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Human Resource Development in China: The Triple Helix Model for Global Tech Expansion

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Abstract
Purpose: Rapid technological competition has elevated human resource development as a strategic priority, particularly for countries seeking to expand their global technological influence. This study examines how human resource development strategy in China supporting global technological expansion.
Research Methodology: This study employs a qualitative descriptive approach using a systematic literature review of academic publications, national policy documents, and official reports on education, innovation, and workforce development in China. The data drawn from peer-reviewed journals, government publications, and international organization reports, were analyzed through thematic analysis to identify key patterns and strategic mechanisms shaping China's HRD model.
Results: China's strategy is built on the Triple Helix model, operationalized through three interrelated mechanisms: (1) education and research institutions as strategic HRD infrastructure, supported by expanded higher education and sustained R&D investment; (2) university-industry collaboration as an institutionalized talent pipeline that reduces skill mismatches and enhances workforce readiness; and (3) strong state coordination that integrates education policy, innovation strategy, and industrial development into a coherent macro-level HRM architecture.
Conclusions: Triple Helix Model represents a state-enhanced approach to human resource development which education systems deliberately mobilized to sustain long-term technological competitiveness.
Limitations: This study relies exclusively on secondary data and literature-based analysis.
Contributions: Contributes to Strategic and International HRM by offering a macro-level perspective on how education systems can function as strategic HRM mechanisms within national innovation frameworks, providing insights for policymakers and HRM scholars responding to global technological change.

Keywords: *China's Triple Helix Model, Global Expansion, Innovation's Systems, Strategic HRM, Workforce Development*

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1. Introduction

The acceleration of technology has fundamentally changed the nature of workforce competition in the global economy. As advanced technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and 5G infrastructure reshape production and innovation processes, their impact on the labor market has become increasingly evident. Recent evidence shows that AI is transforming job structures and reshaping task composition. It is 57% of workers experience task augmentation, and 36% express concerns about potential job displacement across industries (Chhibber, Rajkumar, & Dassanayake,

2025). The ability of nations to develop and manage skilled human resources has become a central determinant of their technological competitiveness (Xiao, Xu, Xiao, Wang, & Skare, 2024). In this context, education systems are increasingly expected to function not only as sites of knowledge production but also as strategic platforms for Human Resource Development (HRD) aligned with technological transformation and national economic growth (Anochiwa, 2021).

This perspective is consistent with recent studies emphasizing that education systems function not only as instruments of knowledge transmission, but also as mechanisms for social transformation and human capability development. Evidence from alternative education policies shows that education can strengthen community participation, build critical awareness, and support inclusive development when integrated with broader institutional and policy frameworks (Rafid, Nurita, & Dores, 2025).

China's transition toward an innovation-oriented development model has intensified the demand for highly skilled human capital capable of supporting high-quality economic growth (Wang, , Miao, & 2019). However, this transition is accompanied by significant workforce challenges. Reports indicate that China faces a substantial shortage of highly skilled workers, particularly in the advanced manufacturing and digital technology sectors, with skill mismatches persisting between university graduates and industry demands (To, 2022). This shift highlights a fundamental Human Resource Development (HRD) challenge: how education systems can be structured to continuously generate skills that match rapidly evolving technological and industrial requirements.

China's growing prominence in global innovation indicators illustrates the outcome of this transformation. Ranked 12th in the 2023 Global Innovation Index, China has emerged as the leading middle-income economy in innovation performance, narrowing the gap with established technological powers (Intellectual Property Organization, 2023). This achievement is further supported by its position as one of the world's largest investors in Research and Development (R&D), reflecting the scale of innovation-driven growth. Beyond signaling technological capability, this ranking reflects the effectiveness of institutional arrangements that connect education, workforce development, and industrial upgrading on a national scale.

Compared with other leading innovation-driven economies, China's trajectory reveals a distinctive development model. According to the Global Innovation Index 2025, China has entered the global top 10 for the first time, ranking 10th among 139 economies, alongside advanced economies such as the United States, the United Kingdom, and South Korea (Davies, 2025). Notably, China remains the only middle-income country in this top-tier group, highlighting its exceptional capacity to accelerate technological upgrading despite structural development constraints (Wipo, 2025). In addition, China leads the world in several innovation output indicators, including patent applications and high-tech exports, and hosts the largest number of innovation clusters worldwide (CNIPA, 2025). This comparative positioning suggests that China's technological rise is not solely a function of market dynamics but is deeply rooted in a coordinated institutional framework that systematically aligns human resource development with national innovation goals.

Beyond innovation rankings, China's technological rise is increasingly reflected in its expanding global footprint in strategic technology sectors. Chinese firms and research institutions have become active contributors to global technology markets, particularly in sectors such as 5G infrastructure, where companies like Huawei play a leading role, and in renewable energy and electric vehicles, where China dominates global production capacity (Brühl, 2024). Consequently, China's technological competitiveness is no longer confined to domestic innovation performance but is increasingly shaped by its ability to project technology, skills, and human capital into global markets (X. Li, Wong, Kim, Qin, & Yuan, 2025).

