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Article

Key Factors In Forming A National Innovation System: A Case Study Of Uzbekistan

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Abstract: Purpose. This study investigates the principal factors shaping a national innovation system (NIS) in a transition economy, using Uzbekistan as an empirical focal point. The research addresses a gap in the literature concerning the interplay between institutional quality, R&D investment intensity, and human capital development in economies undergoing structural transformation.

Design/Methodology. Drawing on the Triple Helix framework and the open innovation paradigm, the study employs a multi-source empirical base comprising the WIPO Global Innovation Index (2019–2023), the World Bank Human Capital Index, UNCTAD Technology Payments Balance data, and Uzbekistan's national statistics. A macro–meso–micro three-level analytical model is applied to classify NIS factors. Uzbekistan is benchmarked against three structurally comparable regional peers — Kazakhstan, Azerbaijan, and Georgia.

Findings. Five interdependent factor groups are identified: (1) institutional and legal environment; (2) R&D financing mechanisms; (3) human capital and education quality; (4) innovation infrastructure; and (5) international technological integration. The analysis reveals a structural 'institutional trap': Uzbekistan's human capital index (0.57) is broadly competitive regionally, yet R&D expenditure constitutes only 0.13% of GDP — approximately 19 times below the OECD average — suppressing the conversion of knowledge endowments into innovation outputs. A 16-fold increase in IT service exports between 2019 and 2023 demonstrates the scalability of targeted infrastructure policy, but the growth remains predominantly adaptive rather than frontier-generating.

Practical Implications. Five targeted policy recommendations are proposed — including an R&D tax credit, patent box regime, university–enterprise consortia, deeper integration into international innovation networks, and a unified digital innovation platform — aimed at positioning Uzbekistan within the Global Innovation Index Top 60 by 2030.

Originality/Value. The study contributes to the scarce English-language empirical literature on NIS formation in Central Asian transition economies and provides a replicable multi-level analytical framework applicable to analogous country contexts.

Keywords: national innovation system; innovation infrastructure; R&D expenditure; human capital; institutional environment; technology transfer; public-private partnership; Uzbekistan.

1. INTRODUCTION

The capacity to innovate has emerged as the primary determinant of national prosperity in the twenty-first century global economy. As production functions become increasingly knowledge-intensive, the ability of states to institutionalise processes of knowledge creation, diffusion, and application — in short, to build functional national innovation systems — distinguishes sustained economic convergence from perpetual technological dependency. The concept of a national innovation system (NIS), developed in seminal contributions by Freeman, Lundvall, and Nelson , captures this systemic dimension: rather than treating innovation as an exogenous technological shock, it emphasises the network of institutional interactions through which new knowledge is generated and converted into economic value [1].

For the Republic of Uzbekistan, the strategic salience of NIS formation is unambiguous. The country's Uzbekistan 2030 Strategy explicitly targets a transition from resource-intensive to innovation-driven growth, with quantitative benchmarks including a Top-60 ranking in the Global Innovation Index (GII). Progress is visible: Uzbekistan advanced from 86th to 82nd place in the GII between 2022 and 2023, reflecting improvements across multiple innovation sub-indices [2]. Yet beneath this aggregate trajectory, structural imbalances persist. R&D expenditure as a share of GDP — a proxy for the economy's investment in knowledge creation — stood at 0.13% in 2023, one of the lowest in the entire GII sample, and far below the 1.5% threshold identified in the literature as necessary for sustained technological progress [3].

This tension between institutional ambition and structural constraint motivates the present study. The research addresses the following questions: (i) What are the primary factor groups that determine the formation and maturity of a NIS? (ii) How does Uzbekistan's NIS configuration compare with structurally analogous regional economies? (iii) Which factors represent the most binding constraints, and what evidence-based policy interventions would most effectively relax them? The study's central hypothesis holds that institutional quality, R&D investment, and human capital are mutually reinforcing NIS determinants, and that weakness in any single dimension creates systemic spillover constraints that cannot be resolved by targeted interventions in the others alone [4].

