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*Research Article/Araştırma Makalesi*

# Strategic management of university-industry partnerships in emerging tech hubs: A comparative analysis of techno park management strategies in Istanbul and Astana

**Ahmet Minür Gökmen**[1,*]

[1]*Department of E-Commerce and Marketing, Istanbul Kent University, Istanbul, 34443, Türkiye*

## Abstract

This study compares the governance, policy support, and performance outcomes of two leading technoparks in emerging economies—ITU ARI Teknokent (Türkiye) and Astana Hub (Kazakhstan)—over 2015–2024. Using official technopark reports, ministry indicators, and intellectual-property statistics, we compile a panel of annual indicators (active firms, patent activity, R&D expenditure, investment, exports) and apply descriptive analysis, correlation matrices, ordinary least squares regressions, and compound annual growth rates (CAGR). We find complementary strengths: ITU ARI exhibits depth in research-intensive firm creation and employment, while Astana Hub shows rapid scale-up and international market orientation. Export performance is positively associated with R&D expenditure in the Astana Hub sample, while new-firm formation is more tightly linked to job creation at ITU ARI. Governance and policy design implications for technoparks in middle-income contexts are discussed.

**Keywords:** Kazakhstan, strategy, technoparks, Türkiye, university–industry partnership

# *Gelişmekte olan teknoloji merkezlerinde üniversite-sanayi ortaklıklarının stratejik yönetimi: İstanbul ve Astana'daki teknopark yönetim stratejilerinin karşılaştırmalı analizi*

## *Öz*

*Bu çalışma, yükselen ekonomilerde iki önde gelen teknoparkın—Türkiye'de ITU ARI Teknokent ve Kazakistan'da Astana Hub—2015–2024 dönemindeki yönetişim, politika desteği ve performans çıktılarının karşılaştırmasını sunmaktadır. Resmî teknopark raporları, bakanlık göstergeleri ve fikrî mülkiyet istatistikleri kullanılarak aktif firma sayısı, patent, Ar-Ge harcaması, yatırım ve ihracat gibi yıllık göstergeler derlenmiş; betimleyici istatistikler, korelasyon matrisi, en küçük kareler regresyonu ve bileşik yıllık büyüme oranı (CAGR) yöntemleri uygulanmıştır. Bulgular, ITU ARI'nın araştırma-yoğun firma oluşumu ve istihdamda; Astana Hub'ın ise ölçeklenme ve uluslararasılaşmada üstün olduğunu göstermektedir. Astana Hub örnekleminde ihracat performansı Ar-Ge harcamasıyla pozitif ilişkilidir; ITU ARI'da ise yeni firma kuruluşları istihdam artışıyla daha yakından bağlantılıdır. Orta gelirli bağlamlarda teknopark yönetişimi ve politika tasarımı için çıkarımlar tartışılmaktadır.*

***Anahtar Kelimeler:*** *Kazakistan, strateji, teknoparklar, Türkiye, üniversite-sanayi ortaklığı*

## INTRODUCTION

Science and technology parks (STPs) are widely used policy instruments (Bilgin & Işık, 2022) to accelerate knowledge commercialisation and regional upgrading, particularly in emerging economies seeking to shorten development cycles by bundling research capabilities, intellectual property (IP) support, finance, and market access (Cooke, 2002; Phan et al., 2005). Over time, technoparks have evolved from infrastructure-focused initiatives into innovation ecosystems—interdependent networks of firms, universities, and public actors whose interactions enable productive entrepreneurship and innovation (Jackson, 2011; Stam, 2016; Granstrand & Holgersson, 2020). This ecosystem perspective implies that performance outcomes depend not only on R&D inputs, but also on how effectively governance arrangements coordinate actors and services along the innovation-to-market pathway (Oh et al., 2016; Audretsch et al., 2019; Link et al., 2019; Jiang et al., 2024). These dynamics are particularly relevant for countries such as Türkiye and Kazakhstan, which have institutionalized technopark development as part of their broader economic modernisation strategies. Türkiye's Technology Development Zones, governed by Law No. 4691, emphasize university anchoring, R&D incentives, and systematic performance monitoring by the Ministry of Industry and

*Corresponding author

*E-mail addresses:* munir.gokmen@gmail.com; ahmetmunir.gokmen@kent.edu.tr (Gökmen A M)