State-driven policy initiatives that explicitly link technological advancement with human resource capacity building are central to this process. Programs such as "Made in China 2025" and "China Standards 2035" articulate long-term strategies for industrial upgrading and global standard-setting, both of which rely heavily on the availability of skilled and specialized labor (Wu, 2022). While "Made

in China 2025" prioritizes to promote industrial transformation and upgrading through intelligent manufacturing and green production (Song, Yu, Chen, Lobonț, & Du, 2025), "China Standards 2035" seeks to shape future technological infrastructures by strengthening China's influence in international standardization processes (Wu, 2022). Together, these initiatives underscore the strategic role of education in sustaining the competitiveness of the national workforce.

Despite extensive discussions on China's industrial and innovation policies, less attention has been paid to the human resource mechanisms that enable the implementation of these strategies over time. This gap is particularly significant given the scale of China's technological expansion and the persistent challenges related to skill mismatches and workforce readiness in the emerging sectors. Existing analyses often focus on investment levels, industrial outputs, or state intervention Nurhakim and Wijayati (2024), while overlooking how education systems are mobilized to function as talent pipelines in emerging technology sectors. From a human resource management perspective, this gap limits our understanding of how workforce development is institutionalized within broader innovation systems.

The importance of governance in shaping development outcomes has also been highlighted in recent Human Resource Development (HRD) and development-oriented studies. Research shows that effective governance plays a mediating role in translating intellectual and social capital into tangible welfare outcomes, even in contexts with limited resources. This suggests that human capital alone is insufficient without institutional coordination and governance mechanisms that align resources, capabilities and strategic objectives. Such insights reinforce the argument that governance structures are central to determining how human resources are mobilized for broader development goals, including technological and economic transformation (Arthana, Nursiani, & Riwu, 2025).

The Triple Helix Model provides an analytical lens to address this limitation by emphasizing the interactive roles of universities, industry, and government in shaping innovation outcomes and human capital formation. When viewed from a political economy perspective, the model reveals how the Chinese state coordinates educational institutions and industrial actors to align human resource development with national technological objectives. This framework is particularly relevant for examining how education systems contribute to the strategic development of human resources at the national level.

Motivated by these considerations, this study investigates how China's higher-education system operates within a state-directed Triple Helix framework to support human resource development for global technological expansion. Specifically, it asks how collaboration between universities, industry, and government enables the systematic production of skills and talent required for sustained technological competitiveness. Using a qualitative descriptive approach based on a literature review, this research aims to contribute to Strategic and International Human Resource Management by offering a macro-level analysis of education-driven workforce development in the era of global technological transformation.

2. Literature Review

2.1 Strategic Human Resource Management and Human Resource Development in Technology-Driven Economies

Recent developments in the global economy indicate that human resource management has become increasingly central to sustaining competitiveness in technology-driven environments. Scholars argue that technological advancement alone is insufficient to generate long-term performance unless accompanied by systematic investment in human capital and workforce capability development (Zaborovskaia, Nadezhina, & Avduevskaya, 2020). According to Alfawaire and Atan (2021), Human Resource Development (HRD) plays a strategic role in facilitating Industry 4.0 readiness and advancing sustainability objectives in emerging economies by continuously upgrading skills, knowledge, and competencies. This perspective positions HRM not merely as an administrative function but as a strategic mechanism that links human capital formation with broader economic and technological objectives, in line with the findings of (Vărzaru & Bocean, 2024).

Within this evolving landscape, Strategic Human Resource Management (SHRM) has gained prominence as a framework that aligns workforce development with long-term organizational and institutional strategies. Omemma Evans-uzosike and Gbemisola Okatta (2019) stated that SHRM emphasizes vertical alignment between HR practices and strategic goals, as well as horizontal integration across HR systems. In technology-intensive contexts, SHRM requires organizations and policymakers to anticipate future skill demands and embed continuous learning and reskilling into their workforce strategies. This shift reflects a broader transformation in the conceptualization of human resources, from operational inputs to strategic enablers of sustainable competitive advantage (Adula, Kant, & Birbirsa, 2022).

Several studies have highlighted the functional role of HRM in strengthening organizational performance in the face of uncertainty and change. HRM functions as an enabling system that empowers employees and enhances organizational resilience when tailored to the contextual challenges. Based on a systematic literature review, they emphasized that empowerment-oriented HRM practices support capability development and performance by aligning human capital with the strategic objectives. Although their analysis focuses on organizational settings, the functionalist view of HRM provides an important conceptual foundation for understanding how human resource development mechanisms can operate within broader institutional and governance frameworks (Adula et al., 2022).

Parallel to these discussions, research on the future of work underscores the profound impact of digitalization on workforce management and HRM practices. Kraus, Ferraris, and Bertello (2023) and Mahfud and Hermawati (2025) highlight that emerging work arrangements, digital technologies, and sustainability concerns are reshaping organizational capabilities and labor markets. Together with the research of Ratih Primandari, Pabisangan Tahirs, and Nur (2025) and Tiwari, Kostenko, and Yekhanurov (2025), their synthesis of future-of-work literature suggests that HRM must evolve beyond traditional practices to address systemic changes in how work is organized, skills are developed, and employment relationships are structured. This perspective reinforces the need to examine HRM at multiple levels, including organizational, sectoral, and policy dimensions of HRM.

