中国创新驱动的演化：从追赶到超越追赶

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摘　要：改革开放以来，中国深入实施创新驱动发展战略，通过追赶到超越追赶的技术追赶方式转变，创新驱动从开放条件下动态的二次创新转向高水平开放条件下的一次创新。本文通过考察新兴智能制造和独角兽企业两大创新驱动新势力，提出在技术生命周期加速缩短、技术范式加快转变的新一轮科技革命和产业变革背景下，中国迫切需要加快建设助推企业超越追赶的新型国家创新体系，摆脱既定技术范式制囿，抢抓“范式转变”的战略机会窗口。本文将为中国以创新驱动引领高质量发展提供理论指导。展望未来，本文还提出创新驱动必须保持对快速发展趋势的适应。

关键词：创新驱动　范式转变　技术追赶　超越追赶
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*Science*杂志曾于创刊125周年之际公布了125个全球最具挑战性的科学问题，其中有一问：“为什么一些国家向前发展，而一些国家发展停滞？”（Kerr，2005）。一般来说，发展中国家的技术水平较之于发达国家低。前者的技术追赶过程常常表现为不断向后者学习。尽管这种后进者向领先者的学习未曾中断，并且我们的确看到发展中国家在保持不断进步，但这种技术差距始终难以弥合，拉美和东南亚等国家落入“中等收入陷阱”的惨痛教训令人扼腕，而中国在很大程度上成功实现了技术水平上与发达国家的趋近，甚至在部分领域实现了超越。中国经济增长奇迹不仅具有典型性，而且具有特殊性，也是西方经典理论难以解释的。中国经济增长的驱动力到底是什么？改革开放以来，华为等一大批领袖企业依靠创新驱动迅速崛起的事实，从实践上回答了这一问题。

一、创新驱动的成就：改革开放以来的经济表现

（一）创新驱动成为增长第一动力

改革开放以来，中国经济取得了巨大的成就，呈现出高速增长的态势。从1978年到2022年，中国GDP年均增长率达到9.5%，远高于全球平均水平。这使中国成为世界上第二大经济体，并且离第

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一大经济体美国的差距还在快速缩小之中，见图1。在贸易方面，中国积极开展对外贸易，特别是加入WTO后，出口规模不断扩大。2022年，中国货物进出口总额达42.07万亿元，货物贸易出口国际市场份额接近15%，连续6年保持世界第一货物贸易国地位。在工业化方面，中国逐步实现了工业化进程，特别是在制造业领域取得了长足进步。中国以拥有41个工业大类、207个中类、666个小类，成为全世界唯一拥有联合国产业分类中全部工业门类的国家。2022年中国全部工业增加值达40.2万亿元大关，占GDP比重达到33.2%；其中制造业增加值达33.5万亿元，占GDP比重为27.7%，制造业规模连续13年居世界首位。2022年中国制造业增加值占全球比重近30%，美国仅占16%；而在2001年，中国加入WTO时，制造业增加值占全球比重还只有6%，远落后于当时位居全球第一的美国。

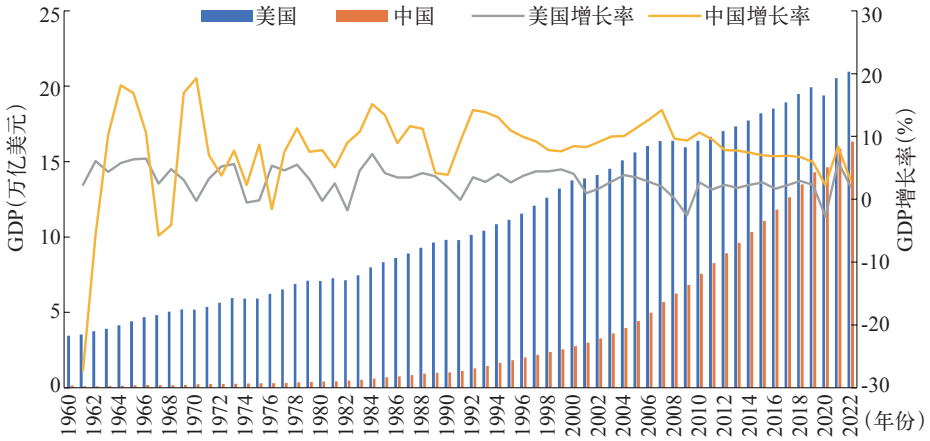

图1：中美GDP及增长率对比（1960~2022年，按2015年不变价美元）

资料来源：作者根据世界银行数据绘制。

如果对比改革开放后中美工业增加值的增长率，发现它们之间存在非常强的相关性，这与改革开放之前两国工业发展的独立性形成鲜明对比，见图2。一方面，中美制造业在国际比较分工上具有互补性，中国制造业在低端产品制造方面具有优势，而美国制造业在高端产品制造方面更具竞争力，双方在全球制造业价值链上的合作，会影响到彼此的制造业增加值增长率；另一方面，中美制造业在全球商品市场上相互依存，美国是中国的主要出口市场，中国是美国的制造业生产基地之一，中美经济的发展状况会对彼此的制造业增加值增长率产生影响。中国制造的产品已经走进了美国的千家万户，以至于没有中国会让美国消费者的生活便利性大打折扣，成本代价高昂（Bongiorni，2007）。

为什么西方主流经济学界认为中国采取的“最糟糕的理论”却创造了经济发展的奇迹？中国为什么能维持如此快速的增长？是西方眼中“最糟糕的政策”让中国产生巨大的成功吗？还是取决于中国还有多少后发优势，取决于中国与高收入国家之间的收入差距？（林毅夫，2019）中国这一个被西方国家视为具备充分低成本优势的劳动密集型经济体，其增长却是由技术变革这一本国相

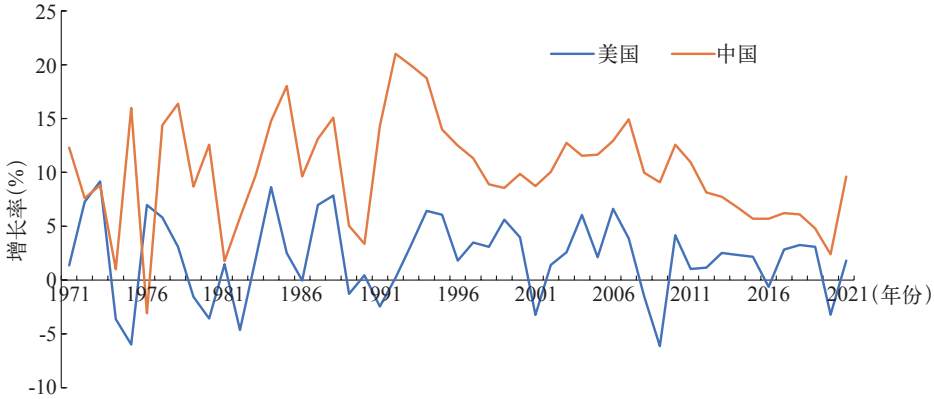

图2:中美工业增加值增长率对比(1971~2021年,按2015年不变价美元)

资料来源:作者根据联合国数据绘制。

对匮乏的生产要素所驱动。中国改革开放的实践证明,务实的创新驱动才是维持经济稳定和高速发展的重要原因。从要素驱动、投资驱动转换为创新驱动,坚持以创新驱动经济增长,是中国克服"中等收入陷阱"的真正力量(吴晓波、吴东,2018)。2022年中国全社会研发经费支出达3.1万亿元,仅次于美国,研发经费支出比上年增长10.4%,已连续7年保持两位数增长,研发经费支出占GDP比重从1978年的1.45%提升到2022年的2.55%,其中基础研究经费达0.2万亿元,基础研究投入比重自2019年以来连续4年超过6%。尽管中国研发支出占GDP的比重在全球依旧偏低,但增长迅速,已成为全世界研发支出增长率最高的国家之一。《中华人民共和国2022年国民经济和社会发展统计公报》显示,2022年,中国授予专利权432.3万件,PCT(Patent Cooperation Treaty)专利申请受理量7.4万件,有效专利1787.9万件,其中境内有效发明专利328万件。从专利数量上来看,中国自2001年已连续多年位居世界第一,成为名副其实的知识产权大国。

(二)持续增长的商业领袖

经济强大的背后是企业的强大。《财富》世界500强的数据表明,在1989年中国仅有1家企业进入榜单,而到了2019年,中国以129家的数量首次超越美国的121家。历史上日本在1995年曾以149家的数量最为接近美国的151家,但是美国始终牢牢占据榜单的首位,而日本则从巅峰一步步滑向失落的二十余年。2022年中国已经有145家企业(其中民营企业28家,占五分之一)进入榜单,超越美国的124家,也远高于日本的47家,中国上榜企业营收占世界500强总营收的31%,首次超过美国,这反映了西方中心主义的跌落,也标志着中国企业全面进入到与西方跨国公司同台竞争的新时代。

中国企业体量上日益增长同时,其创新绩效也显著增强。根据全球知名企业管理咨询公司——波士顿咨询公司2022年最创新公司排行榜,中国的领军科技企业华为(第8位)、阿里巴巴(第22位)、联想(第24位)、京东(第30位)、小米(第31位)、腾讯(第41位)等公司进入了榜单前50。在《2022年欧

盟产业研发投资记分牌》展示的2022年全球研发投入百强企业中，中国企业共有19家进入榜单，华为的研发投入达195亿欧元，在榜单中位列中国第1位、全球第4位。其他入榜的中国企业还包括阿里巴巴（第17位）、腾讯（第18位）、中国建筑集团（第34位）、台积电（第48位）、百度（第53位）、中国铁路总公司（第54位）、鸿海（第55位）、中国交建（第56位）、联发科（第59位）、上汽集团（第61位）、中国铁建（第62位）、中兴（第70位）、美团（第82位）、中国电建（第85位）、中国中冶（第91位）、中国石油（第92位）、快手（第94位）、网易（第98位）。

