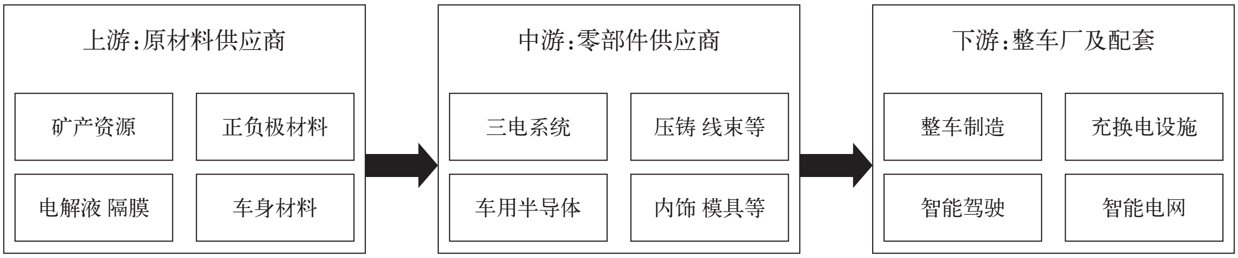

图1：电动汽车产业链的构成

资料来源：根据陈扬、王学锋（2014）整理。

20世纪90年代，日本企业在锂离子电池上实现突破，垄断了全球90%的市场，主要应用在消费电子领域，而中国尚处于技术研发阶段。随着全球消费锂电池市场快速发展和供应链全球化布局，2001年后的十余年间，日韩的锂电制造环节逐渐向中国转移，国内企业逐渐实现了包括正极材料在内的电池主材国产化，并已开始对外出口。

始于“十五”规划的“863计划”启动了电动汽车重大专项，在相关政策的带动下，中国电动汽车产业进入萌芽阶段。随着相关企业和研究机构陆续取得技术突破，专利不断积累，产业链上下游逐步形成。时至2009年，政府启动了“十城千辆”等电动汽车大规模示范试点项目。随后的五年时间，我国电动汽车产销量均实现了迅速提升，全面进入产业规模化发展阶段，并在2015年超越美国成为全球最大的电动汽车市场。2016~2017年，中国企业在电池、电机、电控的核心材料与技术方面均取得自主研发的突破。随着动力电池技术的快速发展，制造成本大幅下降，电动汽车的续航里程不断提升，私人部门的消费逐渐兴起，市场规模快速增长，全球市场份额占比处于领先地位。

2018年以来，取消了外资企业的进入门槛。大量未形成自生能力的电动汽车整车及零部件企业被市场淘汰，产业链的发展逐步走向成熟。而随着电动汽车销量大幅增长，处于产业链下游配套的充换电基础设施行业发展迅速，充电桩覆盖率提升为电动汽车的进一步普及推广奠定了基础。目前，我国在电动汽车产业上已形成趋于完整的本土化产业链供应链体系、高效率低成本的

生产能力、六大区域产业集群。电动汽车产业从原先的垂直配套供应关系演变成以专业分工为基础，系统集成、协同高效、融合发展的产业生态。

（二）产业链各环节协同融合的禀赋基础

电动汽车产业有别于传统汽车工业的核心技术特征是其产业链融合协同发展的决定性因素。可以总结为以下三个方面：第一，科技的可传播性与产业的开放性。电动汽车产业的核心环节，如电池技术、电机驱动、电子控制等，依赖于高度的科学技术，而这些技术相较于传统汽车工业中的内燃机技术，具有更强的可传播性，可以更快速、更广泛地在产业内传播和应用。后者的技术进步往往依赖于生产流程中的默会知识，不利于企业间的信息交流和技术创新的共享。同时，电动汽车不需要传统燃油汽车中的发动机和变速箱等核心零部件，产业尚未形成深厚的进入壁垒和垄断势力，也未固定于某一种技术路线或商业模式，这为各国企业提供了公平竞争的机会，所有参与者几乎位于同一起跑线上。

第二，技术和产品的快速迭代。电动汽车的动力和底盘系统相较于传统汽车更为简化，省去了复杂的变速箱与发动机匹配问题。这种简化不仅降低了制造成本，也加快了技术和产品的更新换代速度。企业为了保持市场竞争力，必须通过不断的技术研发和创新来提升产品性能，实现快速迭代。这种快速的技术进步和产品创新，要求企业持续投入研发资源，以适应市场需求的变化和消费者对高性能、智能化产品的要求。

第三，与前沿科技领域的紧密联系。电动汽车产业与人工智能、信息技术、清洁能源等新一轮科技革命下的领域紧密相连。在电动化、智能化、网联化的趋势推动下，电动汽车的各个环节，无论是产品还是工艺，都建立在前沿科学技术的基础之上。与传统汽车工业相比，电动汽车产业的研究与开发经费在总销售额中的比重、研发人员在从业人员中的比重普遍较高。这种对研发的重视，不仅推动了产业内部的科技创新和技术进步，而且产生了巨大的知识溢出效应。通过形成新的技术体系和产品体系，电动汽车产业为产业链上的各个环节提供了强大的技术支持和广阔的创新空间，进一步加速了整个产业的技术革新和市场发展。

基于上述特征，在电动汽车产业链的各个环节，中国的禀赋结构和技术积累为产业的协同融合发展提供了坚实基础，是将不同环节的潜在比较优势转化为竞争优势的重要前提[①]。

1.上游原材料：下游需求放大成本优势

电动汽车产业上游原材料供应环节涵盖电池系统的原材料以及车身架构等部件的原材料等

① 根据新结构经济学理论，禀赋结构包括自然禀赋、要素禀赋与制度禀赋，其中要素禀赋是指资本、劳动力、人力资本和土地等要素的相对丰裕程度，与自然资源禀赋共同决定了企业的生产成本；而制度禀赋则通过影响企业在市场中面临的交易成本，详细讨论请参考林毅夫等(2019)。

多个产业。其中，电池原材料的矿产开采、精炼、化学加工、正负极材料制造等多个环节具有自然资源和资本密集度高、制备工艺复杂、技术路线多元的特性，对电动汽车的整体性能和成本有着决定性的影响。中国的自然资源禀赋和要素禀赋为这一行业的本土厂商带来更低的生产成本。而在钢铁冶炼、合金等其他原材料行业上，中国具有领先的生产效率。在庞大的下游需求带来的规模效应下，能够进一步强化产业链上游低成本、高效率的优势。

在电动化零部件的原材料方面，目前电动汽车大部分采用锂电池作为动力来源，由于世界范围内锂、钴、镍等制造电池所需的关键矿产资源需求日益旺盛，但供应相对有限，原材料成为制约许多国家电动汽车产业发展的关键因素。中国的锂、铁、锰、烯、石墨等用于动力电池的主要原料储备相对丰富，矿产资源供应商和精炼企业在全球处于先列，关键原材料能够基本实现自主供给，因此企业的开采和运输成本相对较低[②]。据麦肯锡研究统计，当前中国在全球锂产量中所占份额达到28%，钴产量份额也达到23%。此外，中国企业通过并购海外重要矿产、建立长期供应合作关系等方式进一步保障了原材料供应，从而有效填补那些受生产工艺的制约、尚无实现原材料自主供应的供应链缺口环节，降低了供应短缺的风险以及原料采购成本，并进一步提升了企业盈利能力[③]。而在锂离子电池的正极材料、负极材料、隔膜、电解液等核心原材料生产上，中国企业掌握成熟的制备工艺，成本得到有效控制，在消费电子和动力电池等下游行业的庞大需求下，进一步提升了生产规模，形成较为显著的竞争优势。如图2所示，中国厂商在上游各环节的生产供应规模均达到50%以上，处于国际领先地位。

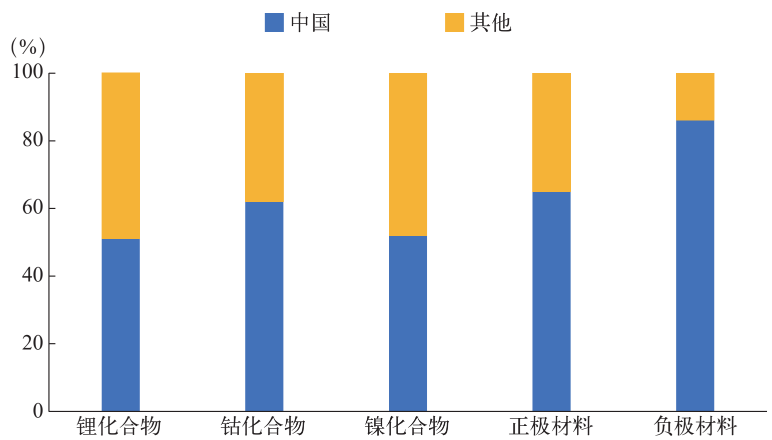

图2：中国电动汽车电池原材料的全球供应份额占比

数据来源：Kumar (2020)。

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② 美国地质调查局(USGS)数据显示，中国是稀土储量最丰富的国家，中重稀土资源储量优势尤为突出，占全球90%以上；锂矿储量约100万吨，占全球储量的7.14%，世界排名第四；石墨储量5500万吨，占比22%，产量在全球占比保持在65%以上。

③ 例如，天齐锂业持有澳大利亚泰利森锂业51%的股份，同时持有位于智利阿塔卡玛盐滩的SQM锂矿26%的股权；江西赣锋锂业控制澳大利亚马里恩山锂矿项目约半数的股权，以及阿根廷马里亚纳卤水提锂项目80%以上的股权(Sanderson，2019)。