The remainder of the article is structured as follows. Section 2 reviews the theoretical and empirical literature on NIS formation. Section 3 presents the methodological framework and data sources. Section 4 reports the empirical findings across three analytical dimensions. Section 5 interprets the results and situates them within the broader literature. Section 6 concludes with policy recommendations and directions for future research [5].

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

2.1. Foundational Concepts of National Innovation Systems

The NIS concept emerged in the late 1980s as a reaction against the limitations of linear, supply-push models of innovation that treated technology as an exogenous input to economic production. Freeman's study of Japan's post-war industrial transformation demonstrated that systematic coordination among government agencies, industrial conglomerates, and university laboratories — rather than any single actor — was the generative mechanism behind Japan's technological catch-up. Nelson's cross-national anthology extended this insight across 15 countries, documenting both the universality of certain NIS elements — notably public R&D funding and science-industry linkages — and the substantial cross-country variation in their configuration [6].

Lundvall provided the most analytically influential formulation, centring the concept of interactive learning: firms innovate not in isolation but through continuous, feedback-rich interactions with suppliers, customers, public research institutions, and regulatory agencies. This relational view of innovation has profound implications for policy design, implying that building connective tissue between actors is at least as important as funding individual nodes within the system. Cooke subsequently demonstrated that these dynamics operate at the sub-national level as well, with regional innovation systems exhibiting significant autonomy in knowledge production and diffusion [7].

2.2. Institutional Determinants

A robust strand of the NIS literature foregrounds the role of formal and informal institutions as enablers or constraints on innovation. North's canonical distinction between 'institutions as rules of the game' and 'organisations as players' provides the conceptual bridge: even well-funded players cannot generate sustained innovation if the rules of the game — property rights regimes, contract enforcement, regulatory quality — are weak or uncertain. Léman and Zeili demonstrate this empirically, showing through a cross-country regression that a one-unit improvement in the IP rights index increases technology-intensive FDI inflows by approximately 12% in developing economies. The implication for transition economies is stark: institutional modernisation is not merely complementary to innovation policy but constitutive of it [8].

For post-Soviet contexts, Gross and Kushnyrenko identify a particular form of institutional inertia they term 'inherited institutional deficiency': the persistence of linear, plan-economy innovation models in which knowledge flows from state research institutes to state enterprises, bypassing market mechanisms entirely. Breaking this path dependency requires not incremental reform but deliberate institutional redesign — new organisational forms, incentive structures, and governance arrangements that reward network-based knowledge exchange rather than hierarchical knowledge transmission [9].

2.3. Financial and Human Capital Dimensions

The relationship between R&D investment and innovation output has been extensively studied. Calhau et al. use panel data from 28 small open economies to establish that R&D expenditure exceeding 1.5% of GDP generates statistically significant knowledge spillovers, while expenditure below 0.5% yields negligible returns at the system level — a finding consistent with the non-linear dynamics documented in endogenous growth theory. Rodrik extends the analysis to policy design, arguing that industrial policy — including public R&D co-financing — is a necessary instrument when private returns to knowledge investment fall below social returns, as is typically the case in early-stage innovation systems where absorptive capacity is limited [10].

Human capital, meanwhile, functions as both an input to and an output of the NIS. Acemoglu and Autor demonstrate that the skill intensity of the labour force determines an economy's capacity to absorb and adapt imported technologies, while Romer's endogenous growth model formalises the role of human capital accumulation in sustaining long-run technological progress [11]. For transition economies, the challenge is not merely the stock of human capital but its allocation: where research careers are poorly rewarded relative to service-sector alternatives, talent systematically migrates away from knowledge production, generating a 'brain drain within borders' that erodes the NIS's generative capacity [12].