世界级领袖企业的背后是世界级的领先市场。在新兴数字经济领域，中国秉持开放并拥抱的态度对待新技术和新经济，抢抓新一轮科技革命和产业变革的战略机会窗口（吴晓波等，2019）。第51次《中国互联网络发展状况统计报告》显示，2022年，中国网民规模达10.67亿人，占世界用户总数的21.56%，形成全球规模最大的网络社会。网络支付用户数量为9.11亿，网络购物用户规模为8.45亿。中国网上零售额达13.79万亿元，而美国仅1.09万亿美元，中国网上零售额占社会消费品零售总额44万亿元的31.34%，占到全球电商零售额的37%。中国已建成全球规模最大、技术领先的移动通信网络。中国移动电话用户总数达16.83亿户，5G移动电话用户达5.61亿，占移动电话用户总数的33.3%，发展水平领先全球。中国互联网上市公司数量达到159家，总市值达10.3万亿元。中国数字经济规模达50万亿元，占GDP的比重超过40%。全国在用数据中心超过650万标准机架，算力总规模位居世界第二。重点工业企业关键工序数控化率达到58.6%，数字化研发设计工具普及率达到77%。

改革开放40余年来，中国集成全球科技创新，以数字技术应用和场景创新为重点，后发先至，成长为全球第二大数字经济大国，同时在多个领域成就了一大批具有世界级影响力的数字经济领袖企业，如华为、阿里巴巴、腾讯、百度等。通过吸纳全球最庞大的用户，构建了全球最丰富数字创新生态系统，极大助力了数字经济与实体经济的深度融合，诞生了诸如智能制造、工业互联网、车联网、平台经济等大量新产业新模式新业态，并为科技创新突破提供了更多场景和模式支持。

（三）富有创新精神的企业家

中国经济的成功更多归功于企业创新及其背后的企业家精神。在改革开放的过程中，涌现出一大批勇于探索、富有创新精神的企业家。他们在中国经济发展中发挥了重要作用，为经济转型和创新驱动高质量发展做出了重要贡献。在这些富有创新精神的企业家推动下，中国逐步确立起了企业的创新主体地位。企业开始作为市场经济中的基本单位和创新活动的核心组织者，在市场竞争以及创新链产业链融合中发挥了至关重要的作用。企业家一方面在市场中担当技术供给的领头人，不断推动技术创新以在市场竞争中获得持续竞争优势，另一方面通过更准确地了解市场需求和变化、更快速地响应市场变化提供更加创新的产品和服务。

相对于发达国家的跨国公司，中国企业拥有的技术、人才、资金等资源基础薄弱，但通过企业

家精神不断整合企业内外部资源，推出更加契合市场需要的创新产品和服务，提高产品和服务的质量、效率和性价比，获得了更高的市场认可和竞争优势。在产业成熟期，他们通过成套成熟技术的引进快速追赶，推动了引进技术的商业化和本地化过程，为本地市场提供了适配的技术，并创造了大量的就业机会，使中国企业在国际市场中占据了重要地位，推动了中国经济的快速增长和世界工厂地位的形成。而在产业新兴期，他们勇于冒险和试错，用全球视野积极探索新技术新赛道，加快推进超越追赶和创新动能转换，抓住“范式转变”的战略机会窗口，推动并塑造了新兴技术范式，培养自主可控的创新能力，实现穿越周期的发展，吸纳并培育了大批创新型人才。企业家精神引领企业不断推动技术进步和产业升级，带动整个产业链的发展，引领行业发展方向，推动整个产业向高端制造业和高附加值方向发展，促进经济增长和社会进步。这些都为中国经济高质量发展和国际竞争力的提升提供了坚实的基础。

（四）穿越周期的产业增长模式

在一些科技产业，中国表现出了非连续的增长过程，其实质就是一种具有方向变化和深层次结构转变的长期增长模式，即建立在技术范式转变基础上的增长模式。以显示器产业为例，中国从CRT领域的陪跑者，到LCD面板领域的跟跑者，到OLED面板领域的并跑者，以京东方为代表的面板企业，通过持续的研发投入，充分利用技术范式转变的战略机会窗口开展超越追赶，塑造了穿越周期增长的成功案例。京东方成立于1993年，当时全球液晶面板技术还处于起步阶段，日本、韩国等发达国家在液晶显示器领域占据了绝对优势。如今，作为全球半导体显示产业龙头企业，京东方带领中国显示产业实现了从无到有、从有到大、从大到强。目前全球每四个智能终端就有一块显示屏来自京东方。全球市场调研机构Omdia和群智数据显示，2022年，京东方在智能手机、平板电脑、笔记本电脑、显示器、电视等五大应用领域液晶显示屏出货量均位列全球第一。截至2022年，京东方累计自主专利申请已超8万件。美国专利服务机构IFI Claims发布2022年度美国专利授权量统计报告，京东方全球排名第11位，连续五年跻身全球TOP20；世界知识产权组织2022年全球国际专利申请排名中，京东方以1884件PCT专利申请量位列全球第七，连续七年进入全球PCT专利申请TOP10。京东方甚至还在柔性显示等新兴技术领域取得了一些重要突破，为中国在全球高端制造业领域的崛起作出了重要贡献。

另一个实现穿越周期增长的产业是ICT（信息与通信）产业，典型的领军企业是华为。华为创立于1987年，当时中国的信息与通信市场被西方发达国家企业长期占据，形成了“七国八制”的局面。即市场上总共有八种制式的机型，分别来自七个国家：日本的NEC和富士通、美国的朗讯、加拿大的北电、瑞典的爱立信、德国的西门子、比利时的BTM公司和法国的阿尔卡特，其中日本的NEC和富士通分别占据了两种制式。华为在信息与通信技术领域的追赶历史可以看作是一个2G陪跑、3G跟

跑、4G并跑到5G领跑的逐步在不同技术范式不断创新和突破的过程(Wu et al.,2020)。通过不断提升技术和研发能力,华为追赶和超越思科、爱立信等老牌国际竞争对手,成为全球通信设备制造商的重要领导者。同时,华为还在人工智能、云计算、物联网等领域不断创新和突破,为中国在全球高科技领域的崛起作出了重要贡献。华为公司采取的是一种开放、合作、双赢的创新策略。如今华为公司已经成长为一个拥有20.7万员工、业务遍及170多个国家和地区、为全球30多亿人口提供服务的全球领先的ICT基础设施和智能终端提供商。2022年,华为全球销售收入达6423亿元,研发费用支出约为1615亿元,占全年收入的25.1%,十年累计投入的研发费用超过9773亿元。华为有研发员工约11.4万名,占员工总数的55.4%,在全球共持有有效授权专利超过12万件。华为在超过200个标准组织中,累计提交标准提案超过6.8万篇,与国内外客户和产业伙伴共同促进全球技术进步和产业升级。华为自主研发的欧拉操作系统累计商业装机量超过300万套;搭载自主鸿蒙系统的华为终端达到3.3亿台、鸿蒙生态开发者超过200万名、鸿蒙智联合作伙伴超过2300家。

二、创新驱动的演化:技术追赶与二次创新

(一)中国情境下的技术追赶

中国企业的自主创新与技术追赶有其鲜明的特性。一是情境上的特殊性,中国企业的技术追赶是在特殊的"中国情境"下开展的,与西方发达国家和新兴工业化国家的技术追赶情境有本质区别。二是发展环境的时代性,中国企业技术追赶已经从以往封闭环境进入全球化、网络化的开放环境,自主创新的内涵也得到了极大地丰富和发展。"中国式"技术追赶有其多阶段性、多样性、多层次性和新兴性的"中国情境"下的独特情境。在西方发达国家情境下,企业通过原始创新站到了世界前沿;而在日本、韩国等新兴工业化国家情境下,企业通过模仿到创新实现了技术追赶(Hobday, 1995; Kim, 1997; Lee and Lim, 2001)。西方发达国家企业崛起时所处的情境是政治制度稳定、技术体制完善、市场经济发达、全球网络尚未形成;而日本、韩国等新兴工业化国家企业崛起时所处的情境是政府主导技术追赶、技术体制决定企业研发、全球一体化经济开始形成、产品主要出口欧美发达国家市场。

不同于西方发达国家以及日韩等国的情境,中国企业的自主创新与技术追赶实践是在转型的"所有制制度"、多样化的"技术体制"、多层次的"市场空间"、新兴的"全球网络"四位一体的中国情境下开展,这决定了中国企业的自主创新与技术追赶的独特性和重要性(吴东、吴晓波, 2013)。一是全球网络化,主要包括外国直接投资和进口溢出、全球价值链和制造网络以及西方危机下的对外直接投资;二是技术机会情境,包括技术范式转变加速以及破坏性技术的兴起;三是国内市场机会,低成本、复杂市场细分以及不断增长的巨大需求塑造出了市场阶梯;四是制度变迁与政策,包括转型

经济下公共领域资源获取、国家创新政策和本地政府的扶持。中国企业技术追赶凸显了“中国式”技术追赶的特色，例如当前已有的基于技术创新和商业模式创新的全面创新。以往的技术追赶只是强调技术层面，中国特色的技术追赶应该包括“制度+技术+市场+网络”，甚至有些是在市场或者制度以及外围非核心技术上先取得突破。

由于历史的原因，中国很遗憾地成为历次工业革命的落后者。中国的技术追赶需要补齐蒸汽机时代、电力时代和信息时代三次工业革命的欠债，开展大量的自主创新活动。尽管这些时代的技术革新和发展对人类社会的发展产生了深远的影响，中国在这些时代中的技术发展和应用相对滞后，导致了技术追赶的欠债。幸运的是，第四次工业革命，以ABCDE（AI、Block Chain、Cloud Computing、Data Tech、Edge Computing）为代表的新兴科技为中国提供了“范式转变”的战略机会窗口。面临这一机会，凭借多年自主创新积累的相关知识和经验，中国既有必要也有可能抢抓新一轮科技革命和产业变革带来的战略机会窗口。中国只有不断加强技术研发和创新，提高科技水平，摆脱西方发达国家确立的技术范式制囿，才能实现中国制造业向高端制造业的转型升级，实现科技自立自强和可持续发展。

（二）二次创新的动态过程

不同于西方国家更加注重源自基础研究的原始创新，试图用一项新科技发明、一种新产品来创造或颠覆整个产业，中国的自主创新走的是“二次创新”的追赶道路，即在逐步掌握并消化吸收一门技术的基础上对其进行创造性的发展。