在原材料制备技术方面，国内复合材料和电化学等领域集聚了大量专业人才和前沿科技，具备潜力巨大的人才禀赋，为行业提供了新的发展机遇。中国头部企业持续进行大量研发投入，在诸多前沿技术上取得了显著进展，例如，在正极材料的磷酸铁锂和三元锂两大技术路线上，中国的相关专利数量已经达到世界首位，足以证明中国企业已经形成了一定的技术积累（见图3）。

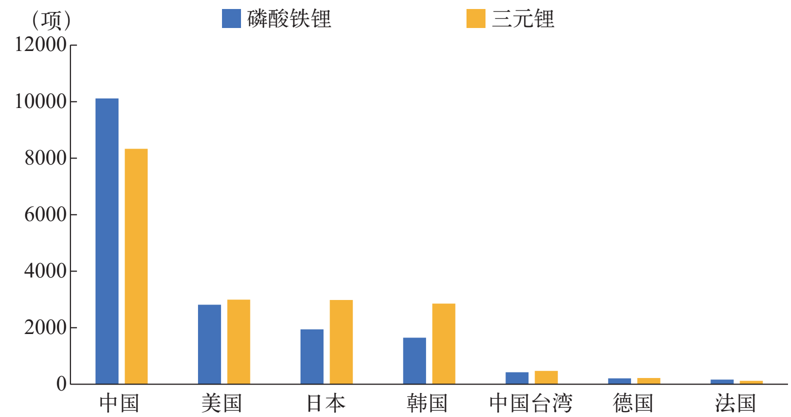

图3：不同技术路线的正极材料累计专利授权数量

数据来源：WIPO数据库。

2.中游零部件：技术优势促进垂直整合

中游零部件制造环节包括电动化零件和智能化零件，直接关系着电动汽车产品的核心竞争力，具有技术、资本密集度高和专业化分工程度高的特征。并且零部件的产品技术迭代速度较快，功能与技术特性需要与整车的需求相匹配，因此技术进步主要由下游需求推动。

按照不同的要素密集度，电动汽车零部件分为劳动密集型、资本密集型以及技术密集型产品。劳动密集型零部件以车身内外饰、汽车玻璃为主，在手工装配和质量检查等环节需要大量的人工或半自动化操作。资本密集型零部件主要包括一体化压铸机、模具、高压线束和连接器等，用于厂房和设备采购以及工艺开发的投入较高。长期供应传统汽车零部件的技术经验帮助国内汽车零部件企业在相关领域形成一定的成本优势和技术积累，因此整体产品的竞争力较高。同时，在车身轻量化、优化空间布局、快充技术普及等下游市场需求的推动下，新能源整车厂商通过与中游零部件企业共享市场信息与底层技术，推动了传统零部件的技术含量和附加值提升。当前，中国企业在一体化压铸机与模具上已展现出明显技术优势，高压线束和连接器也出现国产替代和技术赶超的趋势，而且在天幕玻璃、汽车智能交互大灯等新产品上的产能和生产技术均为国际领先。

技术密集型零部件集中在电动智能化的新兴零部件上，包括电池、电机、电控“三电”系统、车

规级芯片等，核心技术接近世界前沿，需要持续的技术研发投入。在动力电池产业，原材料环节与零部件产业在生产和研发上相互促进。一方面，上游的成本优势传递给了中游的动力电池制造商，另一方面，双方在研发上合作紧密，形成合力。随着上游超高镍、无钴三元电池与电解质材料的技术突破，动力电池厂商陆续推出长续航及高充电倍率的动力电池，并且加快了半固态电池的规模化生产。同时，中国电池厂商根据高能量密度、快速充电、长循环寿命等技术需求，与上游供应商共同改造升级电芯材料与结构，在磷酸铁锂电池和三元锂电池技术上处于世界前沿水平。如图4所示，2023年中国在全球动力电池装机量前十名中占据六家，总市占率达63.5%；其中宁德时代自2017年以来持续占据世界首位[④]。

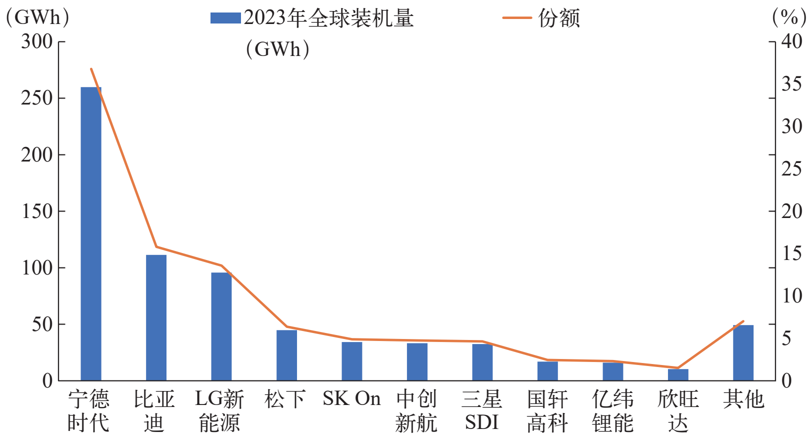

图4：2023年全球动力电池装机量及其份额占比

数据来源：SNE Research (2024)。

而在电机、电控方面，国内中游厂商与下游整车企业通过投资或收购形成了较为充分的配套协同融合。整车厂由于在发展初期产量较小，采购成本高昂，因此大多通过自主生产汽车电机与电控系统，大量资本投入自主研发电驱动技术。相较于第三方电机厂商，随着整车厂配套车型的销量提升，目前以比亚迪子公司弗迪动力为首的整车厂自制电机在电机与电控市场中占据了主导地位。电机电控市场与整车厂市场演变较为同步，中高端车型的电机与电控均为整车厂自研，市场集中度较低。就技术研发方面，电动汽车在轻量化等方面要求越来越高，电机电控集成化产品成为行业发展趋势，以国内电动汽车自主品牌为代表的中国厂商在集成化方案上研发成果突出，处于领先地位。

在车规级芯片产业方面，电动汽车行业的电动化、智能化与网络化推动了对车规级芯片的用

[④] 据SNE Research (2024)统计，2023年全球动力电池装机量较上年增长38.6%，而宁德时代同比增长40.8%，比亚迪同比增长56.9%，增速全球领先。

量与性能需求。然而，国内在中端系统级芯片与高端人工智能芯片供应上依然面临欧美日企业的市场垄断，市占率近乎全覆盖，反映出中国在关键车规级芯片领域的自生能力尚未成型，但差距正在逐渐缩小。在智能座舱与智能驾驶发展的推动下，以华为、地平线为代表的国内厂商在低性能系统级芯片上实现自主研发，但芯片算力与制程方面尚落后于国际发达国家。

3.下游整车制造及相关服务：应用场景推动跨领域协作

产业链下游主要包括整车制造、销售、服务以及配套充换电基础设施建设等行业。整车厂商作为电动汽车产业链的核心参与者，在电动智能化技术研发积累、规模化生产以及多元化营销模式方面。同时，快速发展的配套充换电基础设施行业为电动汽车产业的持续扩张提供了良好支撑。

近年来，国内自主品牌整车厂商发展迅速，一方面通过整合零部件在控制成本的同时确保供应链的安全稳定，提升了自生能力；另一方面基于对消费者需求的洞察并与供应商共享信息资源，有针对性地迭代产品以及进行差异化创新，形成了竞争优势。根据工业与信息化部统计，2023年中国自主品牌在国内电动汽车销量中占比达到80.2%。整车厂产量提升所带来的规模效应不仅形成了成本优势，而且为汽车智能化的技术创新奠定了基础。智能化是电动汽车产业链下游发展的关键趋势，智能驾驶主要包括视觉和多传感器融合两条路线。中国电动汽车整车厂在发展早期便布局智能驾驶技术并持续投入资源，具备一定的先发优势。与此同时，传统车企也通过使用信息技术企业的整体解决方案，突破智能驾驶的技术壁垒。华为等通信技术企业凭借其强大底层技术研发能力及自主研发的汽车专用芯片，率先实现不依赖于高精地图的高速、城区高阶智能驾驶，为国内传统整车厂带来技术优势。并且，通过在智能驾驶、智能座舱等领域投入巨资进行合作研发，下游整车厂与人工智能、大数据、物联网等领域企业的协同融合关系也日益紧密。

此外，下游的配套充换电基础设施具有一定的公共品性质，是电动汽车产业实现快速发展的重要前提。据中国电动汽车充电基础设施促进联盟数据，2016年中国超过欧洲成为全球范围内公共充电网络最为庞大的市场。2019年中国的充电桩保有量在全球的占比超过50%，高出美国、欧洲和日本的充电桩数量总和。在技术水平方面，中国在充电桩的快充和换电技术上有深厚的技术积累，处于全球领先地位。根据国际可再生能源机构数据，自2017年起中国超越美国成为全球充电桩专利累计数量最多的国家，截至2021年中国充电桩相关专利约占全球的50%（见图5）。目前基于400V平台架构的充电体系技术已较为成熟，成本相对较低，应用广泛。顺应消费者的长续航与快速补能需求，中国电动汽车整车厂在快充技术上加大技术研发，各大车厂陆续推出基于800V高电压平台的高倍率充电车型，推动车桩两端快充化发展。

