

Article

The Astana Hub Effect: An Interrupted Time Series Analysis of a National Technology Park, IT Service Exports, and Digital Competitiveness in Kazakhstan

Yesmagulova Nurgul , Ibadildin Nurkhat , Ismailova Rymkul , Mukushev Medet * 
and Mussabekov Zhandos 

School of Digital Public Administration, Astana IT University, Astana 010000, Kazakhstan;
nur7725@gmail.com (Y.N.); ibadildin.nurkhat@astanait.edu.kz (I.N.); r.ismailova@astanait.edu.kz (I.R.);
zhandos.mussabekov@astanait.edu.kz (M.Z.)

* Correspondence: m.mukushev@astanait.edu.kz

Abstract

This article examines the maturation of the Astana Hub technology park and its association with Kazakhstan's national digital competitiveness during the country's transition from resource dependency toward a higher value-added digital economy. As Central Asia's largest international technology park, Astana Hub provides a policy-relevant case of a state-initiated open-innovation ecosystem. To proxy the national enabling environment, we construct the Kazakhstan Digital Performance Index (KDPI), a composite measure that normalizes and aggregates three publicly available global indices: the UN E-Government Development Index (EGDI), the Global Innovation Index (GII, WIPO), and the Network Readiness Index (NRI, Portulans Institute). Using an Interrupted Time Series (ITS) design over 2010–2024, we estimate the change in the level and slope of national IT service exports associated with the establishment of the Hub in 2018. The analysis identifies a statistically significant post-2018 increase in the export-growth slope of approximately \$112.8 million per year relative to the pre-intervention trend, alongside a near 20-fold rise in IT service exports between 2020 and 2024. By contrast, the composite KDPI shows no comparable acceleration, and an exploratory correlation analysis over the short post-2018 window indicates a positive association between Hub growth and e-government infrastructure but a negative association with the GII. We interpret these patterns cautiously as descriptive evidence consistent with a temporary “island of efficiency,” in which commercial scaling has outpaced economy-wide innovation diffusion, rather than as confirmation of a bidirectional feedback loop or of causal national-level human-capital effects, which the single-country quasi-experimental design cannot establish. The paper discusses policy options for diffusing Hub capabilities into the wider economy and sets out the limitations of the design.



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1. Introduction

In the contemporary global landscape, the convergence of digital ecosystems has redefined national resilience and economic diversification. From established innovation districts to emerging tech clusters, nations are increasingly leveraging ICT-driven hubs to accelerate digital transformation and embed themselves into high-value global chains.

These ecosystems do not merely foster local entrepreneurship; they can generate feedback effects that may enhance national innovation capacity, which in turn may attract international investment and collaborative research (Dyussenov, 2025).

For decades, the Republic of Kazakhstan's economic trajectory was tied to natural resource endowments. To mitigate structural vulnerabilities, the government has prioritized a shift toward a knowledge-based economy, characterized by high value-added digital services. The establishment of Astana Hub, the largest international technology park in Central Asia, represents the cornerstone of this vision. Its mission centers on cultivating a comprehensive IT ecosystem by fostering a vibrant startup industry, increasing mobile and IT service exports, and developing domestic human capital through interactive learning models (Amirova et al., 2025).

The government has set an ambitious target to reach \$1 billion in IT service exports by 2026, positioning the Hub as a critical driver of global competitiveness (Ibadildin et al., 2023). The Hub's residents already account for a rapidly growing share of these exports, rising from roughly 30% of the national total in 2020 to about 80% by 2024 (Figure 1). This paper examines whether the establishment of the Astana Hub is associated with a structural break in national IT service exports, and whether such commercial scaling has so far been accompanied by measurable improvement in economy-wide innovation indicators. We frame this question against the theoretical possibility that concentrated, fiscally and legally privileged ecosystems can function as "innovation enclaves" whose gains diffuse only slowly into the surrounding economy, producing a "diffusion gap" between localized performance and national metrics (Glaeser et al., 2010; Rogers, 2003). We therefore treat the bidirectional "feedback loop" not as an assumption but as a hypothesis whose preconditions we can only partially observe, given the available data and design.

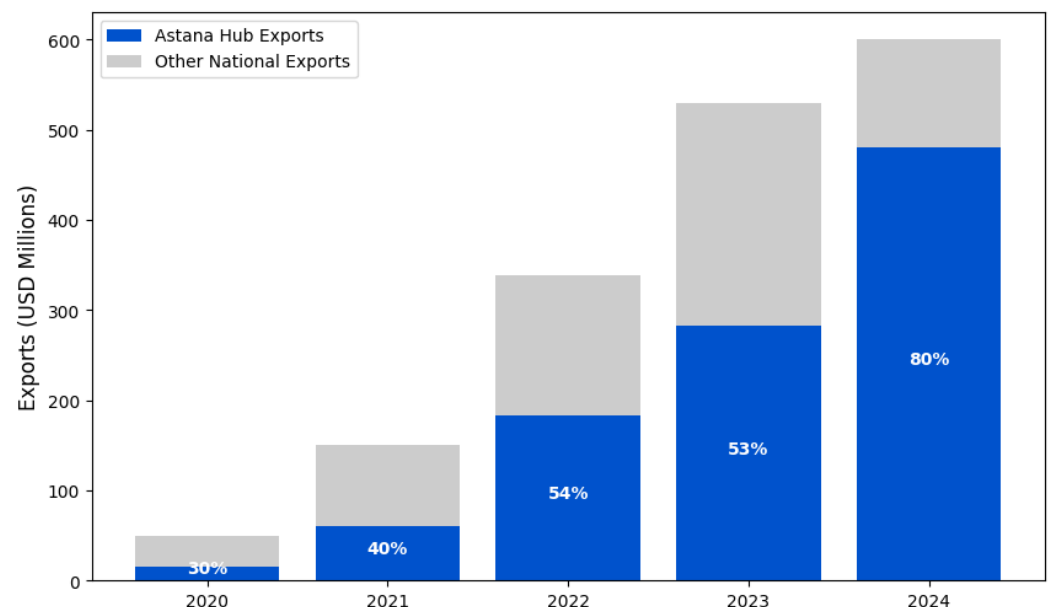


Figure 1. Astana Hub Contribution to National IT Exports. Data sources: Astana Hub annual financial reports (2020–2024) and authors' calculations; "Other National Exports" derived as the residual of total national IT service exports (World Bank/Bureau of National Statistics) net of Hub-resident exports.