基于Dosi（1982）提出的“技术范式”与“技术轨迹”的概念，相对于发达国家“一次创新”的概念，吴晓波（1995）提出了“二次创新”的概念，即“在技术引进的基础上进行的，受囿于已有技术范式，并沿既定技术轨迹而发展的技术创新”。基于Utterback和Abernathy（1975）提出的技术生命周期模型，根据技术源在引进时所处的生命周期阶段，吴晓波（1995）立足技术引进的动态性构建了二次创新的动态过程模型，见图3。二次创新动态过程表明，后发企业在发展初期，由于自身技术能力薄弱，相关知识经验积累较少，适合第Ⅰ类技术（成熟技术）引进，并通过二次创新的三个阶段来推动技术能力的提升。当经过多轮二次创新周期，企业积累足够的知识和经验后，可以选择抓住“范式转变”的战略机会窗口发起对第Ⅱ类技术（新兴技术或实验室技术）引进（即超越追赶I），甚至发起一次创新（即超越追赶Ⅱ）。因此，超越追赶，是一种“技术范式”层面的超越既定范式的追赶，而非“技术轨迹”层面的常规追赶。超越追赶面临的情境是技术范式正在发生根本性转变，技术源在引进时尚处在技术生命周期阶段早期，这最终为行业后发者在技术能力上赶超行业领先者创造了条件。

“二次创新”过程是一个积累进化的动态过程。基于成熟技术引进的“二次创新”大致可分为三个阶段：第一阶段是模仿创新，即引进本地市场尚不存在的技术，通过模仿、干中学、反求工程，并结

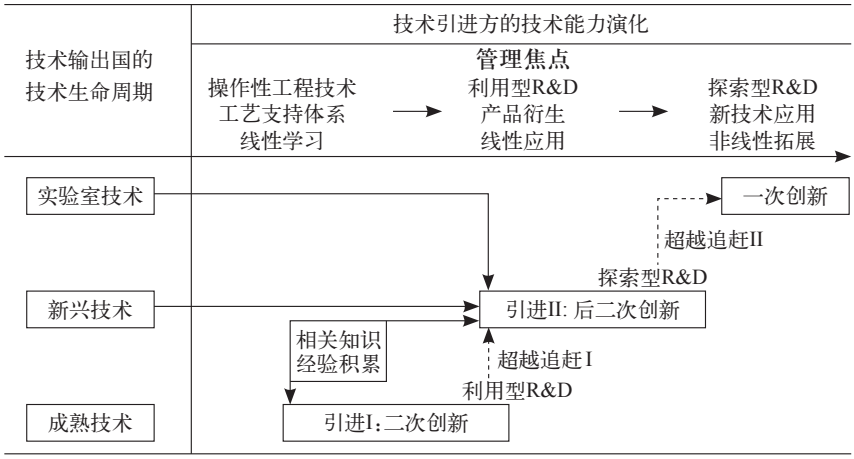

图3:创新驱动的演化路径

资料来源:改编自吴晓波(1995)。

合本地的工艺创新逐渐掌握这门新技术,达到能够原样仿制出产品的目的。第二阶段是创造型模仿,即通过前一阶段的学习、积累和消化吸收后,开始进口替代,逐步提高国产化创新能力,实现引进技术国产化创新。第三阶段是改进型创新,此时引进技术的一方应完全掌握新技术的原理和使用要求,并达到了消化吸收的程度,在此基础上,结合自身的研发能力和目标市场的需要,对引进的技术进行较重大的再创新。这个时候的产品在技术性能和经济性上已经接近甚至局部领先于发达国家的产品,具有很强的市场竞争力。"二次创新"成功的关键是摆脱低水平的重复技术引进,避免陷入"引进—落后—再引进—落后"的技术"追赶陷阱",并且在学习的过程中逐步建立起自己的"超越追赶"的创新管理体系,这就需要在技术范式转变期加强对新兴技术或实验室技术的引进,以及早期探索型研发的介入,开展基于新兴技术或实验室技术引进的"后二次创新",甚至产生能够主动发起和引领新兴技术范式的"一次创新"。

相较于"一次创新","二次创新"具有其独特的优势。首先,它具有后发优势,由于技术和市场的不确定性大大降低,技术攻关的难度和人财物投入也减少了,不需要再花费长时间的研发和设计来取得关键技术和核心技术的突破和反复试验,甚至可以通过适配引进的技术和现有的技术实现组合创新,技术针对的目标市场也比较清晰,有很强的变现预期。因此,"二次创新"的研发和生产时间更短,成本更低,商业化更容易成功。其次,"二次创新"强调在已有技术的基础上进行再创新,包括工艺创新、集成创新、渐进式创新。通过"二次创新",企业逐步掌握全部或部分核心技术和知识产权,显著提升自主创新能力。当然,"二次创新"并不能直接演化成"一次创新",一方面需要受囿于西方发达国家所确立的技术范式开展技术追赶,另一方面还需要通过"超越追赶"来摆脱那些已经成熟的技术范式的制囿(许庆瑞等,2019)。当前,新一轮科技革命和产业变革加速,新技术新模式新业态层出不穷,这为后发企业"超越追赶"创造了机会窗口(吴晓波等,2019)。企业是创新的主体,企业

在重点科技领域和产业链关键环节的突破性创新仍然是中国培育创新能力的重要手段，这也与国家创新体系的整体环境密不可分。

三、创新驱动的新势力

（一）智能制造新势力

中国正在成为网络化和智能化领域最伟大的力量。不同于机械化、电气化、自动化时代的物质世界与物质生产，第四次工业革命的特点是工业化和信息化的两化融合。中国正迈向具有数字化、网络化、智能化为特征的智能制造的新方向，这次是与德国的工业4.0、美国的工业互联网处于同一起跑线的竞争（吴东，2015）。中国正在新一代信息技术、高端数控和机器人、电力设备、农业设备、新材料、航空航天设备、轮机工程设备和高科技船舶、先进轨道交通设备、新能源汽车、生物医疗设备和高性能医疗器械等关键制造领域开展探索。

随之而来的是中国正在从制造大国转变为制造强国，并在以下五方面展开重点布局：一是创新驱动，摆脱重度技术引进的问题；二是提升质量，对关键零部件提出更高要求，巩固产业基础；三是绿色发展，实现低碳可持续的发展道路；四是优化产业结构，鼓励中小企业走专业化、精细化、特色化发展道路；五是人才导向，充分发挥人才作为第一资源的支撑作用，构建与高质量制造相匹配的人才生态。

其中，中国的国家制造创新中心发挥着举足轻重的作用。作为由国家发展和改革委员会、工业和信息化部、科技部、财政部等多个部门共同支持建设的国家级制造业技术创新平台，该平台旨在推动制造业转型升级，提高智能制造和高端装备制造的水平，推动制造业向高质量、高效率、高附加值方向发展。截至2022年，中国已经建设了26个国家制造业创新中心，涵盖智能制造、高端装备制造、新材料、新能源汽车等多个领域，通过整合资源、推动协同创新，在相关领域发挥了重要作用，为中国制造业转型升级和高质量发展提供了有力支撑。

（二）独角兽新势力

具有中国产业背景的独角兽新势力正在以更快的速度走到舞台中央。独角兽企业是指估值超过10亿美元的初创企业，这些企业在全球范围内被认为是非常稀有和重要的创新力量。《福布斯中国2022年新晋独角兽全名单》显示，2022年全球独角兽的总数量达到1597家，美国有746家（占47%），中国有368家（占23%），欧洲有264家（占16.6%），印度有103家（占6.5%），四个主要国家或地区的独角兽占全球总数的90%，创业市场多极化格局已经成型。新能源、清洁技术、医药、生命科学以及加密技术等仍然是全球创新主阵地。2022年全球范围内80%的新晋独角兽公司来自上述领域。2022年新增的独角兽公司中，中国有四个领域创造了70%以上的独角兽增量，其中清洁技术与新能

源贡献最多，其次是医药健康与智慧物流交通板块；而同一时期的美国，企业服务与加密行业贡献了过半的独角兽增量。

从行业分布来看，中国独角兽最主要集中在金融、医疗、教育、交通等领域。尽管这些领域属于垄断领域，产业壁垒高且具有超额利润，但是独角兽企业却充分抓住了“范式转变”的战略机会窗口，在这些垄断领域上生长起来。独角兽还正在通过跨界方式进入更多传统经济领域，让数字经济逐渐繁荣起来。在这些新兴数字产业，政策约束较少，加之数字经济具有轻资产、低成本、高弹性的特点，为独角兽企业的进入创造了低门槛的条件。高新技术产业的独角兽则更多采用科技驱动的新经济增长模式。伴随着消费升级的加快，消费者对体验、品质、品类的不断追求，消费产业的独角兽也飞速发展起来。

四、创新驱动与国家创新体系

（一）重新认识国家创新体系

重新思考中国创新驱动经济高质量发展战略，这与国家创新体系建设密不可分。国家创新体系三螺旋理论强调了大学–产业–政府之间的相互关系和互动，提出了一个全新的科技创新和经济发展的理念和路径，推动了国家的科技创新和经济发展，并在全球范围内提高该国的创新竞争力。科研成果为产业提供技术支持和创新动力，产业商业模式和市场需求又反过来促进了科研的进一步发展和创新。政策推动了产业的发展和科研的创新，形成了一个良性循环的创新生态系统。

新型国家创新体系已经呈现出这样的一个趋势：需求侧从大众市场向垂直市场、个性化市场延伸，供给侧从传统大规模企业向中小私营企业、小微草根创业者延伸，两者共同勾勒出一幅多种经济力量共荣共生的宏伟图景，既有主导型力量，也有逐步发展起的基于市场经济的核心竞争力，更有不断开放并拥抱一切的数字经济生态系统。这将是一个更加接纳草根的、包容性创新和服务的时代。2022年中国移动网络的终端连接总数达35.28亿户，移动物联网用户规模达18.45亿户，占全球总数的70%。通过与网络化的数字经济相融合，一个全新的创新生态系统得以重建起来，越来越多的创新元素和主体被接入到新型的创新生态系统中。草根、开放、包容成为国家创新体系的新特征，为不同的创新主体提供了交流和合作的机会，显著促进了多元创新主体之间的协同创新。

国家创新体系包括多个组成部分，其中最重要的是科技政策和创新政策。新时代对政策制定的决策者提出了新要求，这些政策包括各种激励措施、资金支持、人才引进、知识产权等方面，旨在鼓励创新主体进行科技创新和创业活动，并提高其竞争力和创新能力。国家创新体系还包括科技创新基础设施，例如科技园区、孵化器、技术转移中心等，这些设施提供了创新主体所需的场地、设备、技术支持和人才培训等资源，帮助他们加速技术创新和商业化进程。《中华人民共和国2022年国民经济和社会发展统计公报》显示，2022年中国正在运行的国家重点实验室533个，纳入新序列管理的