The growing integration of advanced digital technologies has accelerated the transformation of HRM. Nastase, Adomnitei, and Apetri (2025) found that technologies such as artificial intelligence, automation, and people analytics redefine SHRM by enabling data-driven decision-making, continuous reskilling, and ethical governance of human capital. Recent studies further emphasize that digital transformation intensifies the demand for hybrid skills that combine technical expertise with adaptive and cognitive capabilities, reinforcing the strategic importance of HRD in national innovation systems (Atmanegara, Aedy, & Hakim, 2025) (Muzulon, Resende, Leal, & Pontes, 2025). This view aligns with the International HRM literature, which emphasizes that workforce development strategies must respond to global technological change while remaining sensitive to institutional and cultural contexts.

Empirical research on Industry 4.0 has similarly emphasized the mediating role of HRD in achieving a sustainable technological transformation. Vong et al. (2025) demonstrated that business pressures alone do not automatically lead to technological readiness unless they are supported by leadership and structured HRD systems. Their findings suggest that HRD functions as a critical intermediary that translates technological ambitions into workforce capabilities. This insight reinforces the argument that strategic alignment between technology, leadership, and human resource development is essential for sustaining innovation and performance, particularly in emerging and transitioning economies.

In addition, the increasing use of analytical tools in HRM has attracted attention from scholars. Muchowe, Mubango, Soko, Dumba, and Chivabvu (2025) showed that HR analytics strengthens the effectiveness of high-performance work systems by enabling evidence-based workforce management and productivity enhancement. Drawing on human capital theory, they argue that investments in HR systems yield optimal results when supported by analytical capabilities that inform strategic decision-making. This highlights the growing importance of HR analytics as a strategic component of SHRM in technologically dynamic environments.

Beyond organizational-level practices, recent literature emphasizes the role of governance in shaping human capital and HRM strategy outcomes. Studies on governance and intellectual capital suggest that effective governance mediates the relationship between resources and development outcomes by ensuring alignment, accountability, and strategic coordination (Awode & Oduola, 2025). This perspective implies that human resource development efforts are most effective when embedded within coherent governance structures that integrate education, industry, and policy objectives. Such insights are particularly relevant for understanding HRM at the macro level, where institutional coordination influences workforce formation and the technological competitiveness.

Taken together, the existing literature demonstrates that HRM, HRD, SHRM, and governance are increasingly interconnected in shaping workforce readiness for technological transformation. However, despite extensive research on digital HRM, the future of work, HR analytics, and organizational performance, limited attention has been paid to how these perspectives intersect within integrated institutional frameworks that link education systems, industry, and state coordination. Most HRM studies remain focused on organizational-level dynamics, leaving a gap in understanding how macro-level arrangements can systematically support human resource development for large-scale technological expansion. This gap is particularly relevant in the context of this study, which seeks to understand how institutional collaboration, specifically between universities, industry, and government, can enable the systematic development of skills and talent required for sustained technological competitiveness

This gap highlights the urgency of examining human resource development beyond individual organizations and situating HRM within broader institutional systems. Addressing this limitation is critical for advancing Strategic and International HRM scholarship, particularly in the context of global technological competition. By integrating insights from HRM, HRD, the future of work, and governance literature, this study responds to the need for a more comprehensive understanding of how human resource development can be strategically aligned with technological transformation at the national and systemic levels.

2.2 Triple Helix Model and Macro-Level Human Resource Governance

The Triple Helix Model, originally proposed by Zhou and Etzkowitz (2021), conceptualizes innovation as a result of dynamic interactions among universities, industry, and government. While the model is widely applied in innovation studies, recent literature suggests that its relevance extends to the governance of human resource development at the national level. By emphasizing role-sharing and institutional overlap, the Triple Helix framework provides insights into how educational systems, labor markets, and policy institutions can be coordinated to support long-term workforce development.

In this framework, universities contribute not only to knowledge production but also to human capital formation; the industry articulates skill demands and absorbs trained labor; and the government shapes regulatory environments, funding mechanisms, and strategic priorities (Linton, 2024; Zadegan, Ghazinoory, & Nasri, 2025). Such interactions create institutional conditions under which HRD can be aligned with the technological and economic objectives. Recent studies highlight that the Triple Helix operates differently in various national contexts. In some economies, interactions among the three actors are relatively balanced and market-driven, while in others, state coordination plays a more prominent role (Zhou & Etzkowitz, 2021). This variation has important implications for HRM, as it influences how education systems are mobilized to support workforce development and technological upgrades.

Although extensive literature exists on innovation systems, university–industry collaboration, and the Triple Helix Model, relatively little attention has been paid to these frameworks from an explicit Human Resource Management perspective. Many studies focus on technological outputs, commercialization outcomes, and policy effectiveness while overlooking the role of education systems as strategic mechanisms for human resource development. Furthermore, HRM scholarship has traditionally concentrated on organizational-level practices, with less emphasis on the macro-level governance of workforce development. Consequently, the ways in which national education systems are integrated into state-led innovation strategies remain underexplored in the Strategic and International HRM

literature. This study addresses this gap by conceptualizing the Triple Helix Model as a framework for macro-level human resource development, highlighting how education systems can function as strategic infrastructure for workforce formation in technology-driven economies. By bridging innovation studies and HRM scholarship, this study contributes to a more comprehensive understanding of how human resource development supports global technological competitiveness.