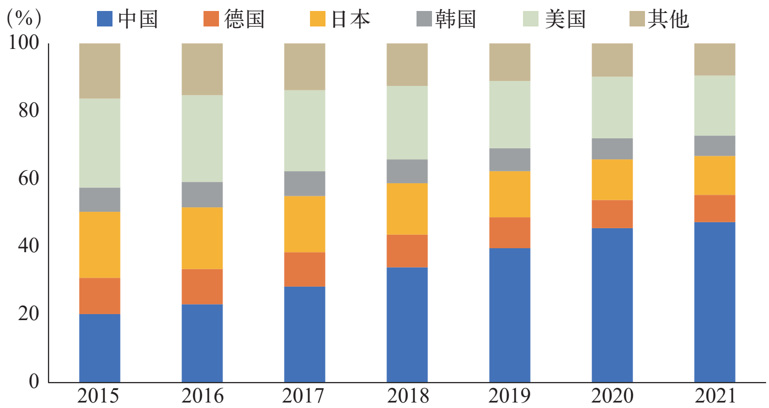

图5：中国电动汽车充电桩专利累计数量的全球份额占比

数据来源：IRENA(International Renewable Energy Agency)。

（三）电动汽车产业协同融合存在的问题

尽管中国的电动汽车产业链已经在过去20年间实现了较大程度的融合协同，但仍不能忽视未来电动汽车产业发展的长期性、艰巨性和复杂性。目前在电动汽车产业链上，仍然存在部分核心零部件及重要材料供应趋紧、关键技术领域国际合作空间被压缩、相关产品出口遭遇贸易壁垒等问题。

具体而言，虽然在产业链上游的核心技术专利申请数量上已呈现出赶超之势，但中国相关企业受限于起步晚、发展时间短，所开发的专利主要围绕在功能和应用层次上，比如在配方比例上做调整和改良等，在核心技术竞争中仍处于劣势，原材料的基础性专利都受制于欧美、日韩企业，国内企业的研发生产难以绕开[5]。

与此同时，在智能座舱与智能驾驶发展的推动下，车规级芯片的用量与性能需求不断提高。以华为、地平线为代表的国内厂商在低性能系统级芯片上已实现自主研发，但自动驾驶人工智能训练芯片制造的核心技术尚未突破，芯片算力与制程方面与国际前沿水平差距明显。特别是在自动驾驶的人工智能训练芯片方面，由于美国英伟达等芯片厂商的先发优势明显，中国企业技术创新依然受制，在车规级芯片供应上存在"卡脖子"的问题，发展更强算力和算法以及大模型支持的自动驾驶技术将因此受限。

同时，在产业链的中游环节，新能源汽车零部件产业正面临市场竞争加剧与行业整合加速的双重挑战。近年来，下游新能源汽车市场的快速扩张及对绿色转型的广泛共识，引发了社会资本的大规模涌入，一定程度上的"潮涌现象"（林毅夫，2007）。由此导致了产能建设与实际市场需求之间的错配，迫使行业步入结构性调整阶段。然而，如果市场未能自发调整有效出清，问题的进一

[5] 例如在正极材料上，美国3M公司和加拿大魁北克水力垄断了三元材料和磷酸铁锂正极的基础专利，电解液、隔膜由松下等日本企业注册了基础专利。

步加剧不仅会带来资金、土地和人才等资源要素的闲置与浪费，而且导致企业的利润空间受到挤压、整体行业盈利性下降，不利于电动汽车产业未来的可持续发展。优胜劣汰是行业走向成熟的必经之路，也对中游零部件企业的成本控制与产品创新提出了更高的要求，驱使企业在供应链和生产环节上进一步整合优化，推动企业通过技术创新和产品差异化来提升市场竞争力。优胜劣汰是行业走向成熟的必经之路，当前产能建设和实际市场需求间的不匹配导致了行业结构性产能过剩，而问题的进一步加剧不仅会带来资金、土地和人才等资源要素的闲置与浪费，而且导致企业的利润空间受到挤压、整体行业盈利性下降，不利于电动汽车产业未来的可持续发展。这一问题对中游零部件企业的成本控制与产品创新提出了更高的要求，驱使企业在供应链和生产环节上进一步整合优化，推动企业通过技术创新和产品差异化来提升市场竞争力。

三、电动汽车产业协同融合发展的政策路径探讨

作为典型的战略性新兴产业，中国电动汽车产业能够实现快速崛起，一方面得益于从原材料供应到核心零部件制造，再到整车生产与基础设施配套间的高效协同融合与相互促进，使得各环节能够充分发挥比较优势，形成成本、效率和安全上的国际竞争力。另一方面，虽然电动汽车的核心技术处于技术前沿，但产业链上中下游之间的技术协同融合降低了企业自主创新的不确定性，促进电动汽车的产品研发与快速迭代，占领技术高地。

中国电动汽车产业实现产业链协同融合的发展经验表明，战略性新兴产业的关键特性决定了其产业链上下游协同促进产业发展的核心途径与传统产业存在重要差异。因此，推动这一类产业协同融合的政策路径，需要从多个维度进行考量。

（一）电动汽车产业链协同发展的主要特征与路径

经过20年的培育和发展，中国电动汽车产业不仅在规模上实现了跨越式增长，更在产业链的协同融合发展上取得了显著成效。与依赖内燃机技术的传统汽车工业相比，中国电动汽车产业展现出一系列独特的核心特征，这些特征不仅重塑了产业的组织形态，也推动了产业的持续创新和进步。第一，产业链组织方式的变革。传统的汽车产业链通常呈现出从上游到下游的静态线性结构。而电动汽车产业链已经向网络化、非线性的生态结构转变，打破了传统的多级供应商体系，模糊各个生产环节之间的分工和边界，促进了生产流程的生态化。例如，中国的“造车新势力”企业，虽然作为整车制造商，但并不直接参与汽车的生产与组装，而是通过外包、合作等方式，将业务重点放在了销售、品牌建设、研发设计等价值链的高位环节，从而实现资源的优化配置和核心竞争力的构建。第二，产业链各环节互动形式的拓展。在电动汽车产业中，产业链上下游的互动不再局限于简单的产品供给与需求关系。企业通过股权投资、构建协作平台等方式，加快了新技术的扩

散和生产应用速度。例如，华为等信息技术企业凭借其在产品研发、销售、供应链管理等方面的丰富经验，积极建设开放的汽车厂商平台，吸引不同厂商共同参与汽车电动化和智能化的进程。第三，产业链协作范围的延伸。当前，电动汽车各环节核心技术的发展不再仅仅由研发推动，而是转向了消费市场与用户需求驱动下的场景式创新，更加注重下游市场的商业化途径，以此来引导产品的研发和创新。为了适应消费者对智能驾驶、车联网等新兴技术的需求，跨界的企业合作不断推出更为智能化和个性化的产品。

从具体途径来看，首先，在国内巨大的市场规模和独特的产业链结构下，通过产业链的中间品需求传导渠道，产业链的协同融合能够放大上下游环节的规模经济效应。2001年后，中国逐步形成了国有企业主导上游中间品行业、民营企业主导下游产业的“垂直结构”（李系等，2014）。而通过产业链上下游的协同融合，国内上游制造业的低成本能更好地传递到下游产业，为终端产品带来成本优势和更大的利润空间。而产品价格的下探能够充分激发战略性新兴产业的市场潜力，刺激下游终端产品的需求不断扩张。这种需求扩张又会进一步推动上游产业扩大生产规模、降低边际成本，形成互相促进的良性循环。

其次，产业链协同融合能够有效缩短产品从概念到研发再到生产落地的整个生命周期。战略性新兴产业内技术较快的更新迭代速度和较短的研发周期决定了产品的时效性特点，因此如果研发出的新产品能够迅速投入市场，不仅有助于企业快速响应市场需求，抢占市场份额，还能为企业赢得宝贵的时间窗口，为后续产品升级和市场拓展奠定基础。因此，产业链上中下游的协同融合能够使企业在市场竞争中处于有利地位，形成效率上的竞争优势。

再次，产业链协同融合可以促进企业间的密切互动与研发合作，加速创新和技术知识的传导，能够推动上中下游在具有潜在比较优势的技术路线上实现价值链的协同升级。通过共享信息、技术和资源，上游企业可以基于下游产品的用户需求进行针对性的产品研发，实现向价值链的两端升级；与此同时，上游产品技术突破能够引领下游实现差异化创新，生产附加值更高的产品。最后，从全球产业竞争的角度来看，大国竞争已经逐渐转向产业链之间的竞争。产业链的协同融合发展不仅能够避免上游产品供应的“卡脖子”问题，确保供应链的安全稳定，还能够降低下游产品需求的不确定性，增强产业链的韧性，形成安全上的比较优势。因此，促进产业链上下游的高效稳定、深度融合与协同融合发展，是驱动战略性新兴产业持续壮大的核心动力。

（二）促进产业链协同融合发展的路径方向

从上述产业链协同融合发展的理论途径可见，一方面，上中下游的纵向合作能够发挥各环节禀赋结构决定的潜在比较优势，另一方面，跨领域横向融合可以形成新产品新技术研发创新的独特途径，成为中国电动汽车产业赶超世界前沿，形成更大国际竞争力的重要源泉。因此，战略性新