国家工程研究中心191个，国家企业技术中心1601家，大众创业万众创新示范基地212家。国家科技成果转化引导基金累计设立36支子基金，资金总规模624亿元。国家级科技企业孵化器达1425家，国家备案众创空间达2441家。政府将在引导基金、公私合作模式上发挥更大的作用，各类创客空间、创新创业平台、孵化器等创新载体将加速技术转移，海外人才引进为新型生态系统注入创新活力，国家实验室的建设为生态系统提供本土创新动能等，这一系列力量成为促进新的知识/技术产生的重要保证。

（二）数字经济时代的国家创新体系

在全球化和数字化的背景下，随着中国更加高水平的对外开放，全球资本、技术和人才要素的流动加快成为确定性趋势，塑造了新型的国家创新体系。全球化和数字化下的国家创新体系，加速了全球经济的一体化和互联互通，促进了全球贸易和投资的发展，并推动了全球经济的增长和繁荣，也增强了各国之间的经济竞争和合作，推动了各国之间的技术创新和人才培养，同时也带来了一些挑战和风险。

一是资本加速流动下的国家创新体系。全球范围内的资本流动越来越便捷，投资者可以通过互联网和数字平台等方式轻松地进行跨境投资和融资。这种趋势加速了全球化的进程，同时也加强了各国之间的经济联系和竞争。资本的力量将主导市场改革，更多的资本支出带动新兴产业发展和繁荣。《2022年欧盟产业研发投资记分牌》显示，中国、美国、日本、欧盟四大经济体对各个领域的研发投资侧重点不同。2022年，中国各产业研发投资占比由高到低分别如下，ICT生产（26.6%）、ICT服务（17.7%）、建筑（12.6%）、工业（10.4%）、其他（9.7%）、汽车及其他交通（9.2%）、健康产业（7%）、能源（3.5%），化工（1.9%），金融（1%），航空航天和军工（0.3%）。特别是中国在ICT生产、工业、建筑、能源的研发投资领域处于全球领先地位，更有全球竞争力。

二是技术加速流动下的国家创新体系。全球化和数字化的背景下，技术的流动也越来越便捷，各国之间的技术交流和合作变得更加频繁和紧密。这种趋势促进了全球技术创新和应用的进步，同时也加强了各国之间的合作和竞争。世界知识产权组织《2022年PCT年度回顾》显示，2021年全球商业PCT专利申请前20强企业中，中国的华为以6952件专利排名第1位，其他上榜企业还包括OPPO（第6位）、京东方（第7位）、平安（第11位）、中兴（第13位）、vivo（第16位）、大疆（第20位），从上榜企业数量来看，中国企业就占到了前20强的三分之一。

三是人才加速流动下的国家创新体系。随着全球范围内的教育水平的提高和移民政策的放宽，越来越多的人才开始跨国流动。这种趋势促进了各国之间的人才交流和合作，同时也提高了全球人才的竞争力和流动性。《中华人民共和国2022年国民经济和社会发展统计公报》显示，2022年，研究生在校人数达365.4万人，毕业生人数达86.2万人，普通、职业本专科在校生3659.4万人，毕业生

967.3万人，显示了本土庞大的人才供给。2019年国家统计局数据显示，中国出国留学人员达70.35万人，学成回国留学人员达58.3万人，与日俱增的留学生促进了全球科技的一体化和互联互通，增强了中国技术创新和人才培养实力，加速了创新和技术应用的传播和普及，同时也推动了全球可持续发展和普惠性增长的进程。

置于这样的新型国家创新体系之中，产业迭代、市场培育将会加速。典型地，新能源汽车产业凭借中国巨大的市场空间正在异军突起，由西方国家主导百年的全球汽车产业亦将面临重新洗牌的巨大变革。根据国家统计局、工业和信息化部发布的数据，中国新能源汽车销量近年来快速增长，其增速高于汽车产业的整体增速。中国新能源汽车产量由2014年的7.8万辆提升至2022年的705.8万辆，销量由2014年的7.5万辆提升至2022年的688.7万辆。根据中国汽车工业协会发布的统计数据，中国新能源汽车产销量已连续八年位居全球第一，2022年新能源汽车产销量分别同比增长96.9%和93.4%。2022年中国占全球新能源汽车销量的比重达58.7%，远高于欧洲的25.5%和北美的10.5%。以新能源汽车为代表的新兴产业机会明显，更将拉动宁德时代等国内中上游企业的快速增长。

五、创新驱动的展望：适应快速发展的趋势

（一）跨行业全球价值网络

跨行业全球价值网络为创新驱动带来更开放更高效的价值整合。由于全球化和数字化的发展，不同行业和领域之间的交流和合作变得更加便利和高效，超越了全球地理边界的局限，促进了价值创造过程利用各区域比较优势的全球分布。跨行业全球价值网络是以跨国公司为龙头，整合多个企业和组织的价值链而形成的网络，这些企业和组织涉及多个行业和领域，通过合作实现跨行业价值的创造和传递。这主要是由于跨行业全球价值网络允许不同行业和领域的企业和组织共享资源和技术，提高资源的利用效率，开展组织合作创新，促进新技术和新产品的开发和应用，在全球范围内选择最优的合作伙伴和供应商，降低采购和生产成本。跨行业全球价值网络是一个充满机遇和挑战的全球性合作模式，需要企业和组织共同努力，建立有效的合作和协作机制，实现跨行业和全球范围内的价值创造和传递。

（二）大数据驱动的产品和基于用户体验的设计

大数据驱动的产品和基于用户体验的设计为创新驱动带来全新的创新源。大数据驱动的产品和基于用户体验的设计是两个在现代数字化产品设计和开发中非常重要的概念。大数据驱动的产品是通过运用大数据技术和方法，对各种来源和渠道的数据进行分析和挖掘，从中发现产品的优化和改进机会，从而推动产品的发展和创新。例如通过分析用户的搜索记录和行为数据，生产商可以根据用户需求和兴趣识别用户偏好，从而提高新产品质量和用户体验。基于用户体验的设计是指将

用户的需求和体验放在设计和开发的中心，通过对用户需求的调查和分析，设计出能够提供更好用户体验的产品。这个设计方法强调用户的体验和满意度，以及产品的功能性和易用性。例如淘宝、京东等头部电商网站通过分析用户行为数据和反馈，设计出更加直观和易用的购物流程和界面，提高用户购物的满意度和体验。通过运用数据分析和挖掘技术，可以深入了解用户的需求和行为，为基于用户体验的设计提供更加准确和有效的参考。同时，基于用户体验的设计可以提高产品的用户满意度和忠诚度，进一步促进数据的收集和分析，形成良性循环。

（三）日益增多的全球并购活动

日益增多的全球并购活动为创新驱动带来全球创新资源的灵活配置。随着全球经济的不断发展和全球化进程的加速，企业之间的市场竞争也变得越来越激烈。为了在全球市场中保持竞争优势，企业需要通过并购等手段来扩大规模和提高效率。目前，在全球范围内，企业之间的并购交易数量和规模呈现出增长趋势。在一些成熟市场和成熟赛道中，企业的增长空间已经趋于饱和。因此，企业需要通过并购等手段来寻找新的增长机会和市场。随着全球资本市场的发展和开放，企业可以更容易地获得资本支持，从而有更多的资金用于并购等活动。在一些行业中，企业之间的竞争日益激烈。因此，通过并购等手段来实现产业整合和优化资源分配，可以提高企业的市场地位和竞争力。甚至有一些企业寻求战略资产的获取，通过并购等手段来获取新的技术和专利，以提高自身的技术水平和创新能力。比如吉利收购沃尔沃是一次经典的并购活动，帮助汽车产业后来者吉利成功跻身全球乘用车领域的领导者。

（四）更多的创新服务生态平台

更多创新服务生态平台为创新驱动带来更加丰富多样的价值主张。随着数字化和互联网技术从Web1.0到Web2.0再到Web3.0的不断发展，创新服务生态平台越来越受到企业和消费者的关注。创新服务生态平台是指通过互联网技术和数字化工具，为企业和消费者提供创新的服务和解决方案的平台。数字化转型、消费者需求、产业升级和政策支持等成为推动创新服务生态平台的重要因素。越来越多的企业正在根据自身情况和市场需求，灵活运用互联网技术和数字化工具来提供更加创新的服务解决方案。同时，企业也需要关注创新服务生态平台的风险和挑战，包括技术风险、市场风险等，以保证创新服务生态平台的成功和效果。例如小米通过建立自己的生态，成功摆脱传统家电技术范式的路径依赖，转型成为一家面向智能家居生态链建设的全球化移动互联网企业、创新型科技企业。

（五）制造业和服务业的融合

制造业和服务业的融合为创新驱动带来高附加值的业务模式。制造业和服务业的融合是指通

过数字化、智能化等新技术手段，将传统制造业和服务业相结合，为消费者提供更加个性化、高效化、智能化的产品和服务。随着消费者需求的不断变化和升级，越来越多的消费者需要更加个性化、高品质、高效率的产品和服务。因此，制造业和服务业需要通过融合来提供更加智能化、定制化的解决方案。随着数字化、智能化等新技术的不断发展和应用，制造业和服务业之间的界限逐渐模糊。因此，制造业和服务业正在通过新兴技术手段来实现融合，提高自身的智能化和效率。特别是在一些传统制造业领域，传统的生产模式已经无法满足市场需求。制造业需要通过融合服务业来实现产业转型和升级。一些政策的制定和实施，可以促进制造业和服务业的融合发展。例如，政府可以出台相关政策支持制造业数字化转型和服务业创新发展。

（六）新兴科技和不可预测的未来

新兴科技和不可预测的未来为创新驱动带来“范式转变”的战略机会窗口。以ABCDE科技为代表的新兴科技正在逐步走下神坛，发育为日益庞大的市场。面对未来科技成果转化和大规模商业化以及数据隐私、网络安全等社会风险的不可预测性，企业需要不断提高创新能力和适应性，以应对未来可能出现的变化和挑战。首先，ABCDE科技需要不断推出新产品和服务，以应对市场需求的变化和竞争压力。企业需要注重创新，不断引入新技术和新理念，提高自身的核心竞争力。其次，ABCDE科技需要具备灵活适应能力，随时调整战略和业务模式，以应对市场变化和不确定性因素。企业需要保持敏捷性，及时调整自身的组织结构和流程，以适应市场需求和变化。再次，ABCDE科技需要领先企业加强与合作伙伴的协同创新，共同应对市场变化和挑战。领先企业需要扩大合作范围，寻找合适的合作伙伴，共同开发新产品和服务，共享资源和信息，提高自身的创新能力和竞争力。最后，ABCDE科技对人才的培养和发展提出了更高的要求，需要建立健全的人才管理机制，吸引和留住优秀的人才。企业需要注重员工培训和发展，提高员工的专业技能和创新能力，为企业的长期发展打下坚实的人才基础。