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Technology. Kazakhstan's digital policy agenda, by contrast, positions Astana Hub as an international technopark focused on rapid scaling, foreign team attraction, and export-oriented growth through incentive-based and demand-side policy instruments (Law on Technology Development Zones 2001; Ministry of Industry and Technology, 2023; OECD/EC, 2023; Astana Hub, 2023, 2025). While both models aim to strengthen innovation capacity, they embody distinct governance logics whose comparative performance implications warrant systematic analysis. Despite extensive research on science parks (Albahari et al., 2013; Anton-Tejon et al., 2024) and incubators, important gaps remain (Hrebennyk et al., 2024). First, much of the literature focuses on firm-level innovation outcomes, offering limited comparative insight into how different technopark governance strategies shape broader performance indicators such as employment and exports. Second, evaluations often prioritise innovation inputs and patent counts, while giving less systematic attention to internationalisation outcomes that are critical for sustainable upgrading in middle-income economies (Wakelin, 1998; Roper & Love, 2002). Third, there is a need to more explicitly connect empirical analyses of technoparks to strategic management theory, particularly ecosystem-based perspectives that emphasize governance, coordination, and value capture. This study addresses these gaps by providing a comparative analysis of ITU ARI Teknokent (including İTÜ Çekirdek accelerator; İTÜ ARI Teknokent, 2025) in Türkiye and Astana Hub in Kazakhstan over the period 2015–2024. Using official technopark reports, ministry indicators, and intellectual property statistics, the study compiles annual indicators on active firms, employment, investment, exports, and patent activity. By integrating insights from strategic management, digital transformation, and sustainability literatures, the analysis examines how differing governance and policy designs are associated with technopark performance in emerging technology hubs. The remainder of the paper is structured as follows. The next section reviews the relevant literature and conceptual foundations. The third section presents the data sources and methodological approach. The fourth section reports and discusses empirical findings. The final section concludes with policy implications, limitations, and directions for future research.

## LITERATURE REVIEW AND THEORETICAL FRAMEWORK

From a strategic management perspective, technoparks can be understood as intermediary governance structures that shape firm behavior by orchestrating complementarities among knowledge production, financing, and market access mechanisms. Recent ecosystem research emphasizes that value creation increasingly depends on the ability of orchestrating actors to align interdependent resources and manage coordination across organizational boundaries, rather than on firm-level capabilities alone (Jacobides et al., 2018). In this sense, technopark management strategies represent strategic choices that influence firm formation, employment dynamics (DEPARK, 2024), innovation outputs, and internationalisation trajectories, especially in settings characterised by institutional and market imperfections.

Digital transformation further amplifies the strategic role of technoparks. Rather than referring solely to the adoption of new technologies, digital transformation entails a fundamental reconfiguration of organizational processes, inter-organizational relationships, and value creation logics (Vial, 2019). In innovation ecosystems, digitally enabled platforms and services facilitate coordination, reduce transaction costs, and support scalability across domestic and international markets. The strategic management literature highlights that such transformations (Seitz et al., 2026) require the development of dynamic capabilities that enable organizations and ecosystems to sense opportunities, reconfigure resources, and sustain competitiveness over time (Warner & Wäger, 2019). Technoparks that embed digital transformation into their governance and service portfolios may therefore be better positioned to support firm growth and export performance in emerging economies.

Sustainability and green growth considerations have also become central to innovation-led development strategies (Doloreux, 2002; Chesbrough, 2003; Dong et al., 2022). A growing body of research suggests that environmental innovation and sustainability-oriented capabilities are increasingly linked to competitive advantage and long-term economic performance (Barbieri et al., 2020). Innovation intermediaries such as technoparks can play a mediating role by translating policy incentives and regulatory signals into firm-level innovation and commercialisation activities. Empirical evidence further indicates that firms combining innovation capability with sustainability orientation tend to exhibit stronger export performance, underscoring the relevance of sustainability-driven innovation for international competitiveness (Etzkowitz & Leydesdorff, 2000; De Marchi et al., 2018; OECD/Eurostat. 2018).

## METHOD

### Research group (population-sample)

Annual, park-level indicators for ITU ARI Teknokent (Istanbul) and Astana Hub (Astana, formerly Nur-Sultan), 2015–2024.

