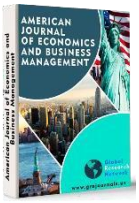

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Article

National Innovation Systems in Leading Asian Economies: Policy Implications for Central Asia

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Abstract: High-technology innovation has become a critical driver of economic growth and national competitiveness in the modern global economy. Knowledge-intensive high-tech sectors — ranging from information and communication technology (ICT) and biotechnology to microelectronics and renewable energy — are characterised by high R&D investment, significant value addition, and strong productivity. This paper presents a comparative analysis of high-tech innovation strategies in China, South Korea, and India, with the aim of deriving actionable insights for Uzbekistan's innovation policy. The study emphasises the growing importance of science-intensive, high-tech sectors — such as information technology, biotechnology, artificial intelligence, and clean energy — in driving sustainable economic growth and enhancing global competitiveness. Comparative High-Technology Innovation Strategies In Leading Asian Economies And Implications For Uzbekistan: a Study The paper, employing a qualitative case study approach (based on secondary data), examines policy instruments, institutional architectures, and investment priorities in selected Asian economies that have enabled them to accomplish technological transformation. It delves into China's state-led industrial planning, South Korea's chaebol-driven innovation ecosystem, and India's startup-driven digital strategy. Each model embodies a specific trajectory based on its historical and institutional specificities, but they are underpinned by similar pillars: top-down approach through targeted government intervention, R&D and human capital investment, and integration into global value chains. For Uzbekistan, the results of the analysis indicate that it is imperatively necessary to strengthen R&D expenditures; improve governance in the field of innovation; enhance high-tech entrepreneurship; and focus on targeted sectors, especially, ICT, agri-tech, and renewable energy. The results indicated that Uzbekistan could make rapid steps toward a knowledge-based economy through the adapted application of tested tools of policy and planning, rather than by direct copying. A comparative examination of the high-tech innovation strategies of China, South Korea India produces some important insights for Uzbekistan's innovation strategy.

Keywords: High-Tech Innovation, R&D Policy, Industrial Strategy, Uzbekistan, China, South Korea.

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1. Introduction

Uzbekistan, a key country in Central Asia, is strategically positioned at the crossroads of Europe and Asia. This unique geographical advantage, combined with its rich natural resources and a young, dynamic population, makes Uzbekistan an ideal candidate for harnessing innovation to drive economic growth [1]. High-technology innovation has become a critical driver of economic growth and national competitiveness in the modern global economy. Knowledge-intensive high-tech sectors — ranging from information and communication technology (ICT) and biotechnology to microelectronics

and renewable energy — are characterised by high R&D investment, significant value addition, and strong productivity. Developing these sectors leads to diversification of the economy, expansion of high-value-added exports, creation of skilled jobs, and a transition toward a knowledge-based economy. Indeed, countries that invest heavily in science and innovation have been able to boost long-term growth and secure a competitive edge in the global market [2]. Science and technology are the primary productive force, and also the inexhaustible driving force for high- quality development, so the research of technological innovation affecting high-quality development has become the focus of all sectors of society [3]. Empirical studies consistently show a positive relationship between R&D investment and industrial competitiveness, underscoring the pivotal role of innovation in sustainable development [4], [5]. As a result, many nations view high-tech innovation capacity as vital to their future economic prosperity and security [6].

Uzbekistan is a country in transition to a new economic environment in which the role of high-tech would be critical for the acceleration of development. Although the country is in the middle of an era of structural reforms and efforts to finally catch up and modernise its economy, its innovation indicators continue to be some of the lowest in the world [7]. As the World Bank reports, in 2022 the gross expenditures on R&D in Uzbekistan amounted to 0.16% of GDP, which is extremely low compared to the average world figure (which is about 2.2%), and a small percentage of 2–5% that is characteristic of the most advanced innovative countries. That is, high-tech economies spend on the order of 20–30 times more (as a share of GDP) on R&D and innovation than Uzbekistan. A similarly alarming indicator is the structure of exports: the share of high-technology products in Uzbekistan's manufacturing exports was only 1% in 2022, which puts the country near the end of the world rankings [8]. This indicates an export structure characterized by dependence on low value-added commodity goods, in contrast to technologically advanced countries, whose exports are largely complex high-tech products.