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Innovation-Driven Development in China: Catch-Up and Beyond

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Abstract: *Since the adoption of the reform and opening-up policy in 1978, China has pursued an innovation-driven development strategy. After decades of catching up with advanced nations, China is taking the lead in certain technological advancements and shifting from dynamic secondary innovations under open conditions to original innovations at a higher level of openness. In a new round of technological and industrial revolutions, shorter technological lifecycles and ever-changing technological paradigms present a strategic window of opportunities. Based on our review of the emerging driving forces of smart manufacturing and unicorns, we suggest that China urgently needs to develop a new national innovation system to help its companies take the lead and bypass the constraint of existing technology paradigms to seize emerging opportunities. This paper provides a theoretical guidance for China's innovation-driven high-quality development. Looking ahead, we suggest that innovation-driven development must adapt to rapidly changing trends.*

Keywords: *Innovation-driven development, paradigm shift, technological catch-up, beyond catch-up*

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In its 125th anniversary series, *Science* posed 125 of the most difficult questions in global science. One question that came up was "Why do some countries grow and others stagnate?" (Kerr, 2005). In general, developing nations are less technologically advanced than developed nations and must learn from developed nations in order to catch up. Despite the persistence of this learning process and the constant progress of developing nations, there are still some technological gaps with developed nations. In contrast to the unfortunate "middle-income trap" that befell some Latin American and Southeast Asian nations, China has largely succeeded in closing its technological gap with advanced nations, and in certain domains has even outperformed them. China's economic growth marvel is both typical and unique, and is difficult to be explained using traditional Western theories. What factors are responsible for China's economic growth? Since reform and opening-up, the innovation-driven emergence of corporate champions led by Huawei has illuminated this question.

1. Achievements of Innovation-Driven Development: Economic Performance since Reform and Opening-up

1.1 Innovation as the Primary Driving Force of Growth

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Since the inception of reform and opening-up in 1978, China's economy has made remarkable strides and maintained a high growth rate. From 1978 to 2022, China's GDP growth averaged 9.5%, surpassing the global average by a wide margin. As depicted in Figure 1, China is currently the second-largest economy in the world and is rapidly closing up to the United States, the world's largest economy. China proactively develops international trade. Since its entry into the WTO, China's exports have steadily increased. In 2022, China's total import and export volumes of goods amounted to 42.07 trillion yuan, with exports of goods representing close to 15% of the global market share. China has been the world's largest commodities trading nation for six years running. With 666 types of industrial activity in 207 subcategories of 41 industrial categories, China is the only country in the world to have all industrial sectors according to the United Nations industry classification system. Industrial value-added in China reached 40.2 trillion yuan in 2022, accounting for 33.2% of GDP. This comprises a manufacturing value-added of 33.5 trillion yuan, which accounts for 27.7% of its GDP. China has been the world's largest manufacturing nation for the past 13 years. In 2022, China accounted for nearly 30% of world total manufacturing value-added, while the US accounted for only 16%. Upon its entry into the WTO in 2001, China accounted for only 6% of global manufacturing value-added, placing it far behind the US, which ranked first globally.

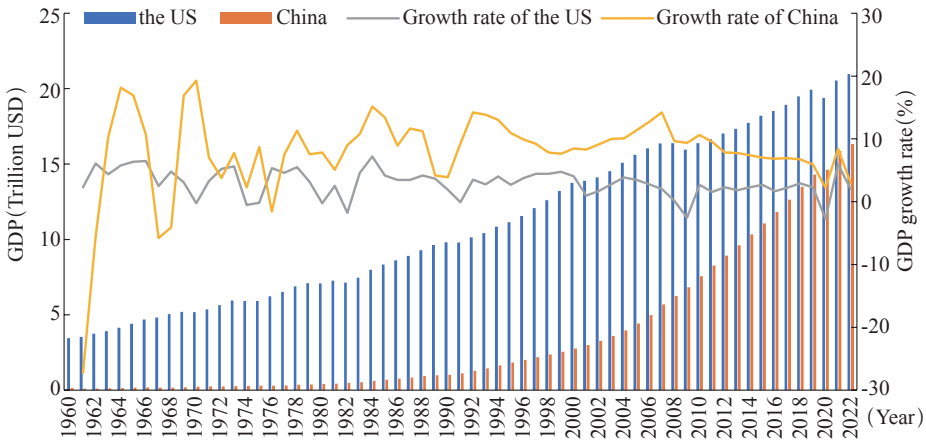

Figure 1: GDP and Growth Rates of China and the US (1960-2022, in constant 2015 US dollars)
Source: Drafted by authors according to the World Bank's data.

As shown in Figure 2, a comparison of industrial value-added growth rates for China and the US after China's 1978 reform and opening-up reveals a strong correlation between the two, in stark contrast to their mutual independence of industrial development before 1978. On the one hand, China and the US complement one another in the international division of manufacturing labor. The US is more competitive in high-end manufacturing, whereas China has comparative advantages in low-end manufacturing. Cooperation between the two nations along the global manufacturing value chain will affect the growth rate of manufacturing value-added in each nation. On the global commodities market, however, China and the US are interdependent. The US is China's largest export market, and China is a manufacturing hub for the US. The manufacturing value-added growth rate of each nation will be affected by the level of economic development in the other nation. Made-in-China products are so prevalent in the US that the absence of China would come at a great expense of American consumers in terms of convenience and cost (Bongiorni, 2007).

The question is that what made it possible for China to achieve its economic miracle based on the "worst theory" as described by Western mainstream economics. How did China maintain such

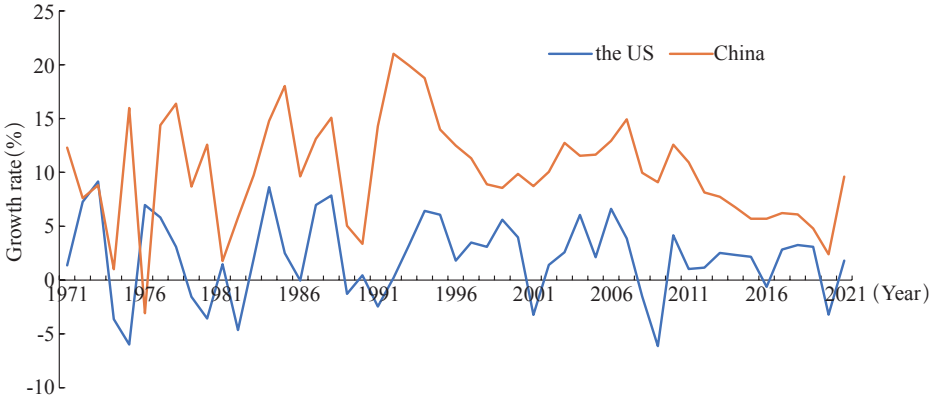

Figure 2: Industrial Value-added Growth Rates of China and the US (1971-2021, in constant 2015 US dollars)

Source: Compiled by the authors based on data from the UN.

a rapid growth rate? Is it because of what appears to be the "worst policy" in Western eyes? Or is it due to China's late-mover advantage and income disparities with high-income nations (Lin, 2019)? Technology innovation, a relatively rare local source of production, turns out to be the primary driver of economic growth in China, a labor-intensive economy with a sufficient low-cost advantage. China's rapid development is a result of a practical and innovation-driven approach, as shown by the country's experience with reform and opening-up. The transition from factor- and investment-driven to innovation-driven growth has been the driving force behind China's escape from the "middle-income trap" (Wu and Wu, 2018).

In 2022, China's R&D expenditures reached 3.1 trillion yuan, second only to those of the US, a 10.4% increase over the previous year. China's R&D spending as a share of GDP increased from 1.45% in 1978 to 2.55% in 2022, with double-digit growth rates for seven consecutive years, and spending on basic research reached 200 billion yuan. Spending on basic research as a share of GDP has exceeded 6% for four consecutive years since 2019. China has one of the highest R&D spending growth rates in the world, despite the internationally modest proportion of R&D spending to GDP. According to the *Statistical Communique of the People's Republic of China on the 2022 National Economic and Social Development*, in 2022, China approved 4.323 million patents and accepted 74,000 patent applications under the PCT with 17.879 million valid patents, including 3.28 million valid domestic invention patents. China has led the world in the number of patents since 2011, establishing itself as an intellectual property rights (IPR) powerhouse.

1.2 Growing Business Champions

A robust economy is supported by robust corporations. From one in 1989, the number of Chinese companies on the Fortune Global 500 list increased to 129 in 2019, surpassing the 121 of the US. Historically, Japan came closest to the US, with 149 companies on the list, compared to 151 of the US in 1995. Since then, the US has held the No. 1 position for many years, while Japan has slipped over the last two decades. In 2022, there were 145 Chinese companies (including 28 private companies, or 1/5 of the total) on this list, surpassing the 124 companies of the US and 47 companies of Japan. These Chinese companies represented 31% of the total business revenues of the Global 500, surpassing the US for the first time. This change reflects the decline of Western centrism and ushers in a new era in which Chinese companies compete with multinational Western firms on the same stage.

Growth of Chinese companies has been accompanied by a sharp improvement in their innovation performance. Chinese technology companies among top 50 on the Boston Consulting Group's (BCG)

annual list of the world's most innovative companies for 2022 include: Huawei (8th), Alibaba (22nd), Lenovo (24th), JD.com (30th), Xiaomi (31st), and Tencent (41st). Nineteen Chinese companies joined the rank of top 100 global companies with the highest R&D spending in 2022 as shown in the *2022 EU Industrial R&D Investment Scoreboard*. With an R&D investment equivalent to 19.5 billion euros, Huawei ranked first among Chinese companies and fourth globally. Other Chinese companies on the list include Alibaba (17th), Tencent (18th), China State Construction Engineering Corporation (34th), Taiwan Semiconductor Manufacturing Company (48th), Baidu (53rd), China Railway Corporation (54th), Hon Hai (55th), China Communications Construction (56th), MediaTek Inc. (59th), SAIC Motor (61st), China Railway Construction Corporation (62nd), ZTE (70th), Meituan (82nd), Power Construction Corporation of China (85th), Metallurgical Corporation of China (91st), PetroChina (92th), Kuaishou Technology (94th), and NetEase (98th).