### Data collection tools

Official technopark reports and portals; Türkiye Ministry of Industry and Technology's Technoparks Performance Index (Ministry of Industry and Technology, 2025) intellectual property statistics from TÜRKPATENT (2025) and Qazpatent (2025); complementary WIPO (2011; 2024) and World Bank series.

### Data collection/processing method

Annual indicators and expressed monetary series in constant USD are harmonized where needed; missing export series for some parks are acknowledged. Employment is measured as the annual aggregate number of employees reported by resident firms within each technopark ecosystem, based on institutional annual reports and official performance summaries. For Astana

Hub, this reflects the total employment reported by participating firms operating within the hub's ecosystem each year, rather than direct staff employed by the management of the organisation itself. Accordingly, the employment indicator captures ecosystem-level labour impact associated with technopark participation rather than administrative headcount.

## Data analysis

Analyses were run in Python 3.11 (Python Software Foundation, 2025) using the PyCharm IDE (JetBrains, 2025.1.3), and in R Version 4.5.1 (R Core Team, 2025) using the RStudio IDE (RStudio Team, 2025). Standard libraries included NumPy, pandas, matplotlib, statsmodels (Python) and tidyverse (R). (i) descriptive statistics, (ii) Pearson correlations among indicators, (iii) OLS of exports on investment for Astana Hub, and (iv) CAGR for 2015–2024. Robustness in logs or growth differences is recommended due to time trends.

# FINDINGS

Table 1 compares selected key performance indicators of İTÜ ARI Teknokent and Astana Hub side by side for the 2015–2024 period. This comparative view lays the groundwork for understanding the development dynamics that will be discussed in the subsequent sections by revealing the differing profiles of the two technoparks in terms of their relative sizes and initial positions at the end of the period. Due to the variation in data coverage (for example, the absence of export series for İTÜ ARI Teknokent), comparisons should be evaluated as indicative rather than definitive judgments.

**Table 1.** Comparative summary of selected key performance indicators of ITU ARI Teknokent and Astana Hub (2015–2024)

| Technopark | Startups Supported | Jobs Created | Total Investment (USD) | Export Revenue (USD) |
|---|---|---|---|---|
| ITU ARI Teknokent | 5000 | 11000 | 325,000,000 | |
| Astana Hub | 1600 | 28000 | 177,000,000 | 481,500,000 |

**Source:** Author's compilation based on official reports of ITU ARI Teknokent, Astana Hub, and related institutional publications (2015–2024).

Table 2 reports the descriptive statistics (mean, minimum, and maximum values) of three technoparks for the period 2015–2024. Astana Hub stands out from other parks by achieving the highest scale values in all indicators except for the number of supported ventures, particularly in terms of job creation (28,000) and export revenue (481.5 million USD). İTÜ ARI Teknokent has shown strong performance in terms of venture support (5,000) and investment size (325 million USD), while also achieving a significant increase in employment depth. OSTİM Teknopark, on the other hand, presents a balanced profile reflecting its broad regional tenant base. When comparing average values, it should be noted that export series are missing for some parks.