2.4. NIS Research in Uzbekistan and Central Asia

Domestic scholarship on Uzbekistan's NIS remains limited in scope and largely absent from international peer-reviewed venues. Abdullayev, Khoshimov, and Ruziyeva provide the most comprehensive treatment, examining NIS formation through a cluster development and public-private partnership lens and identifying fragmented financing, weak university-industry linkages, and regulatory barriers to technology commercialisation as the primary structural constraints. Their findings converge with the broader regional picture: a 2022 OECD assessment of Central Asian innovation systems identified regulatory uncertainty and underdeveloped venture finance ecosystems as systemic bottlenecks across Kazakhstan, Uzbekistan, and Tajikistan alike [13]. The present study builds on this foundation, extending it with a more granular comparative analysis and a structured policy recommendation framework.

3. RESEARCH DESIGN AND METHODOLOGY

3.1. Theoretical Framework

The study employs the Triple Helix model of Etzkowitz and Leydesdorff as its primary theoretical lens. In this framework, the university, industry, and government constitute three co-evolving institutional spheres whose overlapping interactions — knowledge production, commercialisation, and regulation — generate the conditions for sustained innovation. The Triple Helix model is particularly well-suited to transition economy contexts because it illuminates the institutional relationships that must be constructed or reformed, rather than merely the resource levels that must be attained. Chesbrough's open innovation paradigm provides a complementary micro-level perspective, emphasising the increasing permeability of organisational boundaries to external knowledge flows and the consequent importance of ecosystem-level connectivity [14].

3.2. Analytical Framework: Three-Level Model

NIS factors are classified across three analytical levels adapted from Chesbrough's multi-level innovation taxonomy: (i) the macro level, encompassing national policy frameworks and the legal-institutional environment; (ii) the meso level, covering innovation infrastructure, clusters, and intermediary organisations; and (iii) the micro level, addressing enterprise innovation behaviour, human capital endowments, and knowledge creation at the firm and researcher level. This tripartite structure enables targeted policy diagnostics by identifying where within the NIS the most binding constraints are located.

3.3. Data Sources and Scope

The empirical base draws on four primary sources: (1) WIPO Global Innovation Index 2019–2023, providing 80+ internationally comparable innovation indicators; (2) statistical materials from the Agency for Statistics under the President of the Republic of Uzbekistan; (3) UNCTAD Technology Payments Balance database for technology transfer flows; and (4) World Bank Doing Business, Governance Indicators, and Human Capital Index reports. The observation period spans 2018–2023. The comparator group — Kazakhstan, Azerbaijan, and Georgia — is selected based on criteria of structural similarity: comparable income levels, transition economy status, and geographic proximity.

3.4. Methods

Four analytical methods are employed: (i) systematic analysis and synthesis to structure identified NIS factors into a coherent taxonomy; (ii) comparative benchmarking to situate Uzbekistan's performance within its regional peer group; (iii) descriptive trend analysis to trace the dynamics of innovation infrastructure across the study period; and (iv) content analysis of legislative and regulatory acts governing the innovation sphere, enabling assessment of the formal institutional dimension. The study does not employ econometric techniques due to the limited number of comparator observations; findings should accordingly be interpreted as diagnostic and hypothesis-generating rather than causal.

4. RESULTS

4.1. Taxonomy of NIS Formation Factors

Based on the integrative literature review and structured data analysis, five interdependent factor clusters are identified as critical determinants of NIS formation and maturity. Table 1 presents the taxonomy, specifying for each cluster its principal elements, the level within the macro–meso–micro framework, and the primary mechanism through which it shapes innovation activity.