By analyzing the "Astana Hub Effect," this study offers insights into how structured innovation platforms may support the emergence of new technological activity and, potentially, system-level impact. We are careful to distinguish what our design can demonstrate

(a change in the export trajectory coincident with the intervention) from stronger behavioral or causal interpretations, which we do not claim to identify.

The mechanism we have in mind can be stated as a testable conjecture rather than an established fact: as Astana Hub residents innovate and scale globally, they may generate improvements in national indicators related to innovation, digital infrastructure, and workforce skills; these macro-level improvements, captured here through the composite Kazakhstan Digital Performance Index (KDPI) described in Section 3, could in principle create a more enabling environment for the ecosystem itself. Establishing that such a reinforcing cycle actually operates would require evidence of directional and dynamic effects that our single-unit, short-horizon design is not equipped to provide. Our empirical contribution is therefore deliberately narrower: we document the export-side change and characterize, descriptively, its co-movement with national indicators. The annual pace of this expansion, in both exports and investment inflows, is summarized in Figure 2.

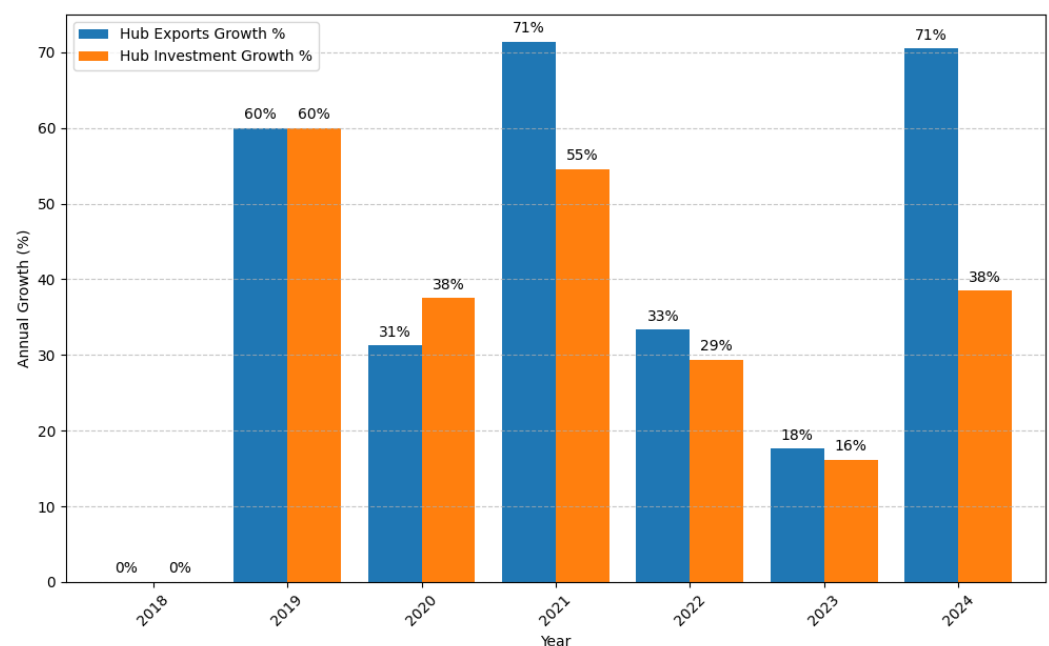


Figure 2. Year-over-Year growth in Hub Exports and Investments. Data source: Astana Hub annual financial reports (2018–2024).

Our contribution is threefold:

Methodological: We introduce the Kazakhstan Digital Performance Index (KDPI), a composite metric normalizing data from the UN, WIPO, and Portulans Institute to track the ecosystem’s evolution across disparate global scales.

Empirical: We document a “hockey-stick” pattern in IT exports (Figure 3). Our regression analysis indicates that, while the KDPI score stabilized, national IT exports exhibited a statistically significant change in slope post-2018, with an estimated additional \$112.8 million per year relative to the pre-Hub trend.

Theoretical: Rather than confirming a bidirectional feedback loop, our evidence is more consistent with a one-directional, infrastructure-enabled commercialization channel accompanied by a diffusion gap. While the Astana Hub appears to have monetized the country’s existing digital infrastructure (the infrastructure–export link), a divergence remains between ecosystem scaling and broader national innovation scores, a pattern we interpret descriptively as an “island of efficiency” (Glaeser et al., 2010).

The remainder of this paper is organized as follows: Section 2 reviews the literature on innovation ecosystems in transition economies; Section 3 details the construction of

the KDPI and our econometric strategy; Section 4 presents the regression results; and Section 5 discusses the policy implications of transitioning from state-led infrastructure to ecosystem-led value creation.