Without a world-class market, there would have been no world-class corporations. China has embraced new technologies and the new economy in the emerging digital economy in order to capture the strategic window of opportunities presented by a new round of technological and industrial revolutions (Wu et al., 2019). According to the *51st Statistical Report on China's Internet Development Status*, China has 1.067 billion internet users, or 21.56% of world total, making it the largest internet-based society in the world. There are currently 911 million paid internet users and 845 million online consumers. The volume of online retail transactions in China is 13.79 trillion yuan, compared to 1.09 trillion dollars in the US. China's online retail sales volume accounts for 37% of world total, constituting 31.34 % of its total consumer products retail sales volume of 44 trillion yuan. China has constructed the world's largest and most advanced mobile communications network, with 1.683 billion mobile phone users, of whom 561 million (33.3%) are 5G mobile phone users. This ratio is one of the highest worldwide. The value of China's mobile payment market is 5.5 trillion US dollars, while the same figure for the US is only 110 billion US dollars. There are 159 publicly listed internet companies in China with a combined market capitalization of 10.3 trillion yuan. China's digital economy is worth 50 trillion yuan, or over 40% of its GDP. In terms of total computing capacity, China's operational data centers contain over 6.5 million standard racks, ranking them second in the world. Of critical processes at key industrial enterprises, 58.6% are digitally controlled, and the penetration of digital R&D tools has reached 77%.

China has become the world's second-largest digital economy over the past four decades of reform and opening-up by integrating global technological innovations and focusing on digital technology applications and use case innovations despite being a late mover. China has fostered a large number of world-class digital economy companies, including Huawei, Alibaba, Tencent, and Baidu, in a variety of fields. By absorbing the largest user base in the world, China has created a thriving digital innovation ecosystem that integrates the digital economy with the real economy, giving rise to new industrial and business models such as smart manufacturing, industrial internet, connected vehicles, and the platform economy. Numerous ecosystems and business models have supported innovations in technology.

1.3 Innovative Entrepreneurs

China's economic success is more attributable to corporate innovation and the underlying ethos of entrepreneurship. During the past four decades of reform and opening-up, a large number of exploratory and innovative entrepreneurs have arisen and played a crucial role in China's economic development, making significant contributions to China's economic transition and innovation-driven development. China has taken steps to establish enterprises as the foundation of innovation, with innovative entrepreneurs at the helm. Enterprises have started to play a pivotal role in market competition and the integration of innovation and industrial chains. Entrepreneurs spearhead the market-based supply of technology and innovate to stay competitive. Moreover, they closely follow and swiftly respond to market changes in order to provide more innovative products and services.

Despite relative disadvantages in technology, human resources, and capital compared to

multinational corporations from developed nations, Chinese enterprises have gained greater market recognition and competitive advantage due to their entrepreneurial spirit and relentless consolidation of internal and external resources, which resulted in the creation of innovative products and services with superior quality, efficiency, and cost-effectiveness. During this phase of industrial development, they imported complete sets of mature technology and accelerated the commercialization and localization of imported technologies. In this way, Chinese entrepreneurs supplied the local market with suitable technologies, created jobs, established a foothold on the international market, and accelerated China's emergence as the world's factory floor. In the new wave of industrial development, they explored new technologies and global markets with audacity, raced to catch up to industry leaders and increase innovation dynamism, and grasped the strategic opportunities presented by a paradigm shift. As a result, they have shaped new technological paradigms, fostered independent innovation capabilities, attained cross-cyclical development, and attracted and nurtured a large number of innovative talents. With an entrepreneurial spirit, enterprises have consistently propelled technology advancement, industry upgrade, and industrial development toward high-end manufacturing and high value-added, thereby contributing to economic growth, social progress, and international competitiveness.

1.4 Cross-Cyclical Industrial Growth Model

In some technology industries, China has demonstrated a discrete growth process, which is essentially a long-term growth model characterized by step changes in technology paradigm and deep-seated structural transition. Taking the display industry for instance, China has evolved from a laggard in CRT to a follower in LCD panels and a leader in OLED panels. Through consistent R&D input, BOE Group, for instance, has taken full advantage of the window of strategic opportunities from a technology paradigm shift, making a success story of cross-cyclical growth. When BOE Group was established in 1993, the global LCD panel technology was still in its nascency. Back then, advanced economies like Japan and South Korea held an absolute advantage in LCD. BOE, a global leader in the semiconductor displays market, has played a pivotal role in the establishment and development of China's display industry. Currently, one in four smart devices in the world is equipped with a BOE screen. According to Omdia, a technology research firm, BOE ranks first in the world in terms of LCD shipments for the five application sectors of smart phones, tablets, laptops, monitors, and televisions. By 2022, BOE had cumulatively submitted 80,000 patent applications. IFI CLAIMS, a US-based patent services company, ranked BOE eleventh worldwide in its statistical report of US patent authorizations in 2022, making it a top 20 global patent applicant for the fifth consecutive year. With 1,884 PCT patent applications, BOE is ranked 7th worldwide in the 2022 World Intellectual Property Organization (WIPO) ranking of global patent applicants. This makes BOE one of the top 10 global PCT patent applicants for the seventh year in a row. Moreover, it has made key breakthroughs in flexible display and other new emerging technological fields, contributing to China's emergence as a high-end manufacturing powerhouse.

China has also experienced cross-cyclical development in the ICT industry, which is led by Huawei. Prior to the founding of Huawei in 1987, the Chinese ICT market was dominated by multinational corporations from "seven countries with eight standards". Namely, there were eight models of equipment from seven countries, including NEC and Fujitsu from Japan, Lucent from the US, Nortel from Canada, Ericsson from Sweden, Siemens from Germany, BTM from Belgium, and Alcatel from France. Among them, Japan's NEC and Fujitsu accounted for two standards. Huawei's history of catching up in the ICT domain can be characterized as a process of constant innovation and breakthrough under various technology paradigms, transforming from a 2G laggard to a 3G follower, a 4G forerunner, and a 5G pacesetter (Wu et al., 2020). Through constant technological advances and R&D investments, Huawei has caught up with and in some instances even surpassed Cisco and Ericsson as the world's leading telecom gear maker. Huawei's constant innovations and advancements in areas such as artificial

intelligence (AI), cloud computing, and the internet of things (IoT) have contributed to China's rise in the global high-tech industry. Huawei has adopted an innovation strategy that is open, collaborative, and win-win. Today, Huawei is a prominent global provider of ICT infrastructure and smart devices, with 207,000 employees and business operations in more than 170 countries and regions serving some three billion people. In 2022, Huawei earned 642.3 billion yuan in global business sales and invested 161.5 billion yuan in R&D, accounting for 25.1% of total annual income. Over a decade, Huawei has spent more than 977.3 billion yuan on research and development. Huawei employs 114,000 R&D personnels, which accounts for 55.4% of its total workforce, and possesses over 120,000 patent authorizations worldwide. It has submitted over 68,000 standard proposals to more than 200 standard organizations, collaborating with domestic and international customers and industrial partners to advance global technological progress and industrial modernization. Installations of Huawei's EulerOS have surpassed 3 million units. HarmonyOS, developed by Huawei, has been installed on over 330 million devices. HarmonyOS has over 2 million developers and over 2300 partners in its smart device ecosystem.

2. Evolution of Innovation-Driven Development: Technological Catch-Up and Secondary Innovation

2.1 Technological Catch-Up in the Chinese Context

In terms of indigenous innovation and technological catch-up, Chinese companies exhibit distinctive characteristics. The first one is context-specificity: Chinese enterprises catch up with industry leaders in the Chinese context, which is distinct from the context for advanced economies and emerging industrialized nations. The second one is a new development environment: Chinese enterprises have embraced a global and network-based open environment, redefining the concept of indigenous innovation. Targeting emerging technologies, Chinese-style technological catch-up occurred in multiple phases across a diverse range of sectors at various levels. In the Western context, it was original innovations that brought Western companies to the global frontiers. In the context of emerging industrialized nations such as Japan and South Korea, however, their businesses have completed technological catch-up from imitation to innovation (Hobday, 1985; Kim, 1997; Lee and Lim, 2001). During their initial stages of development, Western multinationals benefited from a stable political environment, complete technology systems, and flourishing market economies in the absence of a global network. Emerging industrialized nations like Japan and South Korea had their governments take the lead in catching up in technology; national technology systems dictated corporate research and development; and exports were geared primarily toward the European and North American markets.

Unlike Western developed countries and latecomers such as Japan and South Korea, Chinese enterprises have pursued indigenous innovation and technological catch-up in the Chinese context of transitional ownership system, diversified technological systems, multitiered market space, and emerging global networks. These distinguishing characteristics have defined China's homegrown creativity and technological catch-up (Wu and Wu, 2013). First, global networks primarily include foreign direct investment (FDI), export spillovers, global value chains, manufacturing networks, and outward foreign direct investment (OFDI) during Western crises. Second, the context of technological opportunities includes a rapid shift in technological paradigm and the emergence of disruptive technologies. Third, domestic market opportunities arise from China's multitiered domestic market based on its low-cost advantage, complex market structures, and large domestic demand. The extensive technology and business model innovations in China's business community serve as a prime example of the country's way of technological catch-up. Unlike previous technology-focused catch-up efforts, China's comprehensive catch-up strategy should incorporate system, technology, market, and network. In certain instances, breakthroughs have been made first in markets, institutions, and peripheral technologies.

China regrettably fell behind in numerous industrial revolutions due to historical circumstances. China's technological catch-up requires extensive indigenous innovations to compensate for its missed opportunities during the three industrial revolutions that ushered in the eras of steam engines, electric power, and information technology. The Fourth Industrial Revolution, led by the ABCDE (artificial intelligence, block chain, cloud computing, data tech, and edge computing), provides China with strategic opportunities for a paradigm shift. It is both necessary and possible for China to seize this window of opportunities based on its knowledge and experience from decades of indigenous innovation. Relentless research, development and innovation are the only way for China to bypass existing technology paradigms established by Western powers, bolster its manufacturing strength, and achieve technological independence and sustainable development.