3. Methodology

This study adopts a qualitative descriptive research design based on a library research approach. This method is appropriate for examining how human resource development is embedded in China's Triple Helix Model to support global technological expansion. A qualitative approach allows for an in-depth interpretation of institutional arrangements, policy orientations, and governance mechanisms that shape workforce development in technology-driven contexts.

This research is grounded in the Triple Helix Model as the main analytical framework, which conceptualizes innovation as the outcome of interaction among universities, industry, and government. To strengthen HRM orientation, this study draws on Strategic Human Resource Management and Human Resource Development perspectives to analyze how education systems function as strategic mechanisms for talent formation and workforce capability development at the national level. Additionally, a political economy approach was employed to capture the role of state coordination, power relations, and policy direction in shaping human resource development outcomes. These theoretical perspectives are integrated to provide a multilevel analytical framework linking institutional interaction with human resource development outcomes.

Data Sources, for this study relies exclusively on secondary data obtained from authoritative and credible sources. These include peer-reviewed academic journal articles, national policy documents such as Made in China 2025 and China Standards 2035, ministerial reports issued by the Ministry of Education of China, and publications from international organizations including the OECD, UNESCO, and the World Bank. Institutional reports from universities, research institutes, and technology-oriented enterprises involved in university-industry collaboration were also consulted.

The selection of data sources followed the explicit inclusion criteria. First, the sources had to be directly relevant to at least one of the following themes: Human Resource Development (HRD), higher education reform, innovation policy, or university-industry-government collaboration in China. Second, priority was given to peer-reviewed and officially published documents to ensure their reliability and credibility. Third, sources published within the last ten years (2015–2025) were prioritized to capture recent developments in technological transformation and in workforce dynamics. Fourth, widely cited foundational studies were retained where necessary to support the theoretical grounding.

Data collection was conducted through systematic searches in academic databases such as Scopus, Web of Science, and Google Scholar using keywords including "human resource development in China," "Triple Helix China," "innovation policy China," and "university–industry collaboration." Policy documents and institutional reports were obtained from official government and organizational websites. Data Analysis, Data were analyzed using qualitative content analysis. This technique was employed to identify recurring patterns, key concepts, and thematic relationships related to human resource development within the Triple Helix system. The analysis followed a structured, multistage procedure. First, all collected documents were subjected to an initial reading to gain a general understanding of their content and relevance to this study. Second, open coding was conducted to identify key concepts and recurring issues related to the HRD, education systems, and institutional collaboration. Third, these initial codes were grouped into broader thematic categories corresponding to the roles of universities, industry, and government within the Triple Helix framework. Fourth, axial coding was applied to examine the relationships between themes, particularly how institutional interactions contribute to workforce development and technological competitiveness. Finally, the themes were interpreted using the combined lenses of the Triple Helix Model, Strategic HRM, and political economy to generate analytical insights.

This analytical process enabled the study to move beyond descriptive accounts of innovation policy and focus on how institutional collaboration contributes to workforce readiness and talent development in support of technological expansion. To enhance validity and credibility, source triangulation was applied by comparing insights across multiple types of documents, including academic literature, official policy texts, and international institutional reports. In addition, analytical triangulation was employed by interpreting the data through multiple theoretical lenses (Triple Helix, HRD/SHRM, and political economy), thereby reducing single-framework bias. This triangulation helps to ensure consistency between stated policy objectives, institutional practices, and scholarly interpretations. Contextual analysis was employed to assess the alignment between China's national development strategies, education reforms, and human resource development outcomes. By situating the analysis within a broader political and economic context, this study strengthens the robustness of its findings and reduces the risk of bias arising from reliance on a single source or perspective.

4. Results and Discussions

4.1 Education-Centered Triple Helix as a Human Resource Development System

The findings of this study indicate that China's Triple Helix collaboration operates not only as an innovation framework but also as a comprehensive system for developing human resources. Consistent with the Human Resource Development literature, technological competitiveness in knowledge-intensive economies depends on the continuous formation of skills and human capital rather than on technological investment alone (Omemma Evans-uzosike & Gbemisola Okatta, 2019). The Chinese case demonstrates that education and research institutions function as the central nodes through which talent is systematically produced, upgraded, and integrated into technology-driven industries.

Unlike firm-centered HRM models, China's approach reflects a macro-level HRD system in which universities play a dual role as both knowledge producers and talent incubators. This finding supports earlier arguments that national education systems can act as strategic HR infrastructure when aligned with long-term economic and technological objectives (Cavalheiro, Oliveira, Leandro, & Kontz, 2025). Within the Triple Helix framework, education is positioned as a proactive contributor to workforce readiness, rather than a passive supplier of graduates.

4.1.1 University–Industry Collaboration and Workforce Skill Formation

The results further reveal that university-industry partnerships serve as a key mechanism for workforce development within China's Triple Helix system. Consistent with prior studies, collaboration between universities and firms enhances the relevance of academic training by integrating applied research, joint training programs, and industry-oriented curricula (Zhuang, Oh, & Kimura, 2025). These arrangements facilitate the transfer of both technical skills and innovation-oriented competencies required in advanced technology sectors.