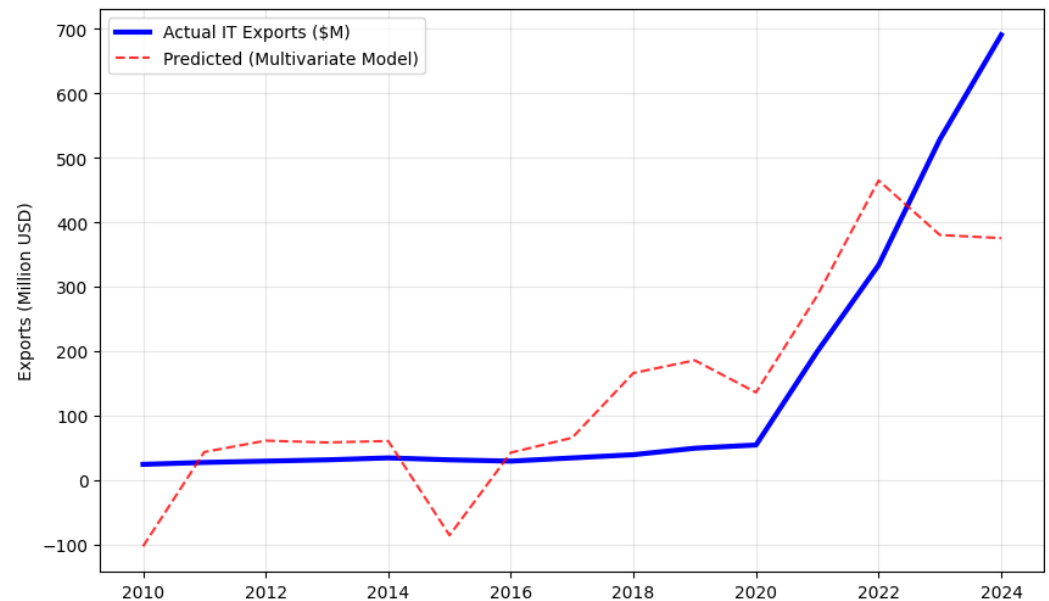


Figure 3. Actual ICT Service exports vs prediction. Predicted values are fitted from a multivariate model using the KDPI, the KZT/USD exchange rate, and the Brent crude oil price. Data sources: Astana Hub reports; WIPO (GII); UN DESA (EGDI); Portulans Institute (NRI); World Bank (exchange rate); U.S. EIA (oil price); authors' estimation.

2. Literature Review

The analysis of national economies and their capacity for innovation-driven growth requires a standardized set of metrics to accurately measure and compare relative success. Global competitiveness indexes provide the fundamental analytical framework for this assessment, identifying the critical pillars upon which a modern, high-performing economy is built.

The Global Competitiveness Index (GCI), developed by the World Economic Forum, evaluates national competitiveness across 12 pillars, including institutions, infrastructure, macroeconomic stability, health, and innovation capability (Kolluru & Suresh, 2020; Pérez-Moreno et al., 2016; Qazi, 2024). It offers a comprehensive framework for assessing the micro and macroeconomic foundations of growth and is widely used for comparing countries' economic performance and ability to sustain long-term productivity (Nečadová, 2020).

The Global Innovation Index (GII) complements this perspective by measuring innovation inputs such as institutions, human capital, and research ecosystems as well as innovation outputs related to knowledge creation and technology diffusion. Its multidimensional structure provides insight into how effectively nations convert resources into measurable innovation outcomes (Huang & Yu, 2022).

Similarly, the International Institute for Management Development (IMD) World Competitiveness Ranking evaluates countries based on economic performance, government efficiency, business efficiency, and infrastructure. Its focus on structural relationships between these elements allows for a nuanced understanding of how competitiveness emerges from interconnected economic and institutional factors (Ju & Sohn, 2014).

Two further indices are central to the present study because, unlike the composite competitiveness rankings above, they are published with sufficient annual regularity and country coverage to support a 2010–2024 time series for a single economy. The UN E-

Government Development Index (EGDI) captures state digital capacity, the online delivery of public services, telecommunication infrastructure, and human capital, and is therefore a proxy for the government-led “enabling” layer of the digital economy. The Network Readiness Index (NRI) measures the readiness and actual adoption of ICT by individuals, businesses, and government. Together with the GII, which measures innovation inputs and outputs, these three indices span the government/infrastructure, adoption, and innovation dimensions that the broader competitiveness literature treats as the core determinants of digital competitiveness; they form the empirical basis of the KDPI introduced in Section 3. We note at the outset that the three indices are conceptually related and partially overlapping (for example, human-capital and infrastructure components appear in more than one), an issue we return to when justifying the construction and weighting of the index.

Together, these global indexes outline the key determinants of national competitiveness, particularly emphasizing innovation capability and digital readiness. To understand the mechanisms through which countries strengthen these drivers, it is necessary to examine the development of successful international technology hubs, which operationalize and advance the factors measured by these indexes.

2.1. Lessons from Major Tech Hubs

The analysis of global competitiveness and the drivers of innovation is now ready to transition to real-world context through empirical case studies. Major tech hubs offer a crucial examination of successful innovation-driven growth, revealing the effective strategies, policies, and ecosystem structures that have translated theoretical competitiveness factors into sustained economic advantage.

Silicon Valley serves as a leading example of a mature innovation ecosystem characterized by strong venture capital networks, a culture of entrepreneurship, and dense concentrations of technology firms and talent (Wonglimpiyarat, 2016b). A symbiotic relationship among universities, research centers, and industry players fosters continuous innovation and knowledge spillovers (Ibadildin et al., 2025; Tovstiga et al., 2003).

Israel’s Silicon Wadi demonstrates how targeted government interventions, such as the Yozma program, can catalyze the creation of a dynamic venture capital industry (Shoham & Avnimelech, 2012; Wonglimpiyarat, 2016a). The country’s adoption of the Triple Helix model government, academia, and industry collaboration has supported the growth of high-tech clusters that contribute significantly to national competitiveness (Wonglimpiyarat, 2015).

Singapore represents another successful model where strategic government planning, significant R&D investment, and favorable policy environments have attracted multinational corporations and nurtured local innovation (Tovstiga et al., 2003). High-tech clusters and talent-oriented policies have played central roles in its global competitiveness (Oqubay, 2020).

Dubai, meanwhile, has rapidly established itself as a regional technology hub through substantial investments in digital infrastructure, regulatory reform, and efforts to attract tech firms and international talent (Tovstiga et al., 2003). These initiatives have contributed to a dynamic environment conducive to innovation-driven growth (Oqubay, 2020).

Taken together, these global experiences illustrate that innovation-driven competitiveness requires strong ecosystem structures, supportive government policy, robust financing systems, and active collaboration across the public and private sectors. In this context, Kazakhstan’s Astana Hub represents an effort to adapt and implement similar ecosystem-building strategies to strengthen national innovation capacity.