兴产业内产业链的协同发展，既需要从纵向维度上立足于中国的产业链垂直结构，促进各环节的资源整合，也需要从横向维度上依托中国的全产业链优势，加强跨领域的创新合作。

1.协调产业链纵向整合，促进各环节优势互补

充分协调产业链企业间的纵向互动与合作，有助于上中下游各自比较优势的进一步放大。在电动汽车产业内，通过降低上游原材料供应商、中游零部件制造商与下游产品或服务企业之间的信息不对称及合作成本，促进生产布局合理与创新研发等多种合作形式发展，有效发挥了各环节禀赋结构决定的比较优势，形成了高效稳定的供应链体系，并强化了成本、效率、技术上的国际竞争力。

一方面，电动汽车产业的产品迭代速度快、技术周期相对较短，上游与中游零部件企业具备要素成本的比较优势。在信息流通充分的情况下，上游厂商能够快速响应电动汽车整车厂需求，在电动化、智能化趋势下完成符合用户需求的工艺和技术创新。特别是在电动化的核心零部件领域，如电池、电机、电控系统等方面，国内厂商已展现出显著的规模和技术优势。通过与上游原材料供应商和下游整车厂的紧密合作，共享资源、共同开拓市场，形成了三方协同研发创新的良性循环。这种模式不仅降低了创新研发的不确定性，而且提高从研发端到产品端的核心竞争力，锻造产业链“长板”。

另一方面，在当前大国产业竞争的背景下，战略性新兴产业的发展面临着关键原材料短缺、设备紧缺和基础性技术专利壁垒的挑战。供应链的不稳定将严重制约产业的稳步发展，甚至可能引发“卡脖子”困境。因此，推动产业链上中下游企业在供应链和生产环节上的整合优化，建立长期稳定的合作关系，成为保障产业链持续协同发展的关键。以电动汽车智能化零部件为例，尽管在核心技术如汽车半导体方面存在不足，但国内整车厂与上游供应链对提升国产替代率的诉求一致，促使企业间形成研发合力，共同培育专注于车规级芯片设计制造的企业，围绕高阶自动智能驾驶技术开展核心技术研发。这种协同合作有望打破底层技术壁垒，突破产业链“短板”。

2.推动产业链横向融通，激活跨领域创新潜力

深化跨领域、跨层级互动与合作，形成产业链整体的创新生态，有助于为产业发展提供良好的技术创新环境。新一轮科技革命的特征使得产业之间的边界逐渐模糊，为产业链的协同融合提供了机遇。中国的电动汽车产业得益于电动化、智能化的发展趋势，发挥了人才和技术积累的巨大优势，不仅推动了电池、电机等传统产业的快速升级，而且形成了与人工智能等技术的深度融合，推动了新技术、新产品的不断涌现。

跨领域企业间的技术融合是产业链协同融合发展的重要驱动力。通过打破行业壁垒，整合不同领域的技术知识和技术能力，重新组合与创新已有技术，企业能够开发出更加多元化、更具市

场竞争力的产品或服务。当前，新能源整车企业与新一代信息技术领域的企业深入合作趋势越发明显，推动了整个产业链的升级和转型。在电动汽车自动驾驶、智能电网、车联网等方面，借助华为等通讯和信息技术领域的巨头在人工智能领域的人才、技术和生态资源，国内电动汽车厂商得以加速构建智能化产品和服务，持续提升核心竞争力。

同时，产学研技术研发合作是打造产业链创新生态的关键途径。产学研合作本质上是通过基础研究实现不同领域技术知识的相互渗透、交叉和重组，能够将高校、科研机构的前沿科研成果与企业的实际需求相结合，催生出突破性的新技术和新产品。在电动汽车领域通过“三纵三横”框架下的一系列产学研合作平台，高校、一系列研究院所与产业链上中下游的企业共同开展基础研究，探索钠离子电池、氢燃料电池等新的技术路径和解决方案，有望绕过被外国企业垄断的正负极材料、隔膜、电解液等核心专利的同时，建立新技术路线上的先发优势。

四、总结与启示

电动汽车产业作为促进能源结构调整、绿色经济发展和汽车工业转型升级的关键产业，其成功发展经验为其他战略性新兴产业的突围提供了重要的经验和启示。近二十年的发展过程中，中国电动汽车产业在产销规模和技术水平上已达到国际领先水平，在上游原材料供应、中游零部件制造以及下游整车制造及相关服务各环节，均展现出显著的成本和效率优势。中国电动汽车产业链的协同融合发展模式通过整合各环节的优势资源，促进了技术创新和产业升级，提升了整个产业链的国际竞争力。这一发展经验为其他相似的战略性新兴产业探索协同融合发展提供了方向。

战略性新兴产业具有创新能力强、成长潜力大的特点，是推动经济结构调整、提升国际竞争力的关键所在，正崛起成为引领中国未来高质量发展的新引擎。然而，由于技术水平前沿、知识技术密集和正外部性显著等特征，战略性新兴产业的发展同样面临着诸多挑战。在外部，海外跨国企业受地缘政治影响，并且为了保证供应链安全，将一系列制造业产业链外迁至别国(倪红福、田野，2021)。在内部，中国战略性新兴产业对进口的核心设备、半导体、基础化工品等上游核心部件仍具有较高依赖度，存在不可忽视的“卡脖子”风险。

在此背景下，对于战略性新兴产业而言，其产业链的协同进步不仅要求从垂直方向上着眼于中国产业链的层次结构，推动各环节之间的资源共享与整合，还要求从水平方向上利用中国全产业链优势，增强不同领域间的创新合作。电动汽车产业链的协同融合发展模式有以下经验值得总结：一是应积极协调战略性新兴产业的产业链纵向整合，通过降低产业链各环节企业间的交易成本，形成各环节比较优势相互促进的良性循环。通过产业链各环节的紧密合作，加速产品从概念设计到市场推广的整个过程，使企业能够快速抢占先机。二是应通过推动产业链的横向融通，

打造跨领域创新生态，促进企业间跨领域技术融合。一方面，政府可以通过建立技术融合促进途径，包括搭建技术交流平台、设立技术融合基金等，为企业提供技术融合的机会和资金支持。另一方面，企业也应加强自身的技术研发和创新能力，积极寻找与其他领域企业的合作机会，共同推动产业链横向延伸。通过促进纵向整合与横向协作，积极推动产业链的融合化、集群化、生态化发展，盘活中国产业链的禀赋基础和规模优势，从而提升战略性新兴产业的国际竞争力，充分发挥其在现代化产业体系建设中的带动作用。CE

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Integration and Coordination in the Development of China's Electric Vehicle Industry: Mechanisms and Policy Implications

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Abstract: *China's electric vehicle industry has undergone a rapid development over the past decade, boasting cutting-edge technology and a mature domestic market. The growth of China's electric vehicle (EV) industry is prominently characterized by integration and coordination along the industrial supply chain. This paper provides a systematic analyze on China's EV industrial integration and develops a framework to investigate its mechanisms in promoting industrial development. In particular, we explored the crucial role of coordinated integration along the industrial supply chain in leveraging the comparative advantages of each segment and building overall international competitiveness. Finally, pathways and policy recommendations are proposed for promoting the high-quality development of other strategic emerging industries through industrial integration and coordination.*

Keywords: *Electric vehicle industry ,industrial integration and coordination, strategic emerging industries*

JEL Classification Codes: O14, E65

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1. Introduction

In recent years, China has witnessed the rise of several strategic emerging industries that have driven technological advancement and overall industrial development. Among them, the electric vehicles (EV) industry is currently at the forefront of international industrial competition and is crucial for decarbonizing the road transportation sector, promoting the growing automotive industry, and achieving national energy security goals. In the short span of the last two decades, China has emerged as a leader among the world's major producers of electric vehicles, and a number of its EV original brand manufacturers (OBMs) has surpassed traditional global automotive leaders in sales growth, market penetration, and production technologies. As of 2023, the total sales of Chinese EV OBMs contributes over 50 percent in the global EV market, and along with the high quality and performances of the EV products, the production costs and average prices are significantly lower than their foreign counterparts (IEA, 2024). Moreover, the success of China's EV producers does not take place in isolation. It is

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accompanied with the emergence of innovative and globally competitive local enterprises in various supply chain segments of EVs. This phenomenon has led to the following questions: Does the supply chain integration and coordination contributes to the development of China's EV industry, and what are the key driving forces?

Existing research and discussions have investigated the level of integration for the EV industry, including local clustering and integrated innovation networks for the EV and other industries in countries such as the United States, Europe, and Japan, and analyzes the differences in the composition and network structure of China's relevant industrial chains and innovation networks (Zuo et al., 2020; Xiao et al., 2022). In terms of the integrated development of upstream and downstream industrial chains, some research literature has delineated the thematic characteristics of the overall structure and coordinated development of the innovation and integration of China's new energy industry through the creation of a patent citation network (Guo and He, 2017; Su and Cao, 2022). Integration of producer services with EV or other manufacturing sectors is critical for increasing service efficiency and realizing economies of scale and specialization, and the EV industry must embrace technological and product innovations to achieve high-end development (Wu and He, 2016; Liu and Shao, 2020). However, in the literature, less attention has been devoted to investigating the development patterns and the nature of EV supply chain integration and the synergies with other emerging sectors.