University–industry partnerships in China constitute a critical mechanism for human resource development within its innovation-driven economy. The deep integration between higher-education institutions and industry has accelerated knowledge transfer and strengthened applied research, positioning China among the world's leading countries in university-industry collaboration (Liu & Yan, 2022). Since 2017, China has become the largest global producer of scientific publications, surpassing the United States in both volume and citation impact, particularly in engineering and computer science, fields that are directly linked to industrial skill demand (Pisani, Boekhout, Heemskerk, & Takes, 2025). This pattern reflects a demand-driven innovation model in which research productivity is closely aligned with workforce and industry needs.

From a human resource development perspective, the expansion of higher education has significantly increased China's talent pool. Gross tertiary enrollment increased from 13.3% in 2000 to 54.4% in 2020, marking a transition from elite to mass and eventually universalized higher education (Hu, Zhou, & Xie, 2025). This expansion has enabled the large-scale formation of the skilled human capital required to support technology-intensive sectors. The strategic embedding of universities within industrial clusters, science parks, and high-tech zones further reinforces their role as talent incubators that supply industry-ready graduates and applied research skills.

State-directed policies provide an institutional framework that sustains education–industry alignment. National strategies, such as the 14th Five-Year Plan and Made in China 2025, emphasize technological self-reliance, industrial upgrading, and workforce capability development as interconnected goals (Hu et al., 2025; Song et al., 2025). University-industry collaboration is institutionalized through mechanisms such as manufacturing institutes, State Key Laboratories, and structured technology transfer arrangements, including licensing and joint training programs (Zhuang et al., 2025). These arrangements strengthen the linkage between education, skill formation, and industrial application, while recruitment pipelines, internships, and industry-involved curriculum design help reduce skill mismatches between higher-education and labor-market requirements.

A concrete example of this collaboration is the partnership between Tsinghua University and leading technology firms such as Huawei and Tencent. Through joint research centers and co-developed training programs, Tsinghua integrates industry-oriented projects into its engineering and computer science curricula, allowing students to engage directly with real-world challenges. Similarly, Huawei collaborates with multiple Chinese universities through its "Huawei ICT Academy" program, which provides standardized training, certification, and hands-on learning aligned with industry needs (De Masi, Di, Li, & Song, 2025). These initiatives demonstrate how university-industry collaboration in China has been institutionalized as a structured mechanism for talent development rather than ad hoc cooperation.

Another example is the integration of Zhejiang University with the Alibaba Group within the Hangzhou digital economy cluster. This collaboration includes joint laboratories, entrepreneurship programs, and digital talent training initiatives that directly support the growth of the e-commerce, cloud computing, and artificial intelligence sectors (Z. Li & Zhang, 2025). Such partnerships illustrate how universities are embedded within regional innovation ecosystems, enabling continuous interaction between education, industry, and technological applications. Overall, the evidence indicates that university–industry partnerships in China function not only as drivers of innovation but also as a systematic human resource development infrastructure. By aligning higher education expansion, applied research, and industrial demand within a coordinated policy framework, China has created institutional conditions that support continuous workforce upgrading and the development of advanced skills necessary for global technological growth.

From an HRM perspective, these partnerships function as institutionalized talent pipelines that reduce skill mismatches between the education and labor markets. This finding aligns with HRD research emphasizing the importance of coordinated education-employment systems in supporting employability and productivity (Anochiwa, 2021). Evidence suggests that workforce development outcomes are strengthened when industry actors actively participate in curriculum design, training provision, and applied research activities. Importantly, the scale of these collaborations indicates that workforce development is not treated as an isolated organizational function but as a systemic process embedded in national innovation strategies. This supports the Strategic HRM perspective that emphasizes the alignment between human resource development and long-term strategic objectives at both the organizational and national levels.

4.1.2 State Coordination and Strategic Human Resource Management

A central finding of this study is the prominent role of the state in coordinating human resource development within the Triple Helix framework. Unlike decentralized innovation systems, where HR outcomes emerge primarily from market interactions, China's model reflects a form of state-enhanced Strategic HRM. Government involvement shapes educational priorities, research agendas, and industry collaboration, ensuring that workforce development aligns with national technological goals.

China's rapid rise as a global innovation power is strongly reflected in measurable indicators of Research and Development (R&D) investment, which form a critical foundation for long-term human resource development and workforce capability. Over the past decade, China has demonstrated a sustained and accelerating commitment to R&D expenditure, positioning itself as one of the leading innovation-driven economies worldwide. In comparative terms, China ranks 13th globally in R&D

intensity, measured as the ratio of R&D expenditure to GDP, and remains one of the highest-performing developing economies in this category (Oecd, 2025a). This sustained investment signals not only technological ambition but also a strategic effort to expand the national capacity for knowledge production and skill development. Empirical evidence from ASEAN indicates that economic and political globalization, along with infrastructure development, has had a positive and significant impact on economic growth, suggesting that across Asia, economic expansion has been increasingly driven by technological advancement and deeper integration into global networks (Wahyudi & Ayunindien, 2022).

In 2023, China's R&D expenditure increased by 8.7% compared to the previous year, significantly outpacing growth rates in major advanced economies such as the United States (1.7%) and the European Union (1.6%), including key EU member states such as Germany (0.8%) and France (–0.5%). This growth also exceeded that of other leading Asian economies, including Japan (2.7%) and South Korea (3.7%), underscoring China's exceptional momentum in strengthening its innovation system (Oecd, 2025b). From a human resource management perspective, this rapid expansion in R&D spending reflects the rising demand for highly skilled researchers, engineers, and technology-oriented professionals, thereby intensifying the strategic importance of education systems and workforce development mechanisms.