These discrepancies emphasized the necessity of increasing the innovative capacity of Uzbekistan for its economic diversification and international competitiveness. Three important cases, China, South Korea, and India, illustrate the broad variety of high- tech innovation models and the instructive power of each. Abstract China has rapidly transformed from a technological follower to a global innovation powerhouse within a few decades, largely through relatively aggressive state-led policies, large-scale investments in R&D, and industrial policies targeting strategic sectors, Made in China 2025 for example.

(AI, microelectronics, biotechnology, etc.). In contrast, South Korea is anexample of a sustained R&D-intensive development path. South Korea until recently was a successful development that was founded in decades long top-down innovation policy, close collaboration between government–industry–academia, and nurturing of technology-centered powerhouses (chaebols) to transition into a knowledge-based economy as one of the most innovative nations. India, on the other hand, presents a very different example of a developing economy — a burgeoning ICT and aspiration-driven startup company ecosystem with relatively little R&D dollars spent.

In this context, a comparative analysis of these four countries' innovation strategies offers valuable lessons for Uzbekistan, an emerging economy undergoing economic reforms and seeking to develop its own high-tech sectors [9].

This paper aims to answer the following research question:

"What policy instruments and strategic approaches have enabled leading Asian economies to develop successful high-tech innovation ecosystems, and how can these be adapted to enhance Uzbekistan's innovation capacity?" By examining these diverse models, the study seeks to generate actionable insights that can guide Uzbekistan's transition toward a more innovative, knowledge-based economy [10].

2. Materials and Methods

This study adopts a qualitative comparative case study approach to explore how high-tech innovation strategies have evolved in China, South Korea, and India, with the goal of drawing context-sensitive implications for Uzbekistan. This methodological choice is well-suited for examining policy frameworks and institutional dynamics in diverse national settings, particularly where innovation systems are shaped by unique political, economic, and cultural factors. These four countries are chosen based on theoretical relevance and practical significance. China and South Korea are posters of innovation at a high level in the socio-economic innovative development, whose learning can be used for other innovation economies with the strong presence of government and higher R&D intensity, while India and Singapore give instructive lessons from emerging and small-state context respectively. All in all, they offer a comprehensive but parallel experience set that can be valuable for Uzbekistan as it pursues its own high-tech innovation path.

In order to perform this analysis the research only uses secondary data. Each case was constructed through a review of a diverse range of academic and institutional sources. Such articles, books, and policy reports covering national innovation strategies, sector- specific initiatives, and structural reforms Furthermore, official documents on national development plans, innovation roadmaps and R&D expenditure reports by government agencies were reviewed to gain some insight into the formal policy context. Consistent and comparable indicators were also derived from international databases and reports of the OECD, UNESCO and World Bank.

The analysis provides valuable information, but it also has its limitations. The research does not make causal claims due to its qualitative secondary-data nature but serves to point to patterns and best practices that indicate actions that can be meaningfully taken. Also, variations in availability of data, analytics standards and terminology between countries may further limit comparability. However, the methodological strategy does in fact fit the purpose of the study: to offer empirically based points of reference at a comparative level that could be useful in strengthening the direction towards a high-tech innovation ecosystem in Uzbekistan.

3. Results and Discussion

3.1 China

Over the past few decades, China has made an impressive leap from being a technological outsider to joining the ranks of global leaders. China's strategy is based on the active role of the state in planning and investing in key sectors, while simultaneously attracting foreign technologies and developing its own innovative capacity. The country's government programs targeting high-tech industries are truly numerous, large-scale, and systematic. These areas span the full spectrum of strategic domains— artificial intelligence, microelectronics, biotechnology, new materials, and the digital economy (see Table 1). China reported the second greatest R&D use throughout the world, today. China's R&D budget in 2021 was about $441 billion, or 2.44% of GDP [11]. For comparison, in 2000, this figure was less than 1%, meaning that over 20 years, China more than doubled its R&D intensity.