In this paper, we systematically analyze the development of China's EV industry through the lens of its industrial supply chains, clusters and networks. We examine the development experiences of upstream, midstream, and downstream sectors within China's EV supply chain, in order to gain a comprehensive understanding of the integration and coordination among different segments. By exploring how these segments interact and align, we highlight the mechanisms driving the industry's rapid growth and comparative advantages on the global stage. This analysis provides insights into how strategic integration across supply chains can enhance efficiency, innovation, and market responsiveness. Furthermore, we offer policy implications for other emerging industries, emphasizing the importance of fostering a coordinated approach to supply chain management that can drive sustainable growth and technological advancement. Our findings serve as a roadmap to promote the integration and coordination of industrial systems and technological development..

The remainder of this study is organized as follows: Section 2 examines, the development experiences of China's EV industrial chains and how upstream, midstream, and downstream sectors leverage its comparative advantages based on endowment structure and industrial technology positions. Section 3 analyzes the mechanism of how coordination and integration promotes industrial development, focusing on the industry's key characteristics. The final section puts forth policy suggestions.

2. Integration and Coordination in China's EV Industry

Amidst the intensifying economic globalization and inter-firm division of labor, industrial chains have emerged as a key factor for industrial development. At a granular level, industrial chains represent supply-demand relationships for the exchange of raw materials, technologies, intermediate inputs, and services between upstream and downstream enterprises, forming a chain of intra-product division of labor (Shao and Li, 2007). As a key aspect of industrial chain coordination, firms share and combine resources such as capital, technology, talent, and information to raise efficiency and reduce cost. In comparison to such coordination, industrial chain integration is a dynamic process where in-depth interactions and collaborations have blurred the boundary between manufacturing and service processes, enhancing their level of integration and giving rise to an interactive ecosystem through the permeation and overlap of various industrial sectors. By facilitating the flow and aggregation of resources, information, and technologies within individual industries, the integration of industrial chain sectors enables companies to combine resources effectively, develop synergy for technological innovation, and promote the technological progress and upgrade of industries (Zhao, 2014). In the development of China's EV industry, the endowment structure and technological progress of the upstream, midstream, and downstream sectors have jointly contributed to the collaborative integration of the industrial chains, serving as driving forces for the EV industry to maximize its potential comparative advantages and enhance its international competitiveness.

2.1 Development of China's EV Industrial Chains

Over the past two decades, China's EV industry has risen to global prominence in terms of technological performance, sales volume, and production capacity. Furthermore, innovative Chinese companies have sprung up in a variety of industrial sectors, exhibiting international competitiveness. EV industrial chains are divided into three sectors: upstream, midstream, and downstream. The upstream sector manufactures anode and cathode materials, as well as mineral resources. The midstream includes battery research and development, as well as manufacture of motors and electronic control systems. The downstream industry includes automobile production, software, electronics, as well as the construction and operation of supporting infrastructure, such as charging and battery swap facilities, as well as smart power grid systems (Figure 1). Over the past two decades, China's upstream EV industrial chains have developed and reached global standards, and downstream EV production has also made remarkable progress. The increase in demand has pushed local producers of critical components to attain world-class manufacturing, cost management, and technological refinement at the midstream level within a few years. Furthermore, rapid progress has been made in the area of downstream charging infrastructure.

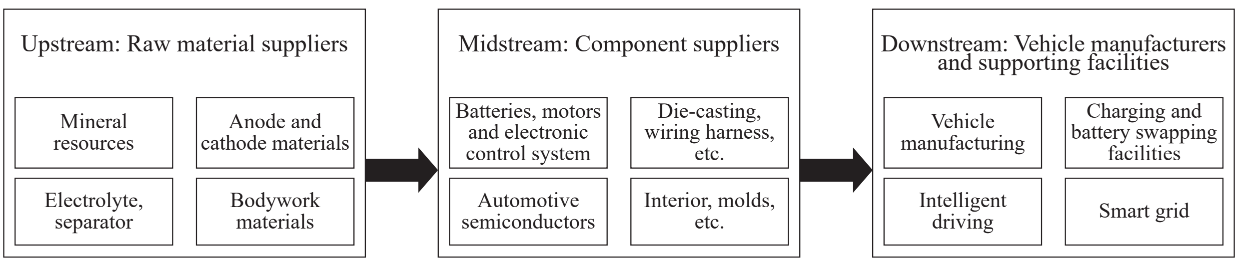

Figure 1: Composition of the EV Industrial Chains

Source: Compiled based on Chen and Wang (2014).

Japanese businesses occupied 90% of the global lithium-ion battery market during the 1990s due to their groundbreaking innovations in the technology. China is still in the research and development phase of technological advancements in the consumer electronics sector, which is the primary market for lithium-ion batteries. With the rapid growth of the global consumer lithium battery market and globalized supply chain distribution, Japan and South Korea moved certain lithium battery production operations to China in the decade following 2001. Meanwhile, Chinese companies began to produce and export key battery components.

The '863 Program', which began during China's 10th Five-Year Plan (FYP) period (2001-2005), unveiled an embryonic stage in China's EV industry. As companies and universities made technological strides and secured patents, the upstream and downstream EV industrial chains started to take form. In 2009, the Chinese government launched large-scale EV demonstration pilot programs, such as the "Ten Cities, Thousand Vehicles" initiative. In the following five years, China's EV production and sales soared. In 2015, China surpassed the United States to become the world's largest EV market. Between 2016 and 2017, Chinese companies made significant advances in the core materials and technologies of batteries, motors, and electronic control systems. Rapid breakthroughs in power battery technologies, along with significant production cost reductions, have resulted in continual improvements in EV range. Burgeoning private-sector consumption and rapid market growth have supported China's global market leadership.

Since 2018, China has removed the market access threshold for foreign-funded companies. As a result, many EV makers and parts and component suppliers which lacked proprietary production capabilities withdrew from the market. Competition has led to greater industrial chain sophistication. With a spike in EV sales, the downstream sectors including charging infrastructure and other facilities expanded swiftly. The growing availability of charging points paved the way for higher EV adoption rates. China's EV industry now has fully integrated local industrial and supply chains, efficient and low-cost production capabilities, and six regional industrial clusters. The EV industry has progressed from a vertical supply relationship to an integrated, efficient industrial system built on specialized division of work.

2.2 Endowment Conditions for Industrial Chain Integration

Unlike the traditional automotive industry, the EV industry features key technologies that allow for integrated industrial chain development. The enabling factors can be summarized as follows: First, technology characteristics and industrial openness. Compared to traditional automobile internal combustion engine technology, key EV technologies such as batteries, motors, and electronic control systems are based on codified knowledge and are more transmissible, and widely applicable across the industry. Technological progress in the traditional automotive industry is more reliant on implicit knowledge gained during internal manufacturing processes, which is detrimental to information interchange and shared technical innovation between companies. Meanwhile, EVs do not require engines and gearboxes seen in conventional gasoline vehicles. The EV industry is neither subject to traditional market access obstacles and monopolistic tendencies, nor is it reliant on a certain technology route or business strategy. This has given EV enterprises in various countries equal opportunities to compete with each other from nearly the same starting point.

Second, rapid technical and product development. EVs have simpler powertrain and chassis systems than typical automobiles, reducing the complexity of gearbox and engine compatibility. This simplicity has allowed EVs to be manufactured at lower costs and with faster technological and product cycles. To remain competitive, businesses must improve product performance through continuous R&D and product innovation. Rapid technology improvement and product innovation necessitate continuous R&D investment to meet shifting demand and consumer expectations for high-performance, intelligent products.

Third, close ties with cutting-edge technologies. The EV industry is intertwined with artificial intelligence (AI), IT, renewable energy, and other transformative technologies. The EV industry, driven by electrification, intelligence, and Internet-based operations, is built on cutting-edge technology ranging from products to processes. In comparison to the traditional automotive industry, the EV industry invests a major portion of its sales volume in R&D and employs a relatively large number of R&D personnel, expediting intra-industry innovation, technological breakthroughs, and knowledge spillovers. The EV industry provides important technological assistance and a diverse range of innovation opportunities to numerous industrial chain sectors, accelerating technological progress and market development.

China's endowment structure and technological superiority have paved the ground for integrated development throughout EV industrial chains, allowing potential comparative advantages in various processes to be converted into competitive strengths[1].

2.2.1 Upstream raw materials: Cost advantage amplified by downstream demand

Upstream raw materials supply for the EV industry includes materials for the battery system and bodywork components. Mining operations for battery raw materials, refining, chemical processing, and anode and cathode material manufacturing are among those that have a significant impact on the overall performance and cost of EVs due to their resource and capital-intensive nature, complex preparation process, and diverse technological paths. China's natural resource endowment and factor endowment have enabled local firms in the industry to cut their manufacturing costs. China has a competitive advantage in other raw material areas such as steel smelting and alloy production. The benefits of low cost and great efficiency in upstream industrial chains can be amplified by economies of scale resulting from huge downstream demand.