The upward trajectory continued in 2024, further reinforcing the role of the state in shaping innovation and investing in human capital. According to data from the National Bureau of Statistics, China's total R&D expenditure exceeded 3.6 trillion yuan (approximately USD 500 billion), representing an 8.3% year-on-year increase. Simultaneously, R&D intensity rose to 2.68% of GDP, an increase of 0.1 percentage points from the previous year (Xinhua, 2025). This simultaneous growth in absolute spending and intensity indicates that R&D activities are becoming increasingly embedded within China's broader economic structure, with direct implications for the scale and continuity of human resource development in science- and technology-intensive sectors.

Taken together, these indicators reveal a clear pattern: China is not only expanding R&D investment at a faster pace than many advanced economies but is also rapidly converging with the United States in terms of absolute R&D spending. The consistent rise in both total expenditure and R&D intensity underscore the strategic prioritization of innovation as the cornerstone of national development. Importantly, from a Strategic Human Resource Management perspective, this investment trajectory strengthens the institutional conditions for sustained talent formation, workforce upgrading, and the development of advanced skills necessary to support China's global technological expansion.

This finding is consistent with the macro-HRM literature, which highlights the role of institutional governance in shaping workforce outcomes, particularly in coordinated or state-influenced economies (Cavalheiro et al., 2025). Through policy instruments, funding mechanisms, and regulatory frameworks, the state facilitates sustained interaction between universities and industries, enabling long-term investment in skill formation and human capital accumulation. From a political economy perspective, this coordination reduces uncertainty for education providers and firms by signaling stable priorities and a long-term demand for specific skill sets. Consequently, HRD activities are embedded within a broader strategic architecture that supports technological upgrading and global competitiveness.

Beyond investment volume, the effectiveness of state-coordinated Strategic Human Resource Management also lies in its ability to integrate education systems, research institutions, and industrial actors into a coherent talent development pipeline (Harinurdin, Laksmono, Kusumastuti, & Safitri, 2025). Within the Triple Helix framework, universities function not only as centers of knowledge production but also as strategic agents of workforce formation, responding to state-defined innovation priorities and industrial skill demands (Matej & Amadeja, 2025). This alignment facilitates the continuous circulation of human capital across the academic, industrial, and governmental domains, enabling faster knowledge transfer and skill upgrading. Importantly, such institutional integration enhances firms' absorptive capacity by ensuring that graduates and researchers possess competencies

aligned with emerging technological trajectories. From a macro-HRM perspective, this configuration illustrates how coordinated governance structures can transform human resource development into a systemic instrument for national innovation rather than a fragmented or firm-level function. Consequently, the Triple Helix model in China operates not only as an innovation policy framework but also as a mechanism for strategic alignment between human capital formation and long-term technological transformation.

4.1.3 Innovation Clusters as Talent Ecosystems

The findings also demonstrate that innovation clusters function as localized talent ecosystems within the Triple Helix system. Prior research suggests that geographically concentrated innovation environments enhance knowledge exchange, skill development and labor mobility. Consistent with this literature, the clustering of universities, research institutes, and firms creates conditions that facilitate continuous learning, applied training, and rapid skill upgrading.

Assessments of State Key Laboratories (SKLs) indicate that China has deliberately designed innovation environments by co-locating universities, enterprises, and research institutes to facilitate a seamless transition from basic research to applied development. Several universities concentrate their research capacity on strategically prioritized fields, such as battery technology, as illustrated by the SKL for Physical Chemistry of Solid Surfaces at the Xiamen University, which employs more than 100 researchers. This scale far exceeds that of comparable research centers in the United States, including NSF Engineering Research Centers, which typically involve approximately 30 researchers. This scale and specialization demonstrate that China's university-based research infrastructure is designed to support industrial upgrading and serve as a central pillar within the national innovation system (Atkinson, 2024).

Simultaneously, industrial clusters have established structured talent pipelines in collaboration with universities through internships, joint training schemes, and scholarship programs targeting high-technology sectors such as quantum information, aerospace, and renewable energy. Firms are increasingly involved in curriculum development, particularly in engineering, computer science, and applied sciences, ensuring that graduates acquire skills that align with industry requirements. This integration strengthens workforce readiness and helps to narrow the gap between academic education and the demands of technology-oriented labor markets. For instance, the Zhongguancun Science Park in Beijing, often referred to as "China's Silicon Valley" hosts a dense network of universities, such as Peking University and Tsinghua University, alongside leading technology firms. This proximity enables continuous collaboration in research, talent development, and startup incubation, creating a dynamic ecosystem in which students, researchers, and industry professionals interact. As a result, innovation clusters not only accelerate technological development but also function as integrated talent ecosystems that support workforce mobility and skill upgrading

Within this institutional setting, the Triple Helix framework conceptualizes universities as hubs of knowledge creation and human capital formation, industries as drivers of commercialization and technological deployment, and governments as providers of strategic direction, regulation, and financial support (Zadegan et al., 2025). Triple Helix framework further distinguishes multiple modes of interaction, including bilateral collaboration between pairs of actors, trilateral coordination among universities, industry, and government, and the formation of innovation clusters that integrate research, production, and policy objectives. Through these interconnected arrangements, the model aims to accelerate technological progress, foster a knowledge-based economy, and enhance national competitiveness by aligning innovation activities with human resource development and institutional collaboration (Zhou & Etzkowitz, 2021). From an HRM perspective, these clusters support workforce development by providing structured pathways for education-to-employment transitions. Internships, joint research projects, and industry-sponsored training programs embedded within innovation clusters strengthen the alignment between academic learning and workplace needs. This supports the International HRM discussions on how national systems can cultivate globally competitive talent pools in technology-intensive industries.