2.2 Dynamic Process of Secondary Innovation

Western nations focused more on original innovation stemming from basic research, trying to create or disrupt an entire industry with one invention or new product China has embarked on a path of "secondary innovation", i.e., creative development on the basis of technology acquisition and assimilation.

Based on the concepts of "technology paradigm" and "technology track" proposed by Dosi (1982), Wu (1995) defined "secondary innovation" as "technology innovation based on technology importation within an existing technology paradigm and along an existing technology track". Based on the technology lifecycle model developed by Utterback and Abernathy (1975), Wu (1995) devised a dynamic process model of secondary innovation, as depicted in Figure 3. The dynamic process of secondary innovation suggests that in the early phases of development, late-mover businesses should introduce Type I technologies (mature technologies) and enhance technological capabilities through the three stages of secondary innovation. After enterprises have accumulated sufficient knowledge and experience through multiple rounds of secondary innovation, they may begin to introduce Type II technologies (emerging technologies or laboratory technologies) by seizing the window of strategic opportunities from a paradigm shift (i.e. Beyond Catch-up I) or even initiate a new round of innovation (i.e. Beyond Catch-up II). In this sense, Beyond Catch-up means bypassing an existing technology paradigm, as opposed to the conventional catch-up along a technological track. Beyond Catch-up occurs in the context of a paradigmatic shift in technology, in which the new technology is still in the early stages of lifecycle. This creates conditions for industry late-comers to catch up to industry leaders in terms of technological capabilities.

"Secondary innovation" is a dynamic process of accumulation and evolution. On the basis of the importation of mature technologies, "secondary innovation" can be approximately categorized into three stages: Stage I: Imitative innovation, or the mastery of a new technology that is not presently available on the local market through importation, imitation, learning by doing, or reverse engineering in order to manufacture the same product. After the previous stage of planning, accumulation and assimilation, Stage II is creative imitation, which involves indigenous innovation and local manufacturing for import substitution. Stage III is improvement innovation: The technology importer masters the principles and use of the new technology through assimilation and re-innovate. In this stage, the product's technical and economic performance is comparable or even superior to that of products from developed nations, making it highly competitive. The key to the success of "secondary innovation" is avoiding repetitive technology importation at a low level that leads to a vicious cycle of importation, falling behind, re-importation, and falling behind again. Throughout the process of learning, the technology importer establishes its own innovation management system for catch-up and beyond. This necessitates the importation of emerging or laboratory technologies, as well as early-stage exploratory R&D interventions for the "post-secondary innovations" of emerging or laboratory technologies, or even the initiation and leadership of the "original innovation" of emerging technology paradigms.

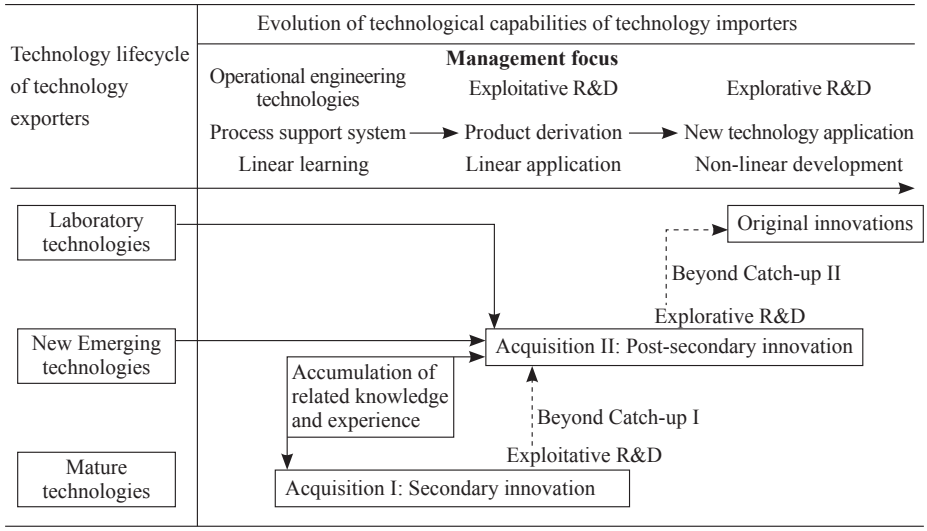

Figure 3: Evolving Path of Innovation-Driven Development

Source: Adapted from Wu (1995).

Secondary innovation presents unique benefits in comparison to original innovation. The first is late-mover advantage. Less uncertainty in technology and the market reduces the difficulty of R&D and the amount of human, financial, and material resources required, obviating the need for extended R&D efforts and repeated tests to achieve crucial progress in technology. In certain instances, innovations combining imported and existing technologies can be realized for a specific target market with a strong expectation of profit. Therefore, the R&D and production cycles of secondary innovations are shorter, less expensive, and simpler to commercialize. Second, secondary innovation is comprised of re-innovations of existing technologies, such as process, integrated, and iterative innovations. Businesses progressively acquire all or a portion of essential technologies and intellectual property rights through secondary innovations in order to sharpen their competitive edge. Obviously, secondary innovation cannot be directly transformed into original innovation for the following reasons: On the one hand, technological catch-up must be conducted under a technology paradigm established by Western developed countries; on the other hand, the late-comer must transcend the constraint of mature technology paradigms (Xu et al., 2019). In the midst of the latest technological and industrial transformations, the emergence of new technologies and business models has opened a window of opportunity for the late-comers (Wu et al., 2019), which are the driving force behind innovation. Their ground-breaking innovations in critical industrial sectors and processes play a crucial role in fostering China's ingenuity, comprising an integral part of the country's innovation system.

3. New Forces of Innovation-Driven Development

3.1 New Forces of Smart Manufacturing

China is becoming a dominant force in IoT and AI. The Fourth Industrial Revolution, unlike physical production in the eras of mechanization, electrification, and automation, is characterized by the integration of industrialization and informationization. China is pursuing the new directions of smart manufacturing enabled by digitalization, IoT, and AI, in competition with Germany's Industry 4.0 and the US industrial internet from the same start line (Wu, 2015). China has started exploratory research on next-generation information technologies, advanced CNC machine tools, robots, power equipment, agri-equipment, new materials, aviation and aeronautics equipment, turbines, shipbuilding, rail transportation

equipment, new energy vehicles, biomedicine equipment, and high-performance medical devices.

Meanwhile, China is strengthening its manufacturing capabilities by: (i) Promoting innovation to reduce reliance on imported technology; (ii) imposing stricter quality and technical requirements for critical components to reinforce the industrial foundation; (iii) pursuing sustainable, low-carbon, and eco-friendly development; (iv) improving industrial structure and promoting specialized, sophisticated, and differentiated development of small and medium-sized enterprises (SMEs); and (v) adopting a talent-oriented approach to fully utilize talents as the primary resource and create a talent ecosystem that supports high-quality manufacturing.

To support these endeavors, China has established national manufacturing innovation centers with joint participation of the National Development and Reform Commission (NDRC), the Ministry of Industry and Information Technology (MIIT), the Ministry of Science and Technology (MOST), and the Ministry of Finance. These national innovation centers are tasked with advancing China's manufacturing transition and upgrade, focusing on smart and high-end equipment manufacturing. The goal is to improve manufacturing quality, efficiency, and value-added. By 2022, China had built 26 national innovation centers for smart manufacturing, equipment manufacturing, new materials, and new energy vehicles. By consolidating resources for innovation synergy, these innovation centers have played a pivotal role in relevant fields, providing robust support for China's manufacturing transition, upgrade, and high-quality development.

3.2 Corporate Unicorns in Ascent

Corporate unicorns with an industrial heritage in China are ascending to the forefront. Corporate unicorns refer to start-ups with a valuation of over one billion US dollars, which are regarded as rare but crucial innovation drivers worldwide. According to Forbes China's 2022 list of new unicorns, the total number of global unicorns reached 1,597 in 2022, with 746 from the US (47%), 368 from China (23%), 246 from Europe (16.6%), and 103 from India (6.5%), which jointly make up 90% of the total. The multipolar unicorn market has taken shape, with new and clean energies, medicine, life sciences, and encryption technology as key innovation fronts. In 2022, 80% of the world's new unicorns arose from those sectors. China contributed over 70% of new unicorns in four domains in the same year. Clean and new energies contributed the most, followed by healthcare and smart logistics/mobility. In the meantime, corporate services and encryption contributed to more than half of the US's new unicorns.

The majority of Chinese unicorns are concentrated in finance, healthcare, education, and transportation sectors. Despite the high barriers of industry monopoly, these unicorns have seized the strategic window presented by paradigm shifts to establish a foothold in those monopolistic, high-profit sectors. Unicorns have forayed into even more conventional economic sectors, fueling the digital economy's boom. Unicorns also benefit from low thresholds to enter digital sectors, which are assets-light, low-cost, high-elasticity, and subject to fewer policy restrictions. In the tech sector, unicorns have adopted a new economic growth model driven by technology. New unicorns have flourished in the consumer sector as a result of consumption upgrade and relentless consumer pursuit of experience, quality and category.

4. Innovation-Driven Development and the National Innovation System

4.1 Revisiting the National Innovation System: A Fresh Perspective

China's innovation-driven development strategy should be deliberated as an inseparable part of its national innovation system. The triple-spiral theory of the national innovation system underscores interactions among universities, industries and the government. It has put forth a brand-new concept and path of innovation and economic development for a country to stay competitive globally. While R&D results provide industries with technical support and innovation dynamism, industrial and commercial

practices and market demand reinforce further development and innovation of scientific research. Policymaking facilitates industrial development and scientific innovations, forming a virtuous innovation ecosystem.

The new national innovation system presents such a trend: The demand side is extending from the mass market to the vertical and individualized market, and the supply side is extending from traditional large enterprises to small, medium-sized and micro businesses. A panorama of shared prosperity has been created by a confluence of economic factors. They include dominant forces, core competencies stemming from the market economy, as well as an open and all-encompassing digital ecosystem. This will be an era more tolerant of grassroots and inclusive innovations and services. In 2022, the number of mobile devices in China reached 3.528 billion with 1.845 billion mobile IoT users, representing 70% of world total. Through integration with the network-based digital economy, a brand-new innovation ecosystem becomes re-established, incorporating more innovation factors and themes. The national innovation system is an open and inclusive platform for collaborative innovation among grassroots innovators.