These analogies, however, should be read with attention to structural differences rather than superficial similarities. Silicon Valley and Silicon Wadi matured over decades

atop deep private venture-capital markets and large or globally integrated demand bases, whereas Astana Hub is a recent, state-initiated park operating in a small domestic market with a thin private-capital ecosystem. A feature that the comparison cases share, and that is especially salient for Astana Hub, is the role of legislative and legal infrastructure in enabling start-up formation, venture-capital mobilization, and investment structuring. The availability of predictable, investor-familiar legal regimes for incorporation, shareholder agreements, and dispute resolution (the function served, for instance, by Delaware corporate law in the United States) materially lowers the cost of structuring and financing high-growth firms, and the comparative law-and-finance literature links such institutional quality to financial development and external finance (La Porta et al., 1998). In Kazakhstan, this function is approximated by the Astana International Financial Centre (AIFC) and the Hub's special regime, which combine English common law principles, an independent court, and simplified investment and visa procedures. We therefore treat the legal-institutional layer, rather than infrastructure alone, as a candidate enabling condition.

The comparison also raises a concern that concentrated, fiscally privileged ecosystems may not be purely additive. By offering tax exemptions and a distinct legal regime, a hub can attract firms, talent, and investment that might otherwise have located elsewhere in the national economy, raising the possibility of crowding out or spatial reallocation rather than net creation. Evidence on special economic zones is mixed on this point, with some studies finding net activity creation and others finding displacement from surrounding areas (Wang, 2013). We cannot resolve this question with our aggregate national data, but we flag it as an important boundary condition on any welfare interpretation of the "Astana Hub Effect."

2.2. Findings on Astana Hub and Kazakhstan's Innovation Policy

The established understanding of global competitiveness indicators and successful international tech hubs presents the necessary context for evaluating Kazakhstan's own innovation strategy. This section transitions the focus to a specific, localized implementation of these lessons: the Astana Hub and the broader national policy framework designed to foster a technology ecosystem and drive economic diversification.

Astana Hub is Kazakhstan's flagship technology park aimed at fostering innovation, entrepreneurship, and digital transformation. By offering infrastructure, funding mechanisms, acceleration programs, tax preferences, and educational initiatives, it seeks to stimulate the growth of technology startups and diversify the national economy beyond natural resource dependence (Danabayeva & Shedenov, 2014; Smagulova & Goncalves, 2024). While the initiative has generated momentum, challenges such as market instability, regulatory barriers, and external shocks including the COVID-19 pandemic continue to hinder the ecosystem's expansion (Smagulova & Goncalves, 2024).

Kazakhstan's broader innovation policy framework including the State Program of Forced Industrial-Innovative Development aims to build a national innovation system that integrates government institutions, universities, research centers, and private enterprises (Danabayeva & Shedenov, 2014). However, the country still faces structural constraints associated with its reliance on the oil and gas sector (Saiymova et al., 2018). Strengthening collaboration between academic institutions, industry, and government remains essential for creating a more knowledge-based and innovation-driven economy (Seitzhanov et al., 2020).

These observations reveal that although Astana Hub has contributed positively to Kazakhstan's digital ecosystem, significant uncertainties persist. These challenges naturally point toward several research gaps that must be addressed to understand the ecosystem's current effectiveness and future potential.

3. Methodology

To empirically assess the impact of the Astana Hub on Kazakhstan's digital economy, this study employs a mixed-methods quantitative approach spanning the period 2010–2024. The analysis integrates macro-level global performance metrics with micro-level ecosystem data to test for a structural break in the outcome trajectory and to describe its association with national indicators, while remaining explicit about the limits of causal inference in a single-unit, quasi-experimental design.

3.1. Data Construction: The Kazakhstan Digital Performance Index (KDPI)

One of the primary challenges in assessing national digital maturity is the heterogeneity of global indices, which often use differing scales and methodologies. To address this, we constructed a composite Kazakhstan Digital Performance Index (KDPI) to serve as a unified proxy for the national enabling environment. The KDPI aggregates three authoritative global indicators:

1. UN E-Government Development Index (EGDI): Measures state capacity, public service digitization, and human capital (Source: UN DESA).
2. Global Innovation Index (GII): Measures innovation inputs (institutions, market sophistication) and outputs (knowledge, creativity) (Source: WIPO).
3. Network Readiness Index (NRI): Measures the adoption of ICT by businesses, government, and individuals (Source: Portulans Institute).

To ensure comparability, all indices were normalized to a standardized 0–100 scale using min-max transformation logic specific to their historical methodologies (e.g., converting the pre-2017 WEF 1–7 scale). The KDPI at time t is calculated as the unweighted mean of the normalized scores:

$$KDPI_t = \frac{1}{3} \sum_{i=1}^3 Index_{i,t}^{norm} = \frac{1}{3} (EGDI_t^{norm} + GII_t^{norm} + NRI_t^{norm}) \quad (1)$$

This composite index allows for a longitudinal analysis that smooths out idiosyncratic volatility in individual reports while capturing the broader trajectory of the digital ecosystem (Figure 4).

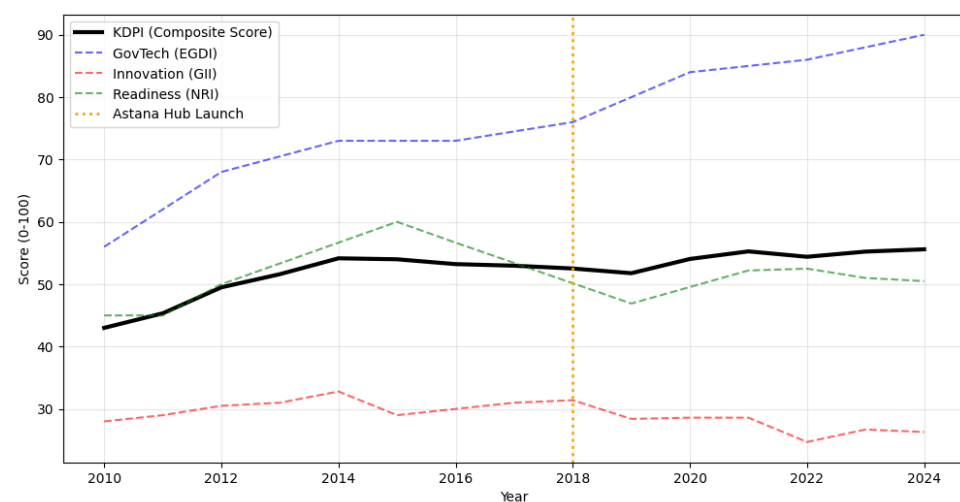


Figure 4. KDPI score.