4.2 Implications for Strategic and International HRM

Taken together, these findings demonstrate that China's Triple Helix Model represents a distinctive approach to human resource development that operates beyond firm-level HR practices and organizational boundaries. Rather than treating HRD as an internal managerial function, China embeds workforce development within a nationally coordinated innovation system that links education policy, industrial strategy and technological upgrading. This arrangement illustrates how HRD can be governed at the macro level through institutional alignment and long-term strategic planning, providing empirical support for Strategic HRM perspectives that emphasize vertical alignment between human resource systems and overarching development objectives.

From a Strategic HRM standpoint, the evidence suggests that the alignment between human resource development and the national innovation strategy is not incidental but institutionally engineered. Large-scale R&D investments, the expansion of higher education, and the deliberate integration of universities into industrial clusters collectively create a sustained demand for advanced skills and continuous workforce upgrading. In this context, HRD functions as a strategic infrastructure that supports technological readiness by ensuring a steady supply of industry-relevant talents. This finding extends the Strategic HRM literature by demonstrating that strategic alignment can be institutionalized not only within organizations but also across national systems through coordinated governance mechanisms.

The results further highlight the importance of education-centered coordination as a core pillar of macro-level HRM. University-industry partnerships, applied research orientation, and structured talent pipelines, such as internships, joint training programs, and curriculum co-design, reduce skill mismatches between education systems and labor markets. These mechanisms enable human capital formation to keep pace with rapid technological changes, reinforcing the view that workforce capability development is a precondition for sustained innovation. From an HRD perspective, this study underscores the strategic role of education systems as talent incubators, rather than passive suppliers of graduates.

In terms of international IHRM, the findings contribute to ongoing debates on the diversity of national HR governance models. Much of the existing HRM literature emphasizes decentralized, market-driven skill formation and organizational autonomy as dominant paradigms (Lenart-Gansiniec, A. Sypniewska, & Chen, 2023). However, the Chinese case illustrates an alternative pathway in which state coordination plays a central role in shaping workforce-development outcomes. By actively orchestrating collaboration among universities, industry, and government, the state reduces uncertainty, aligns incentives, and facilitates long-term human capital investment. This challenges the universalistic assumptions in HRM scholarship and calls for greater sensitivity to institutional variations in global workforce development.

Moreover, the analysis suggests that state involvement in HRD does not necessarily crowd out organizational agency but can enable firms and educational institutions to operate within a stable and predictable strategic environment. In technology-intensive sectors characterized by high uncertainty and rapid skill obsolescence, such coordination may enhance, rather than constrain, organizational HR effectiveness. This insight is particularly relevant for International HRM scholars examining how emerging and transitioning economies design workforce strategies to compete in the global technology markets. The analysis reveals three interrelated findings: (1) Education and Research Institutions as Strategic Human Resource Development Infrastructure; (2) University–Industry Collaboration as an Institutionalized Talent Pipeline; and (3) State Coordination and the Emergence of a Macro-Level HRM Architecture.

4.2.1 Education and Research Institutions as Strategic Human Resource Development Infrastructure

The results demonstrate that educational and research institutions in China function as strategic human resource development infrastructure rather than isolated knowledge producers. Evidence from sustained R&D investment, large-scale expansion of higher education, and the concentration of research capacity in universities indicates that education systems are deliberately positioned to support continuous workforce upgrading in technology-intensive sectors. The steady rise in R&D expenditure and intensity

reinforces the role of universities as large-scale talent incubators that align human capital formation with long-term technological and industrial goals. From an HRD perspective, this finding confirms that China's education systems are embedded within a broader governance framework that treats human resource development as a strategic national asset. Thus, universities play a central role in ensuring the availability of advanced skills required for global technological expansion.

4.2.2 University-Industry Collaboration as an Institutionalized Talent Pipeline

The second major finding is that university-industry collaboration operates as an institutionalized talent pipeline that enhances workforce readiness and reduces skill mismatches. Evidence from applied research partnerships, joint training programs, structured internships, and curriculum–industry alignment demonstrates that collaboration between education and industry extends beyond ad-hoc cooperation. Instead, it forms a systematic mechanism for translating academic knowledge into industry-relevant skillsets. These arrangements facilitate smoother education-to-employment transitions and enable industries to absorb and upgrade human capital more rapidly than before. From a Strategic HRM perspective, university–industry collaboration functions as a workforce alignment mechanism that directly links human resource development to technological and industrial demand.