Table 1. Key State Programs and Initiatives in China.

Program / Initiative	Duration	Description and Goals
Made in China 2025	2015–2025	National strategic plan to modernise industry, enhance technological sovereignty, create global

		brands, and reduce dependence on imported technologies.
New Generation AI Development Plan	2017–2030	Large-scale program to make China a global leader in AI by 2030; focuses on developing AI theory, technologies, and industry, and integrating AI into the economy and society.
Five-Year Plans (13th, 14th, etc.)	2016–2025 and beyond	Comprehensive programs for socio-economic and technological development; annual increases in R&D investment, growth of the digital economy, and encouragement of patent activity.
State Venture Fund	2024–2045 (planned)	The world's largest state venture fund (up to 1 trillion yuan) supports AI, quantum technologies, biomanufacturing, hydrogen energy, and other advanced sectors.
Three-Year and Sectoral AI Plans	2017–2021 and others	Specific plans for developing key technologies and integrating AI into the economy; promotes the development of domestic chips and the creation of national platforms.
Digitisation and Informatisation Plan	2021–2025	Development of digital technologies, large-scale 5G implementation, preparation for 6G, and expansion of the digital economy and digital services.

China has also emerged as a global leader in high-tech production and exports. In 2022, the volume of China's high-tech goods exports reached approximately $770 billion—more than any other country [12]. This includes vast amounts of electronics, telecom equipment, computers, and household appliances. High-tech goods account for over 26% of China's manufacturing exports, and if medium-tech products are included, more than 60% of China's total industrial exports come from medium- and high-tech sectors [13]. In recent years, China has become the world's top exporter of high-tech products such as electric vehicles, lithium-ion batteries, and solar panels, which in 2023 alone grew by 30% and reached a total value of around $150 billion [14]. China has remained the largest market for industrial robots in the world for more than a decade and continues to lead the world in industrial robot production volume. Dozens of native robotics startups like Unitree, Jaka Robotics, Mech Mind, and MegaRobo are flourishing with financial backing from global investors such as Intel Capital, Softbank, and Bosch. In November 2023, China governments told to announce to start mass producing humanoid robots in 2025 and become a world leader in the field by 2027. The rise of Chinese robots has grown up in with manufacturing, logistics, healthcare and agriculture. [15]. The long-term strategy envisions deep integration of artificial intelligence, computer vision, and autonomous technologies into industrial processes. China also ranks third globally in industrial robot density, with 470 robots per 10,000 manufacturing workers—more than double the global average and significantly ahead of the United States [16].

At the same time, China remains the unquestionable leader in the global electric vehicle (EV) manufacturing, sales, and technology market, setting records nearly every quarter, and taling substantial technological achievements in recent years. By March 2025, new energy vehicles (NEVs)—battery electric vehicles (BEVs) and plug-in hybrids (PHEVs)—represented 51.1% of China's automotive market, a record transition toward clean mobility. In 2024 alone, China sold

11.2 million NEVs — a 40% increase over 2023 and more than five times the volume as its nearest global competitors [17]. China currently commands approximately 73% of the global PHEV market, significantly outperforming the United States and Europe in both production and sales. The country's EV industry is led by major domestic players such as BYD, Nio, XPeng, and Xiaomi, supported by battery giants like CATL and WeLion, which together account for over 77% of global battery production capacity.

Chinese electric vehicles are, on average, nearly twice as cost-effective as their European counterparts, while offering superior technological integration [18]. China's strategic success in the EV and broader high-tech sector stems from its hybrid approach: combining technology acquisition through foreign direct investment, localisation mandates, and international partnerships with the systematic development of domestic innovation capacity. State forms the central premise for domestic market protection, as well as bringing large national companies to the global level.