Table 1. Taxonomy of Key Factors in National Innovation System Formation

No.	Factor Cluster	Level	Key Elements	Mechanism of Impact
1	Institutional & Legal Environment	Macro	IP protection, regulatory quality, rule of law, anti-corruption	Lowers transaction costs; secures innovation rents; signals credibility to investors
2	R&D Financing	Macro / Meso	Public R&D budgets, venture capital, tax credits, grants, patent boxes	Closes the gap between private and social returns; enables frontier research
3	Human Capital & Education	Macro / Micro	STEM graduates, research careers, lifelong learning, brain retention	Builds absorptive capacity; generates novel knowledge; sustains learning
4	Innovation Infrastructure	Meso	Technology parks, incubators, SEZs, broadband, shared R&D facilities	Creates ecosystem spillovers and cluster-level economies of agglomeration
5	International Technological Integration	Macro / Meso	Technology-intensive FDI, joint research, technology transfer, diaspora networks	Accelerates knowledge diffusion; connects domestic actors to global frontier

Source: Authors' compilation based on [1; 3; 6; 8; 10; 11].

4.2. Comparative Innovation Performance

Table 2 presents a cross-country comparison of seven key NIS indicators for Uzbekistan and its regional peers as of 2023, benchmarked against the OECD average. The data reveal a consistent pattern: Uzbekistan leads the comparator group in population-adjusted technology park activity but lags significantly in R&D intensity, patent output, and high-technology export share — indicators that capture the depth of knowledge creation rather than the breadth of infrastructure deployment.

Table 2. Comparative NIS Performance Indicators: Uzbekistan and Regional Peers (2023)

Indicator	Uzbekistan	Kazakhstan	Azerbaijan	Georgia	OECD Avg.
GII Rank	82	79	88	68	—
R&D Expenditure (% of GDP)	0.13	0.28	0.22	0.31	2.47
Human Capital Index (WB, 0–1)	0.57	0.63	0.61	0.60	0.74
Patent Applications (national)	1,042	2,518	648	215	—
High-Tech Exports (% of total)	2.1	5.4	3.2	6.8	18.3
Rule of Law Index (WB, −2.5 to	−0.62	−0.51	−0.68	+0.62	+1.35

Indicator	Uzbekistan	Kazakhstan	Azerbaijan	Georgia	OECD Avg.
+2.5)					
Researchers per million population	892	1,048	3,205	2,456	4,221

Note: GII = Global Innovation Index (WIPO); WB = World Bank. Rule of Law Index sourced from World Bank Worldwide Governance Indicators 2023. Researchers per million: UNESCO Institute for Statistics.

Source: Authors' compilation based on WIPO GII 2023; World Bank HCI & WGI 2023; UNESCO UIS.

Several findings warrant particular attention. First, despite holding a slightly higher GII rank than Azerbaijan, Uzbekistan records the group's lowest R&D-to-GDP ratio — a discrepancy explained by stronger infrastructure sub-scores that are not yet backed by commensurate knowledge-creation activity. Second, the Rule of Law gap between Uzbekistan (−0.62) and Georgia (+0.62) represents the starkest qualitative difference in the comparator group and is likely the primary driver of their eight-rank GII differential, given the broadly similar levels of human capital between the two countries. Third, Uzbekistan's researcher density — 892 per million — is less than one-fifth of the OECD average, a figure that places an absolute ceiling on the volume of frontier research the system can produce regardless of institutional improvements.

4.3. Innovation Infrastructure Dynamics (2019–2023)

Table 3 documents the evolution of Uzbekistan's innovation infrastructure across the study period. The data reveal extraordinary growth in IT-sector metrics, driven primarily by the expansion of IT Park and the adoption of a favourable tax regime for technology companies. By contrast, indicators reflecting deep knowledge creation — granted patents and researcher numbers — grew at a substantially slower rate, underscoring the adaptive rather than generative character of current innovation dynamics.