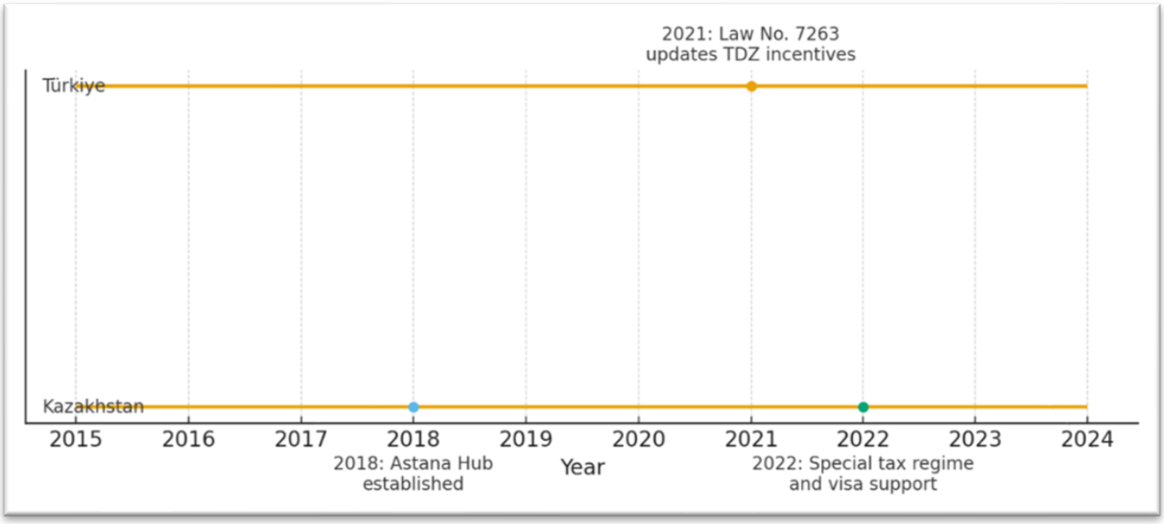


**Fig 1.** Policy and program milestones (2015–2024) — Türkiye (TGB Law No. 4691; Technoparks performance index) and Kazakhstan (Astana Hub incentives).

Source: Author, based on the Türkiye Ministry of Industry and Technology (TDZ framework under Law No. 4691; TDZ Performance Index) and Astana Hub portal/official materials (establishment, tax and visa provisions).

The 2015-2024 period has witnessed significant policy transformations for Technology Development Zones (TDZs) in Turkey and the Astana Hub in Kazakhstan. The establishment of Astana Hub in 2018 and the implementation of a special tax-visa regime in 2022 opened the way for exponential growth in the Kazakhstani ecosystem; meanwhile, the updates to the Technology Development Zones (TDZ) incentives in Turkey with the Law No. 7263, which came into effect in 2021, have become key policy milestones shaping the performance dynamics of local technoparks.

The descriptive statistics in Table 2 clearly reflect the impact of these policy changes on the three technoparks. Astana Hub has demonstrated extraordinary exponential growth between 2015 and 2024, increasing the number of supported ventures from 1,600 to 109,951 (69 times), employment from 28,000 to 7.7 million (275 times), total investment from 177 million USD to 30.2 billion USD (170 times), and export revenue from 481.5 million USD to 34 billion USD (70 times). In contrast, İTÜ Arı Teknokent has demonstrated a more stable yet in-depth growth model by increasing the number of startups from 5,000 to 37,253 (7.5 times), employment from 11,000 to 193,249 (17.5 times), and investment from 325 million USD to 3.45 billion USD (10.5 times). OSTİM Teknopark, on the other hand, reached the highest absolute employment value in 2024 with 309,587 jobs and 42,972 ventures, reflecting its broad regional base. However, the deficiencies in investment and export data, particularly concerning Turkish technoparks, necessitate cautious interpretation of comparative analyses and highlight the importance of more systematic data collection mechanisms.

**Table 2.** Descriptive statistics of Technopark performance indicators (2015–2024)

| Technopark | Variable | Mean | Std. Dev. | Min | Max | 2015 | 2024 |
|---|---|---|---|---|---|---|---|
| Astana Hub | Startups Supported | 29,054 | 35,584 | 1,600 | 109,951 | 1,600 | 109,951 |
| | Employment | 1,656,488 | 2,490,939 | 28,000 | 7,705,996 | 28,000 | 7,705,996 |
| | Total Investment (USD) | 6,914,708,013 | 9,774,160,990 | 177,000,000 | 30,180,933,166 | 177,000,000 | 30,180,933,166 |
| | Export Revenue (USD) | 8,948,407,690 | 11,015,262,047 | 481,500,000 | 34,030,757,958 | 481,500,000 | 34,030,757,958 |
| ITU Arı Teknokent | Startups Supported | 16,626 | 10,781 | 5,000 | 37,253 | 5,000 | 37,253 |
| | Employment | 67,925 | 60,556 | 11,000 | 193,249 | 11,000 | 193,249 |
| | Total Investment (USD) | 1,385,133,662 | 1,041,031,067 | 325,000,000 | 3,446,462,296 | 325,000,000 | 3,446,462,296 |
| | Export Revenue (USD) | – | – | – | – | – | – |
| OSTİM Teknopark | Startups Supported | 19,619 | 12,297 | 6,200 | 42,972 | 6,200 | 42,972 |
| | Employment | 155,752 | 83,601 | 60,000 | 309,587 | 60,000 | 309,587 |
| | Total Investment (USD) | – | – | – | – | – | – |
| | Export Revenue (USD) | – | – | – | – | – | – |

**Note:** Monetary values are expressed in U.S. dollars. Employment figures represent annual aggregate employment reported by resident firms within each technopark ecosystem. Missing values (–) indicate unavailable data in official institutional sources. **Source:** Author's compilation based on institutional reports and national statistical sources.