Several construction choices warrant explicit justification. First, regarding index selection, the three components were chosen because they jointly span the government/infrastructure (EGDI), adoption/readiness (NRI), and innovation (GII) dimensions

of digital competitiveness, and because each is published with the annual regularity and single-country coverage required for a 2010–2024 series; broader composite rankings such as the GCI and the IMD ranking are discussed in Section 2 for framing but are not available on a consistent annual basis for Kazakhstan across the full window. We acknowledge that the three indices are conceptually related and partially overlapping (notably in their human-capital and infrastructure sub-components), so the KDPI should be read as a parsimonious descriptive summary of the enabling environment rather than as a structural measurement model. Second, regarding normalization, min–max rescaling to a common 0–100 range is a standard transformation in the composite-indicator literature for placing heterogeneous source scales (including the pre-2017 WEF 1–7 scale) onto comparable units; we follow the guidance of the OECD/JRC handbook on composite indicators (OECD & JRC, 2008). Min–max rescaling preserves the relative within-index dynamics that drive our longitudinal interpretation, although it is sensitive to the empirical minima and maxima of the observed window. Third, regarding weighting, we adopt equal weights as a transparent, assumption-light benchmark that does not impose unverified priors about the relative importance of the three dimensions; equal weighting is the most common choice in applied composite-indicator work, even though it is not assumption-free and, given the conceptual overlap noted above, implies that overlapping content is effectively up-weighted (Greco et al., 2019; Nečadová, 2020). Because of this, we do not interpret small movements in the KDPI as precise measures of welfare and, in the robustness discussion and limitations (Sections 4.5 and 5.4), we treat the equal-weighting and overlap issues as explicit caveats rather than resolved questions.

3.2. Econometric Strategy: Interrupted Time Series (ITS)

To verify whether the establishment of Astana Hub in 2018 constituted a statistically significant “structural break” in the country’s trajectory, we employed an Interrupted Time Series (ITS) design. This quasi-experimental method segments the timeline into “Pre-Hub” (2010–2017) and “Post-Hub” (2018–2024) periods to measure changes in both the level (intercept) and slope (trend) of the dependent variables.

The regression model is specified as follows:

$$Y_t = \beta_0 + \beta_1(Time_t) + \beta_2(Post_{2018}) + \beta_3(Time_Since_Treatment_t) + \epsilon_t \quad (2)$$

where:

- Y_t represents the outcome variable (National IT Service Exports in Million USD or KDPI Score).
- $Time_t$ is a continuous variable indicating the time in years from the start of the observation period (2010 = 0).
- $Post_{2018}$ is a dummy variable coded as 0 for the pre-intervention period and 1 for the post-intervention period (2018 onward).
- $Time_Since_Treatment_t$ is a continuous variable counting the number of years elapsed since the intervention (0 before 2018, then 1, 2, 3, ...).

The coefficient of interest is β_3 , which represents the difference in the slope of growth attributable to the intervention. A positive and statistically significant β_3 indicates an acceleration in growth post-2018.

Two interpretive points follow from this specification. First, the presence and size of the structural break are inferred from the estimated coefficients and their standard errors, in particular from β_2 (level change) and β_3 (slope change), and not from the model’s overall goodness of fit. We report the coefficient of determination only as a descriptive measure of fit; it does not by itself constitute evidence for a break. Second, a single-unit ITS with

one treated series identifies a change in trajectory coincident with the intervention date, but it cannot, on its own, rule out other events that occurred around 2018 or identify the behavioral or institutional mechanism producing the change. We therefore use the language of “association with” and “coincident with” the intervention rather than asserting that the Hub alone caused the observed acceleration.

Finally, to investigate the robustness of our findings, we incorporated macroeconomic control variables to account for the potential endogeneity of Kazakhstan’s resource-dependent economy. Specifically, we controlled for annual average Brent Crude oil prices and the KZT/USD exchange rate to examine whether the export change could be attributed to broader commodity-cycle or price-competitiveness fluctuations rather than to ecosystem-specific factors. We stress that this is a control strategy in a small-sample, single-country setting; it mitigates, but cannot fully eliminate, omitted-variable and endogeneity concerns, and we do not treat it as a definitive identification of an “innovation effect.” Furthermore, to explore the internal dynamics suggested by the feedback-loop conjecture, we conducted an exploratory Pearson correlation analysis (r) for the 2018–2024 period, examining the strength of the association between Hub scaling metrics (exports, participants) and the individual sub-pillars of the KDPI (infrastructure vs. innovation outputs). The co-movement between Hub exports and the individual national indices over this window is shown in Figure 5. Given only seven post-intervention observations, these correlations are descriptive: they cannot establish direction of causation, lead–lag structure, or the existence of a feedback mechanism, and they do not distinguish shared trending from substantive association.