Table 3. Dynamics of Uzbekistan's Innovation Infrastructure, 2019–2023

Indicator	2019	2020	2021	2022	2023	CAGR (%)
Technology parks (number)	4	6	8	10	12	+31.6
IT Park resident companies	190	380	640	950	1,230	+59.4
IT service exports (USD mn)	32	74	176	328	510	+100.2
Domestically granted patents (units)	820	874	912	981	1,042	+6.2
State R&D grants (bn UZS)	85	142	264	410	620	+64.3
University-business R&D agreements	48	71	104	139	178	+38.8
Venture capital investments (USD mn)	3.2	5.1	9.4	17.8	31.6	+77.2

Note: CAGR = Compound Annual Growth Rate calculated over 2019–2023. IT service export data: IT Park Annual Report 2023. Venture capital: EBRD Venture Capital Monitor 2023.

Source: Authors' compilation based on Ministry of Innovative Development of the Republic of Uzbekistan; IT Park Annual Report 2023; EBRD.

The contrast between the compound annual growth rate (CAGR) for IT service exports (100.2%) and for granted patents (6.2%) is especially instructive. It suggests that current innovation activity is concentrated in service-model businesses — primarily software development outsourcing — rather than knowledge-creation activities that generate protectable intellectual assets. The emerging venture capital ecosystem, while small in absolute terms (USD 31.6 million in 2023), registered a CAGR of 77.2%, indicating nascent but genuine market interest in innovation investment that policy can amplify.

5. DISCUSSION

5.1. The Institutional Trap and Its Implications

The most analytically significant finding is the divergence between Uzbekistan's human capital endowment (competitive by regional standards) and its R&D investment intensity (critically sub-threshold). This configuration matches the 'institutional trap' described by Gross and Kushnyrenko : in the absence of adequate domestic demand for research labour — created by well-funded R&D programmes, commercialisation incentives, and clear IP rights — qualified scientists and engineers rationally allocate their human capital to the service sector or emigrate, generating what might be termed 'brain drain within borders'. The consequence is a self-reinforcing cycle: low R&D investment produces low innovation output, which discourages further private R&D investment, which keeps the system in a low-equilibrium trap.

Breaking this cycle requires what Rodrik calls a 'big push' in public R&D co-financing — sufficient to shift private expectations about the profitability of knowledge investment and to create the critical mass of research activity needed for knowledge spillovers to become self-sustaining. The empirical literature suggests this threshold lies in the range of 1.0–1.5% of GDP [6], implying that Uzbekistan would need to increase its R&D expenditure by a factor of approximately 8–12 to reach the zone of dynamic returns. Achieving this within a five-year horizon requires mobilising not only public budget resources but also private sector co-financing — through matching grants, tax credits, and dedicated innovation funds managed on market principles [15].

5.2. The Infrastructure Paradox

The rapid expansion of technology parks and the spectacular growth of IT service exports demonstrate that well-designed infrastructure policy can generate measurable innovation ecosystem activity at relatively modest cost. However, the patent grant data reveals a structural paradox: Uzbekistan has built the 'hardware' of an innovation system — the parks, the incubators, the digital networks — without yet generating the 'software' of frontier knowledge creation. This mirrors a pattern observed in other emerging NIS contexts: Vietnam's technology parks, for instance, achieved high occupancy rates and export volumes before developing meaningful indigenous R&D capability, requiring a subsequent 'second-stage' policy shift toward knowledge-intensive activities [16].

The implication is that Uzbekistan is approaching an inflection point. The infrastructure foundation is largely in place; the strategic challenge is now to create incentive structures that shift resident companies from service delivery toward product innovation and knowledge generation. This transition requires — at minimum — robust IP protection, competitive researcher compensation packages, and financial instruments (venture debt, convertible grants) aligned with the risk profile of deep-tech ventures.