Uzbekistan can learn from the positive aspects of Chinese experience, particularly the merits of active industrial policy, cluster-based development and long-term planning on a sectoral level. Even though the scale and institutional scene varies widely, a number of policy devices like technopark growth, expenditure incentives reinforced through localising and precise public-private partnerships could be employed to establish science-intense high-technology sectors within Uzbekistan.

3.2 Republic of Korea (South Korea)

A case in point is South Korea, which in not much more than three decades — from the 1960s — recorded an unprecedented turnaround from an agrarian-industrial society to one of the world's pre-eminent technology power houses. This model was too special with a significant participatory role for the state in the first phases of the industrial revolution, a high conscious reliance on big family-run businesses (chaebols), and high prioritisation of education and R&D.

Today, South Korea ranks among the most R&D- intensive economies globally. The country spent a whopping 5.21% of its GDP on research & development in 2022, only behind Israel [19]. The South Korean government has a layered support system to promote technological growth, ranging from direct financial support, tax benefits, infrastructure, skilled workers, and programs that bring in foreign experts. In 2023, the government foreshadowed a target 50 trillion won (~$34.4 billion) fund for the priority sectors: semiconductors, batteries, biotechnology, artificial intelligence, advanced materials and others [20]. This initiative also includes programs such as K- Tech Pass, a new "top visa" scheme for attracting foreign specialists, and KIURI, aimed at integrating young scientists and university startups into the business ecosystem.

South Korea's innovation ecosystem is characterised by strong integration between industry, government, and academia. In 2022, total R&D investments reached approximately

$85 billion, with 76.6% coming from the private sector and 23.4% from public sources [21]. This demonstrates the high level of corporate innovation activity and strong engagement in developing strategic technologies. Leading South Korean corporations such as Samsung, LG, Hyundai, and SK Group play a central role in this innovation-driven model. In 2023, the 1,000 largest Korean companies increased their R&D spending by 8.7%, reaching 72.5 trillion won, even amid declining global sales. Of these, 171 were major conglomerates, while the rest were medium and small enterprises [22]. The four largest chaebols—Samsung, SK, Hyundai Motor, and LG—collectively accounted for 40.8% of South Korea's GDP in 2023, and the top 30 business groups made up 76.9% of GDP. Their total revenue reached 980.5 trillion won (~$729 billion) [23].

Major sectors of success for South Korea include electronics, automotive manufacturing, chemicals, and advanced materials. In fact, flagship company Samsung

operates in multiple global leading areas: Samsung Electronics is a global leader in DRAM and NAND memory, one of the world's largest microprocessors producers (currently receiving chips made from leading edge 3nm process), and billions of dollars are continuously poured into new fabrication plants. Samsung is also amongst the top smartphone vendors, OLED display manufacturers, and consumer electronic device manufacturers. SK Hynix is one of the global top 3 memory chip makers. Hyundai Motor Group (Kia included) are nowadays a global manufacturer in the automotive sector, investing billions in electric vehicles and hydrogen technologies. LG Chem and Samsung SDI are two of the largest producers of lithium-ion batteries, which provide timely infrastructure for electric mobility and energy storage. Korea has an edge in the biotechnology sector, with strengths including biopharmaceuticals and medical technology; Samsung Biologics, for example, is the largest contract manufacturer of biologic drugs in the world and played a significant part in the COVID-19 vaccines.

South Korea experience has great importance because resouce-poor economies can see that the country which has raw material cannot achieve true wealth unless it invest in knowledge and human capital. With global top class brand names created through a hybrid based upon planning and the market system, Korea has become one of the world technological leaders, together with the U.S., EU and Japan. Korea´s model has much to teach Uzbekistan: the crucial role of technical education, of domestic producer support, of global trade integration, and of a long-term science and technology plan.