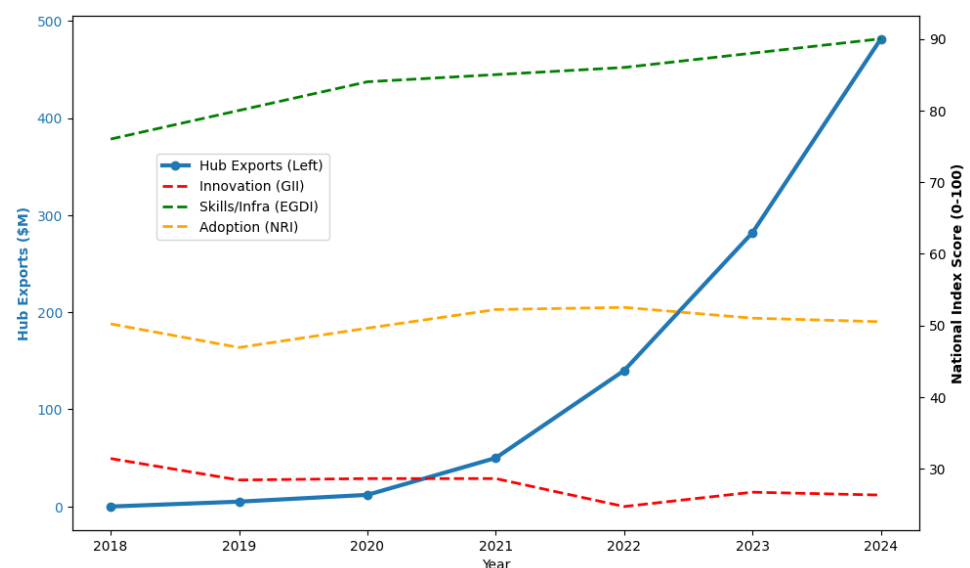


Figure 5. Astana hub export vs Index correlation. Data sources: Astana Hub annual reports (Hub exports); WIPO (GII); UN DESA (EGDI); Portulans Institute (NRI); authors’ calculations.

4. Results

The application of the Interrupted Time Series (ITS) model reveals a distinct divergence between the trajectory of commercial output (IT exports) and national digital readiness scores (KDPI). This divergence is consistent with sectoral decoupling during the transition phase.

4.1. Effect on IT Exports

The ITS analysis reveals a stark dichotomy between the pre- and post-Hub eras regarding export performance. The structural break is evidenced by the post-2018 slope-change

coefficient (β_3), reported in Table 1; the model's coefficient of determination ($R^2 = 0.939$) is reported only as an indication of overall fit and is not itself evidence of the break. The fitted ITS models for both outcome series, together with the observed values, are shown in Figure 6.

Table 1. Interrupted Time Series Results: Impact on IT Exports (Y_1).

Variable	Coefficient	Std. Error	p-Value
Intercept (β_0)	27.17	37.63	0.485
Pre-2018 Trend (β_1)	1.06	9.00	0.908
Level Change Post-2018 (β_2)	−106.09	60.35	0.106
Slope Change Post-2018 (β_3)	112.84	14.22	0.000 ***

Dependent Variable: IT Service Exports (Million USD). *** $p < 0.001$.

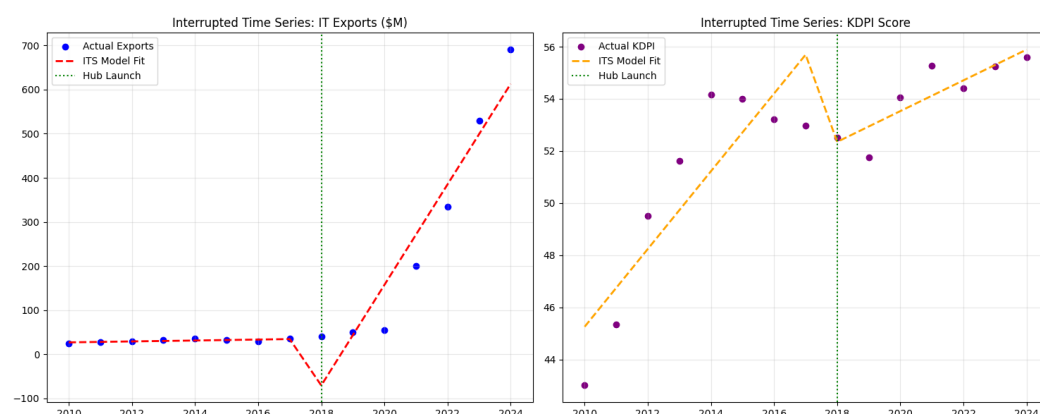


Figure 6. Time series analysis. Markers are observed values; dashed lines are ITS model fits. Data sources: Astana Hub reports and World Bank (exports); UN DESA, WIPO, and Portulans Institute (KDPI components); authors' ITS estimation.

4.2. Structural Break in National IT Service Exports

The primary dependent variable, National IT Service Exports, showed the largest change over the intervention period among the series examined. As above, the break is identified by the slope-change coefficient rather than by the goodness-of-fit statistic ($R^2 = 0.939$).

Pre-Intervention Trend (2010–2017): Prior to the Hub's establishment, Kazakhstan's national IT exports showed no statistical significance in growth trends. The baseline time trend coefficient ($\beta_1=1.06$) was statistically insignificant ($p = 0.908$), indicating that despite infrastructure investments, the sector failed to generate organic export growth, maintaining a flat trajectory between \$30 million and \$35 million annually.

Post-Intervention Acceleration (2018–2024): Following the launch of Astana Hub, the export series exhibited a statistically significant change in slope. The slope-change coefficient (β_3) is +112.84 ($p < 0.001$), indicating that, on average, the post-2018 period is associated with an additional \$112.8 million per year in the growth rate of national exports relative to the extrapolated pre-2018 trend. We attribute this association to the intervention period with the caution noted in Section 3.2: the ITS design dates the change to the intervention but does not, by itself, exclude other contemporaneous factors.

This finding is consistent with the interpretation that the policy intervention coincided with the transition of a previously stagnant sector into a period of rapid growth, while leaving open the contribution of concurrent factors discussed in Section 5.4.

4.3. Stabilization of Digital Readiness Scores (KDPI)

In contrast to the rapid expansion in exports, the impact on the composite KDPI score was stabilizing rather than accelerating ($R^2 = 0.818$).

Methodological Shock: The model detected a statistically significant negative level shift in 2018 ($\beta_2 = -4.84$, $p = 0.02$). This level shift coincides with documented methodological changes in the source indices around 2017–2018 (notably the discontinuation of the ITU IDI from the composite and stricter NRI criteria), and we therefore caution that part of this estimated “shock” reflects measurement discontinuities in the inputs rather than a real change in Kazakhstan’s digital environment.