In terms of raw materials, most electric vehicles (EVs) use lithium batteries as their power source. In contrast to the strong demand, critical mineral resources such as lithium, cobalt, and nickel, which are required for battery manufacturing, have remained in short supply. As a result, raw materials have become a major impediment to the EV industry in various countries. China has a relatively abundant supply of raw materials for power batteries, including lithium, iron, manganese, alkene, and graphene, and its mineral resource suppliers and refinery firms are among the largest in the world. The inherent self-sufficiency of vital materials resources results in low mining and transportation costs[2]. According to McKinsey & Company, China currently produces 28% of the world's lithium and 23% of its cobalt. Furthermore, Chinese firms have ensured the supply of raw materials by purchasing significant overseas natural resources and forming long-term supply partnerships. As a result, they have compensated for supply chain gaps caused by manufacturing process constraints and a lack of raw material self-sufficiency, lowered the risk of supply shortages and raw material procurement costs, and boosted business profitability[3]. Chinese enterprises have gained a competitive edge in the production of critical raw materials for lithium-ion batteries such as anode and cathode materials, separator, and electrolyte through mature preparation technologies, effective cost control, and manufacturing capacity expansion driven by massive demand from downstream sectors such as consumer electronics and power batteries. Figure 2 shows that Chinese manufacturers account for more than 50% of EV upstream manufacturing and supply capacities, giving them a dominating global position.

[1] The endowment structure, according to the new structural economic theory, consists of natural endowment, factor endowment, and institutional endowment. Factor endowment structure refers to the relative abundance of capital, labor, human capital, and land, which, along with natural resource endowment, determines enterprise production costs; institutional endowment contributes to production costs by influencing business transaction costs. Refer to Justin Lin et al. (2019) for detailed discussions.

[2] According to USGS data, China holds the world's largest rare-earth reserves, accounting for more than 90% of medium and heavy rare-earth resources. China holds around one million tons of lithium ore deposits, accounting for 7.14% of total reserves and ranking fourth in the world, as well as 55 million tons of graphite reserves, accounting for 22% of the total and more than 65% of total production output.

[3] Tianqi Lithium, for example, acquired a 51% stake in Talison Lithium and a 26% stake in Chile's SQM lithium producer in the Atacama salt flat; Jiangxi Ganfeng Lithium owns nearly half of Austria's Mt Marion lithium mine project and more than 80% of Argentina's Mariana lithium brine project (Sanderson, 2019).

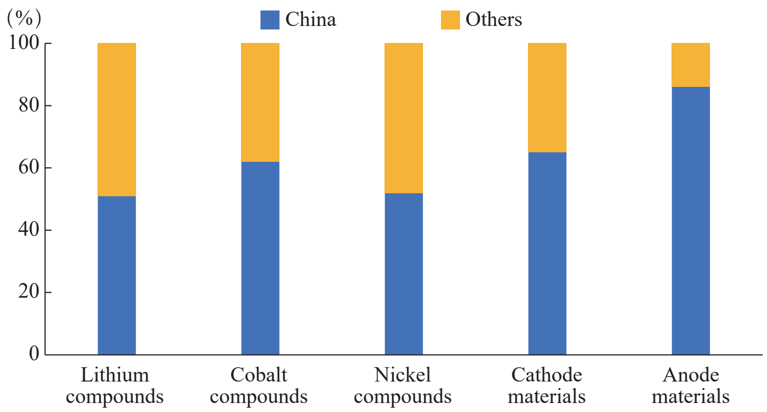

Figure 2: Share of China's EV Battery Raw Materials in Global Supply

Source: Kumar (2020).

China's abundance of professionals, cutting-edge technologies, and strong talent pool in the composite materials and electrochemistry sectors offer new development opportunities for the raw material preparation technologies. Leading Chinese companies have made significant strides in various advanced technologies through continuous research and development efforts. Notably, China leads the world in patent filings for two key anode material technologies—lithium iron phosphate and ternary lithium—demonstrating the technological prowess and innovation capabilities of Chinese firms (see Figure 3).

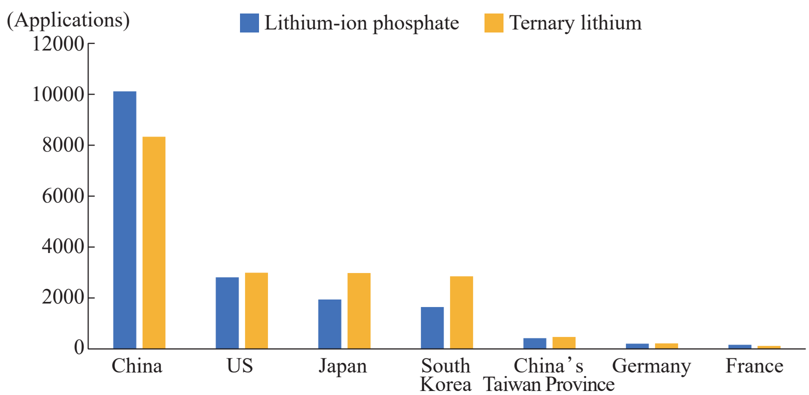

Figure 3: Number of Cumulative Patent Authorizations for Cathode Materials under Different Technological Paths

Source: WIPO database.

2.2.2 Midstream components: Technological strength promotes vertical integration

Midstream manufacturing of components, including electrical and smart components, has a direct impact on the core competitiveness of EV products. These components are high-tech and capital-intensive with a high degree of specialization. Due to relatively short product and technology cycles, EV components are subject to functional and technical compatibility requirements. Therefore, their technological progress is primarily driven by downstream demand.

We divide different EV components into labor-intensive, capital-intensive, or technology-intensive based on their factor intensities. Interior and exterior, as well as car glass, are among the most labor-intensive components. Such activities as manual assembly and quality inspection necessitate considerable manual or semi-automated tasks. Capital-intensive components mostly include integrated diecasting machines, high voltage wiring harnesses, molds, and connectors, which need considerable upfront investments in factory building, equipment purchase, and process development. With the technology and experience in supplying traditional automotive components, Chinese component makers have built a considerable cost advantage and technological accumulation, resulting in fairly high overall product competitiveness. Driven by downstream consumer demands for lightweight bodywork, optimal spatial layout, and quick charging technology, EV makers have helped to increase technology content and value addition of traditional components. Currently, Chinese companies have exhibited considerable technological advantages with integrated diecasting machines and molds. There has also been a tendency of domestic substitution and technological catch-up for high-voltage harnesses and connectors. Furthermore, Chinese companies lead the world in terms of output, manufacturing, and technology for new products like skylight glass and automobile intelligent interactive headlamps.

The majority of technology-intensive components are emerging electrical and smart features, such as batteries, motors, and electronic control systems, as well as automotive-grade chips. To stay ahead of the curve in core technologies, Chinese companies must keep investing money into research and development. In the power battery sector, raw material manufacturing and R&D complement each other, as does the component industry. On the one hand, upstream cost advantages are transferred to midstream power battery makers. On the other hand, both parties have developed synergy through a close R&D relationship. Manufacturers of power batteries have expanded the range and charging rates of their products, as well as sped up the production of semi-solid-state batteries, thanks to innovations in electrolyte materials, long-range power batteries, and ultra-high nickel ternary batteries. Furthermore, Chinese battery makers have enhanced cell materials and structures in collaboration with upstream suppliers to meet the technological criteria of high energy density, fast charging, and long cycle life. As a result, they have achieved international leadership in lithium-ion phosphate batteries and ternary lithium battery technologies. Figure 4 shows that six of the top ten global firms in terms of power battery installations in 2023 were from China, accounting for 63.5% of the total market. CATL has been ranked top in the world since 2017[4].

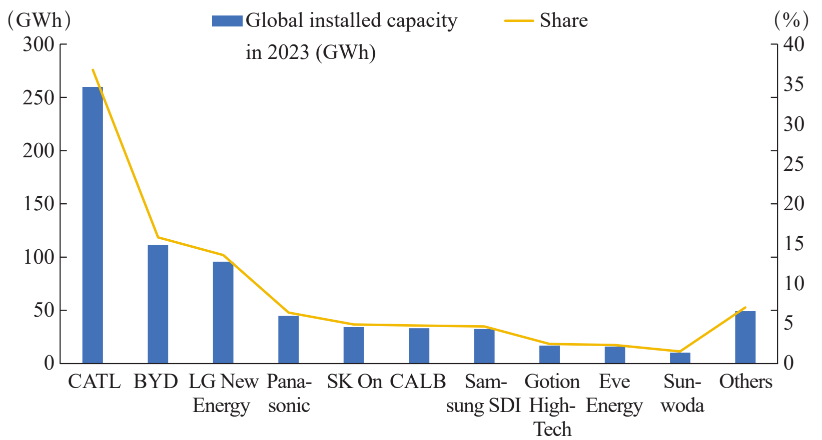

Figure 4: Global Installed Capacity of Power Batteries (GWh) and Share (%) in 2023

Source: SNE Research (2024).

[4] According to SNE Research (2024), the global installed capacity of power batteries increased by 38.6% in 2023 from the previous year, which pales in comparison with the growth rate of 40.8% for CATL and the growth rate of 56.9% for BYD.

When it comes to motor and electronic control systems, Chinese midstream manufacturers and downstream automotive OEMs have achieved fairly good coordination and synergy through investment or acquisition. Because of their low production output and high initial procurement costs, most automotive OEMs have made significant investments in independent R&D of electrical powertrain technology. With rising sales volumes, some automotive OEMs began to build their own motor systems. Companies such as FinDreams Powertrain, a BYD subsidiary, have held a leading position in the motor and electronic control systems sector, which develops alongside automotive OEMs. The motor and electronic control systems of mid and high-end vehicle models are created by automotive OEMs with a low market concentration. In terms of research and development, EVs must meet rigorous specifications, such as lightweight design, which necessitates integrated motor and electronic control systems. Chinese automotive OEMs, represented by indigenous EV brands, have achieved significant progress in integrated solutions, establishing a leading industry position.