3.3 India is confidently emerging as one of the leading economies focused on the development of science-intensive and high-tech sectors. In recent years, the government has launched ambitious strategies to promote innovation and high-level industrialisation. Although India's R&D spending remains modest at around 0.65% of GDP (TheGlobalEconomy.com, 2020), the country demonstrates robust growth in its high- tech sector, driven by its vast talent pool and ongoing policy reforms. In the 2024 Global Innovation Index (GII), India maintained its position as an "innovation overperformer" or a country in which innovation outcomes are above expectations for its income level. India is above the GII trend line, pointing at the success of its science and technology policy — in the area of ICT, startup growth, growth of IT services service exports, research capacity, though with very little public investment.

Various flagship initiatives have been launched by the government to create an ecosystem for high-tech industries and innovation (Table – 2).

The IT industry in India is the pillar of its knowledge economy. India which has historically a strong software development and outsourcing ecosystem is now one of the largest IT services providers worldwide. A growing share of the sector now specializes in relatively advanced technologies, including cloud computing, big data, AI, and cybersecurity. India is also largest global exporter of ICT services exports and has emerged as significant software R&D hub in the world. Furthermore, the AI as a national priority in India, with programs such as AI for All, national AI research labs backed by the government, and other initiatives for applying AI to governance, industry, and agriculture. Experts in machine learning and big data are dense enough to keep India among the global top 3 for the overall AI ecosystem flourish. AI startups garnered $0.78 billion in VC investments in 2024, generating lucrative opportunities in generative AI [24]. AI is being deployed across sectors, including smart cities, justice systems, education, and healthcare.

In clean technology, India has made strategic strides, balancing energy security and environmental sustainability. As of late 2023, installed renewable energy capacity (excluding large hydro) exceeded 133 GW, including ~72.7 GW in solar power, up from near zero a decade ago. India now ranks fifth globally in new solar installations. Government initiatives like the National Solar Mission, PLI schemes for local manufacturing, and green hydrogen programs support these developments. EV adoption

is also growing: over 1 million EVs were sold in 2022, backed by programs like FAME, battery production incentives, and EV manufacturing by local firms (e.g., Tata Motors).

India's success in building globally competitive IT—alongside nascent industries like AI and hydrogen energy—illustrates that even with modest R&D investment (under 1% of GDP), a combination of scale, entrepreneurship, policy support, and global integration can yield impressive outcomes. For Uzbekistan, India's example underscores the value of investing in digital and physical infrastructure, developing technoparks and incubators, encouraging private sector and startup activity, and fostering export-oriented, high-tech industries.

Table 2. Key national high-tech development Programs in India.

Initiative	Launch Year	Key Objectives
Digital India	2015	Digitisation of public services, ICT infrastructure, and digital literacy
Startup India	2016	Support for startups, tax/regulatory incentives, creation of funds, and incubators
Make in India	2014	Raise manufacturing's GDP share to 25%, attract investment, boost exports
Atmanirbhar Bharat	2020	Enhance technological self-reliance, localise R&D, and strengthen critical sectors

Noted: Data from Press Information Bureau, Government of India https://www.pib.gov.in

4. Conclusion

In the 2024 Global Innovation Index (GII), India maintained its position as an "innovation overperformer" or a country in which innovation outcomes are above expectations for its income level. India is above the GII trend line, pointing at the success of its science and technology policy — in the area of ICT, startup growth, growth of IT services service exports, research capacity, though with very little public investment. Various flagship initiatives have been launched by the government to create an ecosystem for high-tech industries and innovation (Table – 2). The IT industry in India is the pillar of its knowledge economy. India which has historically a strong software development and outsourcing ecosystem is now one of the largest IT services providers worldwide. A growing share of the sector now specializes in relatively advanced technologies, including cloud computing, big data, AI, and cybersecurity. India is also largest global exporter of ICT services exports and has emerged as significant software R&D hub in the world. Furthermore, the AI as a national priority in India, with programs such as AI for All, national AI research labs backed by the government, and other initiatives for applying AI to governance, industry, and agriculture. Experts in machine learning and big data are dense enough to keep India among the global top 3 for the overall AI ecosystem flourish. AI startups garnered $0.78 billion in VC investments in 2024, generating lucrative opportunities in generative AI.

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