Stabilization Role: The Hub period did not coincide with a statistically significant acceleration of the index ($\beta_3 = -0.90$, $p = 0.06$). Rather than acceleration, the data are consistent with stabilization of the composite score after the 2018 level shift. One reading is that growth in the commercialization-related components offset weakness elsewhere; however, given the measurement discontinuities just noted and the small sample, we present this as a plausible interpretation rather than a demonstrated compensatory effect.

4.4. Divergence Between Ecosystem and National Metrics

To explore the patterns suggested by the feedback-loop conjecture, we computed Pearson correlations (r) for the short Hub-scaling window (2018–2024, seven observations). These statistics are exploratory and descriptive: with so few post-intervention points they cannot identify the direction of any relationship, distinguish co-trending from substantive association, or establish a feedback or diffusion mechanism. We report them as suggestive associations to be probed in future work, not as tests of the loop.

Association with infrastructure: We observed a strong positive correlation ($r = 0.80$) between Hub growth and the UN EGDI. This co-movement is consistent with the idea that the state-led digital foundation (government/infrastructure) accompanies, and may underpin, ecosystem expansion, but it could equally reflect shared upward trends over the same short period.

Association with innovation: contrary to the expectation of immediate national-level innovation gains, Hub growth is negatively correlated with the Global Innovation Index ($r = -0.61$) over this window. Several non-exclusive explanations are plausible, and we cannot adjudicate among them with the present data. (i) Diffusion lag: the gains concentrated within the Hub’s resident firms (whose exports rose by a factor of roughly 13.8) may not yet be reflected in economy-wide innovation inputs and outputs, so that a fast-growing enclave coexists with a slower-moving aggregate (Glaeser et al., 2010; Rogers, 2003). (ii) Composition and denominator effects: the GII aggregates many sub-indicators across the whole economy, and rapid growth in one concentrated sector can move the aggregate little or even coincide with declines in unrelated components. (iii) Measurement changes: revisions to GII methodology and country samples over 2018–2024 affect comparability of the series. (iv) Small-sample noise: with seven points, a single year can flip the sign of the correlation. We therefore read the negative correlation as a signal worth investigating, most likely indicative of a diffusion gap, rather than as evidence that Hub growth depresses national innovation.

4.5. Robustness Checks

To check whether the results were driven by external macroeconomic factors, we examined the control variables. The KZT/USD exchange rate showed a positive association with exports (consistent with devaluation improving price competitiveness), whereas the Brent oil price was not a statistically significant predictor in the export model. We are careful not to over-read this null result. The absence of a significant oil-price coefficient in a small-

sample, single-country model is consistent with the interpretation that the post-2018 export growth was driven by sector-specific rather than commodity-cycle factors, but it does not prove that the growth was an endogenous outcome of the ecosystem policy. A statistically insignificant control may reflect limited power, multicollinearity with the time trend, or the particular years observed, and other concurrent influences (for example, pandemic-era demand for digital services, currency dynamics, and parallel digital government programs) cannot be excluded. We therefore present commodity-cycle independence as suggestive evidence of diversification rather than as a demonstrated causal claim.

5. Discussion

The findings of this study contribute to the evidence on targeted ecosystem interventions in transition economies. By quantifying a structural break in export performance, this research moves beyond purely descriptive accounts toward a documented change in trajectory coincident with institutional design. We frame this as an association strongly suggestive of a policy effect rather than as a fully identified causal link, in line with the design limitations set out in Sections 3.2 and 5.4.

5.1. Divergence Between Localized Performance and National Metrics

A central finding of this study is the statistical divergence between the rapid expansion of the Astana Hub ecosystem and the comparatively flat trajectory of broader national innovation metrics, such as the Global Innovation Index (GII). While the Hub has shown rapid growth in participant numbers and export volume, the negative short-window correlation with the GII is consistent with a concentration effect. The special legal regime, characterized by tax exemptions, English law principles, and simplified visa procedures, appears to have created a high-performance enclave that operates distinctively from the wider economy. This legal-institutional design is plausibly not merely incidental but central: predictable, investor-familiar rules for incorporation, contracting, and dispute resolution lower the cost of structuring and financing high-growth firms, a channel emphasized in the law-and-finance literature (La Porta et al., 1998), and the AIFC's common law framework approximates this function in the Kazakhstan setting.

At the same time, the concentration that makes the enclave effective also raises a crowding-out question. To the extent that the Hub's fiscal and legal privileges draw firms, talent, and capital that might otherwise have located elsewhere in Kazakhstan, part of the measured "Astana Hub Effect" could represent reallocation rather than net national creation; the special economic zone literature finds both net-creation and displacement outcomes depending on context (Wang, 2013). Our aggregate, single-country data cannot separate these possibilities, and we flag this as a key open question.

This divergence is consistent with a diffusion lag. Insofar as the Hub has concentrated talent and generated commercial outputs, these benefits appear not to have fully permeated the traditional sectors of the economy within the short window observed. The innovation ecosystem currently functions more as a specialized vertical than as a horizontal enabler across industries. For national competitiveness scores to rise commensurately with export volumes, the digital capabilities developed within the Hub would need to be integrated into Kazakhstan's primary industrial sectors and to register in the economy-wide indicators that the GII aggregates.

5.2. Independence from Commodity Cycles

A further contribution of this study concerns the apparent sectoral decoupling from commodity cycles. Historically, Kazakhstan's economic performance has been strongly

correlated with hydrocarbon price cycles. In our regression, the structural break in IT exports was not significantly associated with oil-price fluctuations.

At the same time, this is consistent with the possibility that growth in the digital sector reflects policy consistency and ecosystem maturity rather than external commodity shocks. We do not, however, interpret an insignificant oil-price control as proof of endogeneity: as noted in Section 4.5, the null could also reflect limited statistical power or the specific years observed. If the pattern holds in longer series, it would represent a tangible step in the country's diversification strategy, suggesting that non-extractive sectors can grow through institutional design even absent favorable commodity conditions.