4.2.3 State Coordination and the Emergence of a Macro-Level HRM Architecture

The third key finding highlights the central role of state coordination in integrating education policy, innovation strategy, and industrial development into a coherent, macro-level Strategic Human Resource Management architecture. National strategies, policy directives, and governance mechanisms provide the institutional glue that aligns universities and industries with their long-term development goals. Rather than replacing organizational agency, state coordination creates a stable and predictable environment that encourages sustained investment in human capital and applied research. This finding underscores that China's Triple Helix Model represents a state-enhanced approach to human resource development, in which workforce development is governed at the system level to support technological competitiveness and global expansion.

By framing the Triple Helix as a macro-level HRM architecture, this study offers a new analytical lens for understanding the relationship between human resource development and global technological expansion. The Chinese experience shows that technological competitiveness is sustained not only through innovation outputs but also through institutionalized systems of talent formation, workforce upgrading, and strategic coordination. This perspective broadens the scope of HRM research by situating human resource development within national innovation systems and highlights the need for future HRM scholarship to engage more deeply with questions of governance, policy, and international competition in shaping the future of work.

5. Conclusions

5.1 Conclusion

This study examined how China's Triple Helix Model operates as a mechanism for human resource development to support global technological expansion. By applying the Triple Helix framework from a political economy perspective, this study demonstrates that China's education system functions as a strategic component of national human resource governance, aligning human capital formation with long-term technological and industrial objectives. The findings indicate that the objectives of this study were accomplished in three interrelated ways. First, this study confirms that education and research institutions in China function as strategic human resource development infrastructure rather than as isolated knowledge producers. The expansion of higher education and sustained investment in research and development have enabled universities to act as large-scale talent incubators that support continuous workforce upgrading in technology-intensive industries. Second, this study shows that university-industry collaboration operates as an institutionalized talent pipeline, supported by applied research, joint training programs, and curriculum-industry alignment, thereby reducing skill mismatches and enhancing workforce readiness. Third, the analysis highlights the central role of state coordination in integrating education policy, innovation strategy, and industrial development into a coherent, macro-level Strategic Human Resource Management architecture.

Overall, the study concludes that China's Triple Helix Model represents a form of state-enhanced human resource development in which education systems are deliberately mobilized to sustain long-term technological competitiveness in the economy. By framing the Triple Helix as a macro-level HRM architecture, this study extends the existing HRM literature beyond firm-level analysis and provides a new perspective on how national governance structures shape workforce development in innovation-driven economies.

Importantly, these findings demonstrate that effective human resource development in technology-driven economies requires not only organizational HR practices but also systemic coordination between education, industry, and the government. For policymakers, this implies the need to design integrated education and innovation policies that align skill formation with long-term industrial strategy. For organizations, particularly in technology-intensive sectors, the findings highlight the importance of actively engaging with universities through structured partnerships, such as joint training programs, internships, and collaborative research initiatives, to ensure workforce readiness. For HRM scholars, this study underscores the need to expand analytical frameworks beyond firm-level practices and incorporate macro-level institutional dynamics in understanding workforce development and global competitiveness.

5.2 Research Limitation

Despite these contributions, this study has several limitations. First, the analysis relies exclusively on secondary data and literature-based evidence, which limits the ability to capture micro-level dynamics within organizations, universities, and individual labor markets. Second, the focus on a single national context constrains the generalizability of the findings, as different countries may exhibit distinct institutional arrangements and governance traditions. Third, this study does not incorporate primary empirical data, such as interviews or surveys, which could offer richer insights into how Triple Helix collaboration is implemented and experienced by key stakeholders in human resource development.

5.3 Suggestions and Directions for Future Research

Based on these limitations, several directions for future research are proposed. Future studies could employ qualitative methods, including interviews with policymakers, university leaders, and industry practitioners to explore how macro-level HRM architectures translate into organizational HR practices. Comparative cross-national research would also be valuable in examining how different governance models influence the effectiveness of education-driven human resource development in supporting technological competitiveness. In addition, quantitative studies could assess the long-term impact of the Triple Helix-based HRD systems on workforce productivity, employability, and innovation performance. From a practical perspective, the findings suggest that policymakers should strengthen institutional coordination between educational systems, industries, and innovation agencies to ensure sustained workforce readiness in technology-driven sectors. For HRM scholars and practitioners, this study underscores the importance of extending HRM analysis beyond organizational boundaries and incorporating national-level governance and education systems into Strategic and International HRM frameworks.

From a practical perspective, policymakers should develop formal platforms for university-industry collaboration, such as national talent development programs, sector-specific training consortia, and innovation clusters that integrate education and employment pathways. Governments can also incentivize firms to co-invest in workforce development through tax incentives and research grants and public–private partnerships. For organizations and HR practitioners, implementing structured talent pipelines, such as apprenticeship programs, industry-linked curricula, and continuous reskilling initiatives, can help align workforce capabilities with rapidly evolving technological demands. HRM scholars should further explore how macro-level HRD systems interact with organizational HR practices, particularly in emerging economies navigating digital transformation and global competition.

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Author Contributions
ADM contributed to the conceptualization of the study, research design, supervision, and manuscript review and editing. HW contributed to data collection, literature analysis, methodological development, and drafting of the manuscript. HH contributed to the data organization, thematic analysis, interpretation of the findings, and manuscript preparation. All authors have reviewed and approved the final version of the manuscript.

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