The electrification, intelligence, and networked features of EVs have increased demand and performance expectations for automotive-grade chips. However, companies from Europe, the United States, and Japan have nearly monopolized the market for medium-end system-grade chips and high-end AI chips in China. This underscores the reality that China has yet to build its own capabilities for key automotive-grade chips, although it is closing the gap. Chinese businesses led by Huawei and Horizon Robotics have developed independent R&D capabilities for low-performance system-grade chips, but they are behind developed countries in terms of processing power and manufacturing process.

2.2.3 Downstream vehicle manufacturing and services: Application scenarios drive cross-sectoral collaboration

Downstream industrial chains generally involve vehicle manufacturing, sales, service, and the installation of auxiliary charging and battery swapping infrastructures. Automakers, as key players in the EV industrial chains, have gained experience in electrification and intelligence technology R&D, mass manufacturing, and differentiated marketing strategies. Meanwhile, the rapid development of auxiliary charging and battery swapping infrastructure is driving the further growth of the EV industry.

In recent years, Chinese automakers have made great advances. They have controlled costs by integrating component supply while maintaining supply chain security and stability, hence enhancing their viability. Based on their understanding of consumer needs and access to shared information from suppliers, they can differentiate their products to gain a competitive advantage. According to the Ministry of Industry and Information Technology (MIIT), Chinese-made EV brands accounted for 80.2% of total domestic EV sales in 2023. Economies of scale from increased EV manufacturing output have provided automakers with a cost advantage while also paving the road for smart vehicle technologies. Intelligence is a vital trend in the development of EV downstream supply chain, and self-driving is based on two technological pathways: visual technology and multi-sensor integration. During their early stages of development, China’s EV manufacturers invest heavily in self-driving technologies, gaining an first-mover advantage. Meanwhile, many of the conventional automakers are looking for ICT solutions to overcome technological impediments to automatic driving. With their powerful underlying R&D capabilities and proprietary automotive ECU chips, Huawei and other ICT companies were the first to achieve advanced smart driving in urban districts at high speeds without the use of HD maps, offering competitive solutions to traditional Chinese automakers. Downstream automotive OEMs have formed close links with companies in AI, big data, and the Internet of Things (IoT) through collaborative R&D.

As a public good, downstream charging infrastructures are essential to the sustainable development of EV industry. According to data from the China Electric Vehicle Charging Infrastructure Promotion Alliance (EVCIPA), China surpassed Europe in 2016 as the world's largest market for public charging infrastructure. In 2019, China accounted for more than half of the world's charging piles, more than the United States, Europe, and Japan combined. China leads the world in technological performance, thanks to its strong capabilities in quick charging and battery swap technologies. According to data from the International Renewable Energy Agency (IRENA), China surpassed the United States in 2017 in terms of the number of charging pile patents globally. As of 2021, China accounted for over half of all charging pile patents worldwide (see Figure 5). China's current charging system, based on the 400V platform design, is technologically mature, low-cost, and has a wide range of applications. Chinese EV makers have increased their focus on developing quick charging technology to suit consumers' demands for range and charging speed, producing high-rate charging models based on the 800V high-voltage platform and hastening fast-charging development for both the vehicles and charging stations.

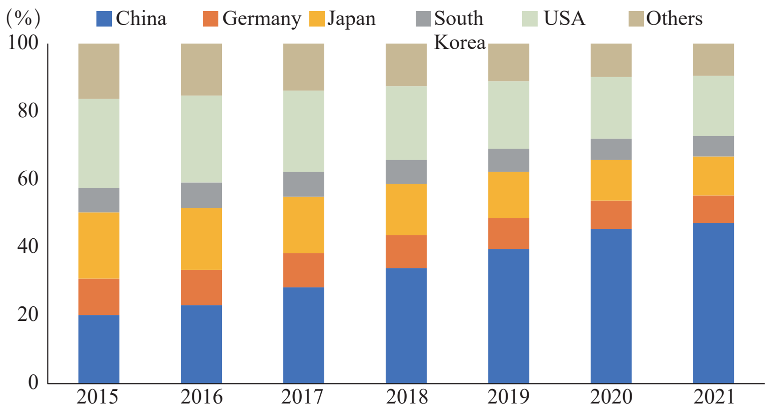

Figure 5: Cumulative Number of China's EV Charging Pile Patents as a Share of World Total

Source: IRENA (International Renewable Energy Agency).

2.3 Problems of the Coordination and Integration within the EV Sector

Over the past two decades, China's EV industrial chains have reached a high degree of integration. However, the long-term, difficult, and complex nature of the EV industry's future development cannot be underestimated.

China is catching up with leading nations in terms of patent filings for essential technology used in the upstream of the supply chain. As latecomers, Chinese enterprises have focused on the functional and application components of their patent inventions, such as formula ratio adjustments and improvements. Chinese companies are at a disadvantage in core technological competitiveness because they rely on European, American, Japanese, and South Korean companies for raw material patents, which are required for R&D and manufacturing[5].

Meanwhile, driven by the growth of intelligent cockpits and autonomous driving technologies, both the volume and performance requirements for automotive-grade chips have continued to escalate. While domestic firms such as Huawei and Horizon Robotics have achieved independent research and

[5] For instance, in terms of cathode materials, the American company 3M and Hydro-Québec of Canada have monopolized the basic patents of ternary materials and lithium iron phosphate cathode. For electrolyte and separator, Panasonic and other Japanese enterprises have registered the basic patents.

development in low-performance system-on-chip (SoC) designs, they have yet to make breakthroughs in the core manufacturing technologies for autonomous driving–related AI training chips. In this domain, there remains a pronounced gap in both computing power and process nodes when compared with international frontiers. In particular, with regard to AI training chips for autonomous driving, the first-mover advantages held by U.S. chipmakers such as NVIDIA continue to constrain Chinese firms' capacity for technological innovation. As a result, supply bottlenecks persist in automotive-grade chips, ultimately restricting the advancement of higher computing power, enhanced algorithms, and large-model-based autonomous driving solutions.

At the same time, mid-stream segments of the industrial chain, specifically the new energy vehicle (NEV) components sector, face dual pressures from intensifying market competition and accelerated industry consolidation. In recent years, rapid expansion of the downstream NEV market combined with a broadly shared consensus on green transitions have attracted large-scale inflows of social capital, resulting in a certain degree of "herd behavior" (Lin, 2007). This has led to a mismatch between capacity expansion and actual market demand, pushing the industry into a phase of structural adjustment. If the market fails to spontaneously adjust and achieve effective clearance, exacerbating problems may not only lead to the underutilization and waste of resources such as capital, land, and skilled labor, but also squeeze profit margins and reduce overall industry profitability, undermining the sustainable development of the electric vehicle sector. As the industry matures, a process of survival of the fittest is inevitable, placing higher demands on cost control and product innovation among mid-stream component manufacturers. This pressure, in turn, compels firms to further integrate and optimize their supply chains and production processes. Ultimately, it drives enterprises to enhance their market competitiveness through technological innovation and product differentiation.

3. Policy Paths for Coordination and Integration of EV Industry

China's EV industry has risen quickly as a strategic emerging industry for two reasons: first, many stages within the EV sector have gained international competitiveness in terms of cost, efficiency, and security through collaboration, integration, and synergy. They range from raw material supply to core component manufacture, EV production, and infrastructure construction. Second, upstream and downstream industrial chains have decreased the risks of independent innovation by collaborating to build cutting-edge core EV technologies. Therefore, producers are able to quickly upgrade its products and to maintain technological advantages.

In terms of the coordination and integration within the EV sector, the critical characteristics of strategic emerging industries have revealed significant differences in the core mechanism by which upstream and downstream EV supply chains contribute to coordinated industrial development when compared to traditional industries. As a result, we need to look at potential policy avenues from multiple dimensions that might allow these sectors to work together more effectively.

3.1 Characteristics and Mechanisms of EV Supply Chain Integration and Coordination

After two decades of cultivation and development, China's EV industry has not only grown by leaps and bounds, but also made significant strides in industrial supply chain integration. Compared to traditional gasoline vehicles driven by the internal combustion technology, China's EV industry has shown distinct features that have transformed industrial organization and accelerated innovation and growth. First, the industrial organization of the supply chain has been evolving. Traditional automotive industry chains have a static, linear structure from upstream to downstream sectors. In contrast, EV industrial chains have evolved into a networked nonlinear ecosystem that goes beyond the traditional hierarchical supplier system. The blurring of boundaries in the division of work and manufacturing process has led to a production process ecosystem.

For instance, China's emerging EV brands position themselves as automakers while many of them do not actually participating in vehicle manufacturing and assembly. They have optimized resource allocation and fostered core competitiveness by focusing their company operations on high-value functions such as sales, branding, and R&D via outsourcing and partnership. Second, various stages of the EV supply chain have engaged in interactive extensions. In the EV industry, linkages between upstream-downstream industrial chains extend beyond the product supply-demand relationship. Companies have hastened the diffusion and application of breakthrough technology by investing in equity and establishing collaborative platforms. With their extensive experience in product R&D, sales, and supply chain management, IT companies like Huawei have established smart driving open platforms for automakers to embrace electrification and intelligent transition. Besides, the scope for integration and coordination is broadening. The development of core technologies in various stages of EV supply chains has shifted from an production-based to a scenario-based approach of innovation driven by the consumer market and user needs, with a greater emphasis on commercialization in the downstream market to stimulate product R&D and innovations. Companies from different sectors have teamed up to launch intelligent and customized solutions that meet customer demand for smart driving and connected cars, among other emerging technologies.