5.3. The Institutional Quality Gap

The comparison with Georgia is particularly instructive. Georgia ranks 14 positions higher in the GII (68th) despite broadly similar human capital levels, smaller territory, and lower absolute volumes of innovation infrastructure. The primary differentiating factor is institutional quality: Georgia's Rule of Law Index of +0.62 contrasts sharply with Uzbekistan's −0.62, a gap that affects innovation through multiple channels — deterring IP-intensive FDI, raising the cost of enforcing technology licensing agreements, and reducing the certainty of returns to long-horizon R&D investment. Léman and Zeili's econometric estimates suggest that closing this governance gap could increase technology-intensive FDI inflows to Uzbekistan by 15–20%, representing a potentially transformative augmentation of the system's innovation inputs.

5.4. Limitations

The study is subject to several limitations. First, the comparative analysis is confined to aggregate national-level data, which may obscure significant sectoral or regional heterogeneity within Uzbekistan. Second, the small comparator group (four countries) precludes formal econometric inference; the causal claims made are informed by theory and existing empirical literature rather than original regression analysis. Third, periodic revisions to Uzbekistan's national statistical methodology introduce breaks in some time series. Future research should address these limitations through firm-level survey data and, where data permit, panel regression techniques [17].

6. CONCLUSION AND POLICY RECOMMENDATIONS

This study has systematically analysed the key factors shaping national innovation system formation in Uzbekistan, situating the country's performance within a regional comparative framework and against international benchmarks. Five interdependent factor clusters were identified — institutional environment, R&D financing, human capital, innovation infrastructure, and international integration — and assessed through a macro–meso–micro analytical lens. The central finding is that Uzbekistan has successfully constructed the infrastructure layer of an innovation ecosystem, but remains constrained by a structural institutional trap in which low R&D investment and weak legal-institutional quality suppress the conversion of a competitive human capital base into frontier innovation outputs.

The following five evidence-based policy recommendations are proposed to address the identified constraints:

Recommendation 1. Implement an R&D Tax Credit. Introduce a super-deduction mechanism (150–200% of qualifying R&D expenditure deductible from corporate income tax) to leverage public fiscal incentives for private research investment, modelled on analogous instruments in France, South Korea, and Poland. This single instrument, if adopted at scale, could increase aggregate R&D spending by an estimated 0.2–0.3 percentage points of GDP within three years.

Recommendation 2. Establish a Patent Box Regime. Introduce preferential taxation (at a rate of 5–10%) on income derived from the licensing or sale of domestically registered intellectual property rights. This creates a direct financial incentive for firms to patent innovations in Uzbekistan rather than in offshore jurisdictions, deepening the domestic IP base and improving GII scores on the innovation outputs sub-index.

Recommendation 3. Launch University–Enterprise Research Consortia. Establish co-financed research partnerships between universities and private firms, with clearly defined contractual rules for IP ownership and benefit sharing, building on the 178 existing university-business agreements documented in 2023. A target of 400 active consortia by 2028 would represent a structurally significant deepening of Triple Helix interactions.

Recommendation 4. Expand International Innovation Network Integration. Pursue associate membership in the EU's Horizon Europe research programme, consolidate participation in UNCTAD EMPRETEC, and establish formal technology transfer agreements with the Asian Development Bank Technology Hub. These linkages would provide access to frontier research networks, competitive funding, and technology licensing pipelines unavailable through domestic channels alone.

Recommendation 5. Build a Unified Digital Innovation Management Platform. Create an interoperable digital platform integrating data from technology parks, the patent office, the State Tax Committee, and the Ministry of Innovative Development grant management system. This infrastructure would enable evidence-based monitoring of innovation policy effectiveness, reduce administrative friction for innovators, and provide the data foundation for the transition to outcome-based innovation policy evaluation.

Coordinated implementation of these recommendations across the 2025–2030 horizon has the potential to raise Uzbekistan's R&D-to-GDP ratio to 0.8–1.0%, increase domestically granted patents to 2,500+ annually, and position the country within the GII Top 60 — consistent with the quantitative targets of the Uzbekistan 2030 Strategy. Future research should employ enterprise-level panel data and sector-specific policy analysis to develop more granular implementation roadmaps for individual innovation sub-sectors.

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