Science, technology, and innovation policies are essential components of the national innovation system. The new era imposes new requirements on policymakers regarding issues spanning from incentives to financial support, talent importation and IPR, with the goal of fostering innovation and entrepreneurship and boosting competitiveness and creativity. Infrastructure for innovation is another component of the national innovation system. Science parks, incubators, and technology transfer centers, for example, provide innovators with space, equipment, technical support, and talent training in order to accelerate innovation and commercialization. According to the *Statistical Communique of the People's Republic of China on the 2022 National Economic and Social Development,* in 2022, China had 533 national key labs in operation, 191 national engineering research centers as part of the new series management, 1,601 national corporate technology centers, and 212 mass entrepreneurship and mass innovation demonstration bases. The national guidance fund for the commercialization of scientific and technological results has established 36 sub-funds totaling 62.4 billion yuan. Nationally, there are 1,425 technology enterprise incubators and 2,441 mass entrepreneurship spaces. The government is expected to play a greater role in public-private partnership (PPP) and guidance fund models. Technology transfer will be accelerated by maker space, innovation and entrepreneurship platforms, incubators, and other innovation vehicles. Overseas talent will inject innovative vitality into the new ecosystem. National laboratories will facilitate domestic innovation. These forces have become essential for the invention of new knowledge and technologies.

4.2 National Innovation System in the Era of the Digital Economy

As China opens more broadly in the context of globalization and digitalization, the rapid global flows of capital, technology, and human resources have become defining trends and shaped our new national innovation system. In the age of globalization and digitalization, the national innovation system promotes global economic integration and interconnectivity, trade and investment, economic growth and prosperity, international economic competition and cooperation, as well as innovation and talent cultivation in various countries. Meanwhile, new challenges and risks have surfaced:

The first is the national innovation system amid accelerating capital flows. As it becomes simpler for capital to flow across borders, investors may conduct cross-border investment and financing through the internet and digital platforms with relative ease. This development has accelerated the globalization process and strengthened economic relations and international competition. The influence of capital will predominate market reforms, and an increase in capital expenditures will propel the growth and prosperity of emerging industries. According to the *2022 EU Industrial R&D Investment Scoreboard 2022*, China, the US, Japan, and the European Union have distinct R&D investment priorities in various domains. In 2022, China's R&D investments were concentrated in the following industries:

ICT manufacturing (26.6%), ICT services (17.7%), construction (12.6%), industry (10.4%), others (9.7%), automobiles and other transportation (9.2%), the health industry (7%), energy (3.5%), chemical engineering (1.9%), finance (1%), and aviation, aerospace, and defense industry (0.3%). Particularly, China has greater global competitiveness in the areas of ICT manufacturing, industry, construction, and energy R&D investments.

The second is the national innovation system amid accelerating technological progress. In the context of globalization and digitalization, it has also become easier for technology to migrate across borders, making technology exchange and cooperation between nations more common and intimate than ever before. This trend has increased international cooperation and competition while facilitating global technological innovation and application. According to *the 2022 PCT Annual Review of the World Intellectual Property Organization (WIPO)*, Huawei ranked first among the top 20 global commercial PCT applicants in 2021 with 6,952 patents, followed by Oppo (6th), BOE (7th), Ping'an (11th), ZTE (13th), Vivo (16th), and DJI (20th). Chinese companies comprise one-third of the top twenty.

The third is the national innovation system amid accelerating talent migration. Increasing levels of education worldwide and a more permissive immigration policy have facilitated the movement of talents across borders. This trend has increased human resources cooperation and exchange between nations, as well as the global competition and flow of talent. According to the *Statistical Communique of the People's Republic of China on the 2022 National Economic and Social Development*, in 2022, China had 3.654 million postgraduate students on campus, 862,000 master's and doctorate graduates, 36.594 million university and vocational college students, and 9.673 million graduates. Without a doubt, China has a massive local talent pool. According to data from the National Bureau of Statistics (NBS), in 2019, China sent 703,500 students abroad and received 583,000 students returning from overseas. Increasing international student exchange is conducive to global technology integration, productivity, innovation and application of technology, talent cultivation, and sustainable global development and inclusive growth.

This new form of national innovation system is expected to accelerate industrial innovation and market development. Typically, China's new energy vehicle (NEV) industry is prospering in its vast market space, which has the potential to transform the Western-dominated global automotive industry of the past century. According to data from the National Bureau of Statistics (NBS) and MIIT, the growth of China's NEV sales has outpaced the overall growth rate of the automotive industry. From 2014 to 2022, China's NEV production increased from 78,000 to 7,058,000 units, while sales volume increased from 75,000 to 6,887,000 units. China's NEV sales volume has ranked first in the world for eight consecutive years, according to data from the China Automotive Industry Association. China's NEV production and sales volume increased by 96.9% and 93.4% in 2022, respectively. China accounted for 58.7% of global sales of NEVs in 2022, surpassing Europe (25.5%) and North America (10.5%). NEVs and other emerging industries have facilitated the rapid expansion of China's midstream and upstream businesses, including Contemporary Amperex Technology Co., Limited.

5. Future of Innovation-Driven Development: Getting on a Fast Track

5.1 Cross-Industry Global Value Networks

Cross-industry global value networks enable more accessible and effective value integration for innovation-driven growth. As a result of globalization and digitalization, exchange and cooperation across industries and sectors become more convenient and efficient, transcending global geographical boundaries and facilitating a global layout in which regional comparative advantages are utilized to create value. Global value networks, which are led by multinational corporations, unite businesses and organizations from a vast array of industries and domains that collaborate to create value. Cross-industry global value networks enable businesses and organizations from various sectors and fields to

share resources and technologies for more efficient resource utilization, collaborate for the development and application of new technologies and products, and select optimal partners and suppliers around the world to reduce procurement and manufacturing costs. Cross-industry global value networks are a global partnership model rife with opportunities and challenges for businesses and organizations to establish effective partnerships and collaboration mechanisms for the transmission of cross-industry value creation on a global scale.

5.2 Big Data-Driven Products and User Experience-Based Design

As essential concepts for contemporary digital product design and development, big data-driven products and user experience-based design provide a brand-new source of innovation for innovation-driven development. The development of big data-driven products is founded on the analysis of data from multiple sources to identify opportunities for product optimization and improvement. By analyzing user search logs and behavioral data, for example, manufacturers can identify user needs, interests, and preferences to improve product quality and user experience. User experience-based design entails putting the user's requirements and experience at the center of product design and development in order to design more user-friendly products based on a demand survey and analysis. This design strategy prioritizes user experience and satisfaction in addition to product functionality and usability. Leading e-commerce websites such as Taobao and JD.com have designed more intuitive and user-friendly purchasing procedures and interfaces to improve user satisfaction and shopping experience. Data analysis and mining technologies can be used to obtain a more in-depth understanding of user needs and preferences and to provide more accurate and effective preferences for user experience-based design. In addition, user experience-based design can increase user satisfaction and loyalty, which reinforces data collection and analysis in a positive cycle.

5.3 Increasing Global M&As

Increasing global mergers and acquisitions (M&As) have resulted in a flexible deployment of global innovation resources in accordance with the innovation-driven development strategy. In the face of intensifying global competition, M&As provide a means for businesses to expand and become more efficient. There has been an increase in the number and volume of business mergers and acquisitions on a global scale. Given the saturation of certain markets, the only way to discover new growth opportunities and market demand is through M&As. With the development and opening of global capital markets, businesses have easier access to capital support for financing mergers and acquisitions. In some industries, intense competition has compelled businesses to consolidate and optimize resource distribution through mergers and acquisitions, which helps them maintain their business position and competitiveness. M&As allow businesses to acquire strategic assets, new technologies, and patents to enhance their innovative and technological capabilities. Geely's acquisition of Volvo, for example, enabled Geely to ascend from industry latecomer to global leader in passenger vehicles.

5.4 More Innovation Service Ecosystem Platforms

More innovation service ecosystems provide innovation-driven growth with diverse value propositions. With the evolution of digital and internet technologies from Web1.0 to Web2.0 and Web 3.0, innovation service ecosystem platforms have gained an increasing interest from businesses and consumers. Innovation service ecosystem platforms deliver innovative services and solutions to businesses and consumers using internet technologies and digital tools. To ensure the success and efficacy of innovation service ecosystem platforms, businesses should also be aware of the risks and difficulties associated with innovation ecosystem platforms, including technical and market risks. Xiaomi, for example, has successfully evaded the path dependence of traditional technical paradigms for home appliances, transforming into a global mobile internet technology company specializing in the

smart home ecosystem.

5.5 Manufacturing-Service Integration

Manufacturing-service integration serves as a high value-added business model for innovation-driven development. Manufacturing-service integration allows more individualized, efficient and smart products and services to be offered to consumers by integrating traditional manufacturing with services via digital and smart technologies. Amid changing consumer needs and consumption upgrade, there has been an increasing demand for individualized, high-quality and efficient products and services. That is why smarter and customized solutions should be provided through manufacturing-service integration. Digital and smart technologies have blurred the boundary between manufacturing and services, enabling manufacturing-service integration for more intelligent and efficient operations. In some traditional manufacturing sectors, in particular, traditional manufacturing modes may no longer meet market demand. Manufacturing needs service integration to realize industrial transition and upgrade. The government may issue policy documents to support manufacturing digital transition and service innovations to promote manufacturing-service integration.

5.6 Emerging Technologies and Unpredictable Future

Emerging technologies and an uncertain future open a window of strategic opportunities for an innovation-driven paradigm shift. Emerging technologies such asABCDE have fostered the growth of ever-expanding markets. Faced with the commercialization of R&D results as well as the risks and unpredictability of privacy and network security, businesses must persistently increase innovation and adaptability to deal with future changes and challenges. Frist, Businesses should prioritize innovation and implement new technologies and ideas to remain competitive. Second, ABCDE technologies necessitate that businesses strengthen their collaborative innovation partnerships to jointly face market changes and challenges. Leading businesses should broaden the purview of their cooperation and seek out suitable partners for the joint development of new products and services to share resources and data and enhance their innovativeness and competitiveness. Finally, ABCDE technologies have imposed greater demands on talent cultivation and development, necessitating effective management mechanisms to recruit and retain qualified professionals. Businesses place a premium on staff training and development to enhance employees' specialized skills and inventiveness, which in turn supports business development.

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