5.3. The Sequencing of Digital Development

The correlation analysis highlights a strong link between state-led infrastructure (measured by the EGDI) and ecosystem growth. This is consistent with a “sequencing” interpretation of digital development, in which state capacity may serve as an enabling precondition for market creation, though our design cannot establish this ordering causally. Kazakhstan's significant investment in e-government and connectivity (2010–2017) provided the necessary foundation, which the Astana Hub (2018–2024) subsequently leveraged for commercialization.

The stabilization of the KDPI score further emphasizes this dynamic. Absent the Hub's private-sector output, the national digital ranking, which is heavily reliant on state inputs, might have declined, in part owing to methodological shifts in global indices; we present this as a plausible counterfactual rather than an estimated effect. On this reading, the Hub appears to have shifted part of the locus of digital development from government procurement toward private export generation.

The findings suggest four strategic imperatives to sustain the current momentum and bridge the gap between the digital enclave and the broader economy. We present these as conditional policy directions rather than guaranteed remedies; each carries implementation constraints and risks, which we note alongside the recommendation, and each should be read in light of the design limitations discussed in Section 5.4.

Vertical Integration: To address the divergence between high Hub exports and flat national innovation scores, policy could shift from supporting supply (startups) toward stimulating demand (corporate adoption), for example through tax credits for traditional industries (mining, agriculture, energy) that procure digital solutions from Hub residents. Such credits require administrative capacity to verify procurement and guard against relabeling of existing spend, and their fiscal cost must be weighed against uncertain adoption responses in incumbent sectors.

Regional Export Strategy: The rapid post-2018 growth is unlikely to be sustainable on the basis of the domestic market alone. Continued scaling requires positioning Astana Hub not just as a national operator but as a regional export gateway for Central Asia. Diplomatic and trade efforts should focus on harmonizing digital standards with neighbors to lower transaction costs for Kazakh startups expanding into Uzbekistan, Kyrgyzstan, and the wider Silk Road region.

Transitioning Funding Models: While state-led infrastructure (EGDI) successfully jumpstarted the ecosystem, the low GII score in “Investment” sub-pillars indicates a lack of private venture capital. Future policy should reduce direct government grants in favor of “fund-of-funds” structures that de-risk private venture capital. This ensures that capital allocation is driven by market signals rather than administrative milestones.

Institutional Predictability: The structural-break analysis is consistent with the export boom being closely tied to the specific legal and fiscal regime established in 2018. On this reading, maintaining the stability of the Hub's tax preferences and English law jurisdiction

is economically important. Premature reintegration of the Hub into the standard tax code could risk reversing the growth pattern observed in the data, potentially returning the ecosystem toward its pre-2018 trajectory. Indefinite preferential regimes also raise equity and revenue concerns and may entrench the very enclave boundaries that the other imperatives seek to dissolve, so predictability must be balanced against a credible, pre-announced path toward broader integration.

5.4. Limitations and Future Research

Several limitations bound the interpretation of our results and define an agenda for future work. First, the study uses a single-country, quasi-experimental design with one treated time series. Interrupted time series analysis dates a change in trajectory to the intervention but does not include a comparison unit, so it cannot rule out that other events near 2018 contributed to the observed acceleration, nor can it identify the behavioral mechanism behind it. Second, the post-intervention window is short (seven annual observations, 2018–2024). This limits statistical power, makes coefficient estimates sensitive to individual years, and is the principal reason we treat the correlation analysis as exploratory rather than confirmatory. Third, the period coincides with several concurrent shocks and policies, including the COVID-19 pandemic and the associated surge in global demand for digital services, exchange-rate movements, and parallel digital-government and AIFC initiatives; these confounders cannot be separately identified here and may share credit for the export change. Fourth, the KDPI inherits limitations from its inputs and construction: the source indices are conceptually overlapping, underwent methodological revisions around 2017–2018 (including the discontinuation of the ITU IDI and stricter NRI criteria), and our use of min–max normalization and equal weights, while transparent, is an analytical choice that affects the level and apparent volatility of the composite. Fifth, the correlation evidence is descriptive and cannot establish direction, dynamics, or feedback. Finally, our aggregate data cannot distinguish net national creation from reallocation across regions and sectors (the crowding-out question), nor can they measure diffusion into incumbent industries directly.

These limitations point to concrete next steps. A credible causal design would draw on a comparison group, for example a synthetic control constructed from peer economies, or a difference-in-differences comparison with countries that did not establish comparable hubs. Firm- and region-level data would allow direct tests of diffusion and crowding-out, distinguishing reallocation from net creation. Longer post-intervention series, and outcome measures less affected by index methodology changes (such as balance-of-payments IT-services exports and patent or trademark filings) would strengthen inference.

6. Conclusions

This study set out to empirically determine whether the creation of a centralized technology park could effectively catalyze a transition from a resource-based economy to a knowledge-based digital ecosystem. The quantitative evidence indicates that the Astana Hub has functioned as a plausible converter mechanism. While Kazakhstan had accumulated the “hardware” of a digital economy (infrastructure and human capital) over the preceding decade, it appears to have lacked the “software” (commercialization and private-sector R&D) required to generate value. The structural break in export performance post-2018, characterized by an average annual slope increase of \$112.8 million, is consistent with the Hub having helped unlock the latent potential of the state’s earlier digital investments, although our single-country design cannot attribute the change to the Hub alone.

Notably, this growth was not significantly associated with the commodity price cycle, which may mark a departure from Kazakhstan's historical economic volatility. At the same time, the negative short-window correlation with broader innovation indices highlights a likely diffusion lag. The ecosystem currently operates as a high-performance enclave; while it has concentrated talent and capital, it has not yet fully permeated the traditional industrial base.

Ultimately, this research is consistent with the view that state-led digitalization is a necessary but likely insufficient condition for economic transformation. To escape the “middle-income trap,” nations may require targeted market-creating institutions like the Astana Hub to bridge the gap between government capacity and private commercial success. The policy challenge for the next decade will be to soften the boundaries of this enclave so that the digital efficiencies generated within the Hub can spill over into the wider national economy. We reiterate that these conclusions rest on a single-country, short-horizon, quasi-experimental design; confirming the causal and bidirectional claims that motivate this agenda will require the comparison-group designs, data, and longer series outlined in Section 5.4.

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