The mechanisms for coordination and integration along the supply chain are threefold. First, the integration may increase upstream and downstream economies of scale. Since 2001, China has developed a "vertical structure" in which state-owned enterprises (SOEs) dominate the sector of upstream intermediate inputs and private enterprises dominate the downstream sectors (Li et al., 2014). Upstream-downstream integration has allowed for the transmission of low-cost manufacturing advantages from upstream to downstream sectors, resulting in lower costs and higher profit margins for final products. Price cuts will unlock market potential for strategic emerging industries and support the expansion of downstream end products, which will drive growth in upstream capacity expansion, lower marginal costs and create a virtuous cycle of reciprocal reinforcement.

Second, industrial chain integration can efficiently shorten the complete product lifecycle, from concept to R&D and manufacturing. Time-to-market is critical in strategic emerging industries due to fast technological progress and a relatively short R&D cycle. Being able to quickly launch new products will allow businesses to respond to market demand, gain market share, and secure a valuable window of opportunity for future product improvements and market development. Hence, upstream, midstream, and downstream integration can give companies a market advantage by building efficiency-based competitive strengths.

Third, integration of the supply chains may encourage companies to work together on R&D, speed up innovation and the dissemination of technology and know-how, and encourage collaborative value chain upgrades along technology paths that could give companies in the upstream, midstream, and downstream sectors a competitive edge. By sharing information, technology, and resources, upstream companies can conduct targeted product R&D based on user needs for downstream products, resulting in value chain upgrades at both ends. Meanwhile, disruptive innovations in the upstream may result in distinct innovations in the downstream, which would also lead to creation of products with higher value-added. Finally, major-power competition has evolved into competition among their respective supply chains. Industrial chain integration and development will not only avoid 'chokepoint' problems in the supply of upstream products while ensuring supply chain security and stability, but will also reduce uncertainty in downstream product demand, increase supply chain resilience, and develop a security comparative advantage. As a result, promoting upstream and downstream supply chain efficiency, stability, and integration will provide a significant boost to strategic emerging industries.

3.2 Pathway for Promoting Integrated Industrial Chain Development

As demonstrated by the mechanisms outlined above, vertical coordination among upstream, midstream, and downstream sectors leverages each sector's potential competitive advantage based on its endowment structure. Meanwhile, cross-sectoral integration may open up new avenues for encouraging R&D and creation of new goods and technologies, allowing China's EV industry to advance toward the global forefront and strengthen its competitive edge. Therefore, the synergistic development of the EV value chain in strategic emerging industries should focus on integrating resources vertically across different sectors within China's robust industrial structure. Fostering horizontal innovation and collaboration across sectors will capitalize on China's comprehensive and interconnected industrial networks, driving further technological breakthroughs and reinforcing the industry's global standing.

3.2.1 Coordinating vertical industrial chain integration for complementary advantages of various sectors

Coordinating vertical interactions and cooperation among industrial chain companies will highlight the comparative advantages of the upstream, midstream, and downstream sectors. In the EV industry, efforts should be taken to reduce information asymmetry and the cost of collaboration between upstream raw material suppliers, midstream component makers, and downstream product or service suppliers. The rational manufacturing distribution and the development of various forms of collaboration for innovation and R&D have effectively given rise to the comparative advantage of endowment structure in each sector, forming an efficient and stable supply chain system and strengthening international competitiveness in terms of cost, efficiency, and technology.

For the opportunities, China's EV industry stands out for large potential market demand, short technological cycles, and cost advantages for upstream and midstream component manufacturers. With sufficient information flow, downstream manufacturers can respond quickly to automakers' requirements while also completing process and technical advances in line with the trend of artificial intelligence (AI). Chinese manufacturers have demonstrated considerable scale and technological advantages in the production of basic electrification components such as batteries, motors, and electronic control systems. They have effectively collaborated with upstream raw material suppliers and downstream automakers, fostering a virtuous cycle of shared resources and collaborative R&D. This partnership model not only reduces the uncertainties of innovation and R&D, but also enhances core competitiveness from R&D to product innovation, leading to a unique strength of the EV industry.

On the challenging side, China's strategic emerging industries face unstable supply of essential components, as well as significant patent barriers in the context of global industrial competition. This could severely hamper sustained industrial growth. To ensure sustained development of the industry, upstream, midstream, and downstream sectors must consolidate effort and form long-term partnerships, for instance for the R&D alliance of EV intelligence component makers to support the design and manufacturing of automotive semiconductors and the advancement of autonomous driving technologies. Such collaboration is vital for overcoming fundamental technological barriers and addressing weaknesses within the industrial chain, paving the way for greater self-reliance and resilience.

3.2.2 Propelling horizontal integration to unleash cross-sectoral innovation potentials

Deepening cross-sectoral and cross-hierarchical interactions and collaboration will result in an industry-wide ecosystem that promotes EV innovations. The new round of technological revolution has blurred the lines between economic sectors, creating opportunities for coordination and integration. China's EV industry has benefited from the trends of electrification and intelligence, capitalizing on its huge skill pool and technological accumulation to upgrade traditional industries such as power batteries and motors. Furthermore, integration with AI solutions has resulted in the emergence of new technologies and products.

Technological integration between industries and companies is a key driver of industrial development. Companies can generate more diverse and competitive products and services by breaking down industry barriers and integrating technical capabilities and know-how across sectors. There has been an increasing trend of closer collaboration between EV firms and new-generation IT companies, which is driving the upgrade and transition of automotive supply chains. With their AI professionals, technology, and ecosystems, tech titans led by Huawei have enabled Chinese EV manufacturers to produce smart products and services, thereby increasing their core competitiveness in autonomous driving, smart power grids, and connected cars.

Furthermore, joint R&D between industry, universities, and research institutions is a vital step toward developing a sectoral innovation ecosystem. The goal of such collaboration is to facilitate the mutual permeation, intersection, and reorganization of technologies and know-how across various sectors, as well as to match the results of frontier scientific research conducted by universities and research institutions with the actual needs of businesses to generate groundbreaking new technologies and products. Numerous platforms for collaboration between industry, universities, and research institutes have been formed under the "three horizontal, three vertical" structure, which includes hybrid cars, electric vehicles, and gasoline vehicles, as well as batteries, motors, and electronic control system. Universities and research institutes have partnered with midstream and downstream industrial enterprises for basic research into new technical routes and solutions, such as sodium-ion batteries and hydrogen fuel cells. Such research alliances have the potential to break away from foreign monopolies on core patents for anode and cathode materials, separators, and electrolytes, establishing an early-mover advantage along emerging technical paths.

4. Concluding Remarks and Policy Inspirations

As a key driver for enhancing energy security, promoting green economy, and upgrading of the automotive industry, China's EV industry provides valuable lessons and insights to other strategic emerging industries. Over the past two decades, China's EV industry has emerged as a new global leader in terms of manufacturing technology and cost-effectiveness across various segments, from upstream raw material supply and midstream component production to downstream vehicle manufacturing and related services. By adopting an integrated development strategy, different sectors within the China's EV industry have shared resources to accelerate technological advances and industrial upgrading, thereby enhancing their global competitiveness. This development experience sheds light on the ways in which other strategic emerging industries might pursue coordinated and integrated development.

Strategic emerging industries serve as a catalyst for economic restructuring and global competitiveness due to their ingenuity and growth potential. They are ready to serve as new engines that propel China's high-quality development forward. However, strategic emerging industries face various obstacles as a result of their technological sophistication, knowledge and technology-intensive nature, as well as positive spillovers. Externally, some multinational corporations have transferred manufacturing activities to other countries due to geopolitical and supply chain security concerns (Ni and Tian, 2021). Internally, China's strategic emerging industries remain heavily reliant on imported critical upstream components, such as core equipment, semiconductors, and essential chemicals, which are vulnerable to supply interruptions.

In this context, different sectors of strategic emerging industries must share and integrate resources along the vertical axis of supply chains. Furthermore, it is critical to leverage China's advantage of complete industrial chains to boost innovation and collaboration across sectors. The following lessons can be drawn from the coordinated development of EV industry: first, proactive efforts should be made to coordinate the vertical integration of industrial chains in strategic emerging industries, and by lowering transaction costs between companies, foster a virtuous cycle in which EV sectors complement their strengths. Close collaboration between different stages of the supply chain will speed up the process from conceptual design to product marketing, offering businesses an early competitive advantage. Second, the horizontal integration of different sectors creates an innovation ecosystem by encouraging technical integration among enterprises from various sectors. On the one hand, the government may construct a mechanism to promote technological integration, such as technical exchange platforms and integration funds, to provide opportunities and financial support to enterprises seeking to integrate technology. On the other hand, enterprises should improve their R&D and innovation capabilities, as well as actively explore opportunities for collaboration with those from other sectors to horizontally extend the scope of integration and coordination. By encouraging vertical integration and horizontal coordination, the government should promote the integration, clustering, and ecosystem development of industrial chains, as well as fully exploit the endowment and advantageous scale of China's industrial chains, in order to increase the international competitiveness of strategic emerging industries and maximize their role in the development of the modern industrial system. CE

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