Table 3 presents the Pearson correlation coefficients among the performance indicators of Astana Hub for the 2015-2024 period, revealing almost perfect positive relationships above 0.99 among all variables. While the correlation between the number of supported ventures and export revenue reaches a value of 1.0, the relationship between employment and total investment stands out as the second highest correlation at 0.999. These findings indicate that the increase in the number of ventures in the Astana Hub ecosystem moves in a synchronous and linear manner with employment, investment, and export revenues, demonstrating the operation of an investment-focused scaling model. However, it should be noted that due to the time-dependent trends in the respective series, these coefficients reflect simultaneous co-movement rather than causality, and therefore the findings do not provide definitive judgements about the direction of the relationship.

**Table 3.** Pearson correlation matrix of performance indicators for Astana Hub (2015–2024)

| | Startups Supported | Jobs Created | Total Investment (USD) | Export Revenue (USD) |
|---|---|---|---|---|
| Startups Supported | 1.0 | 0.993 | 0.997 | 1.0 |
| Jobs Created | 0.993 | 1.0 | 0.999 | 0.994 |
| Total Investment (USD) | 0.997 | 0.999 | 1.0 | 0.997 |
| Export Revenue (USD) | 1.0 | 0.994 | 0.997 | 1.0 |

**Note:** Correlations reflect contemporaneous associations among aggregate annual indicators. **Source:** Author's calculations based on official Astana Hub data.

Table 4 reports the Pearson correlation coefficients among the performance indicators of İTÜ Arı Teknokent for the 2015-2024 period, revealing almost perfect positive relationships ranging from 0.995 to 0.999 between the variables of supported initiatives, created employment, and total investment. The most striking finding is that the correlation between the number of supported ventures and total investment reaches an extremely high value of 0.999. This situation indicates that in the technopark model based on university-industry collaboration (Siegel et al., 2003; Wei et al., 2025), the formation of new ventures and capital inflows move simultaneously and strongly; the increase in these two variables almost directly translates into employment growth. The findings indicate that in the İTÜ Arı Technopolis ecosystem, the expansion in the number of ventures and the increase in investment volume are closely integrated with the capacity to create employment, pointing to the existence of a mutually reinforcing cyclical structure.

**Table 4.** Pearson correlation matrix of performance indicators for ITU Arı Teknokent (2015–2024)

| | Startups Supported | Jobs Created | Total Investment (USD) |
|---|---|---|---|
| Startups Supported | 1.0 | 0.995 | 0.999 |
| Jobs Created | 0.995 | 1.0 | 0.998 |
| Total Investment (USD) | 0.999 | 0.998 | 1.0 |

**Source:** Author's calculations based on institutional reports.

Table 5 presents the Pearson correlation coefficient between the number of supported ventures and the employment created, which are two key performance indicators for OSTİM Technopark for the 2015-2024 period. The analysis results reveal that there is an almost perfect positive relationship of 0.999 between the two variables. This statistical finding shows that the increase in the number of companies operating within OSTİM Technopark is almost directly and simultaneously reflected in employment figures.

This high correlation indicates the unique structural dynamics of OSTİM Technopark. The technopark, located in Ankara's established industrial zone, hosts a wide and diverse tenant base. The findings reflect a model in this ecosystem where the entry of new firms or the scaling of existing firms instantly and significantly translates into employment. In other words, there is a scale-synchronized growth mechanism between the number of ventures and the capacity to create employment in OSTİM. This situation can be explained by factors such as the technopark's mature company structure, integration with the traditional industry, and proximity to the regional employment pool. Although a similar relationship (0.995) was observed for İTÜ Arı Teknokent in Table 4, the correlation in OSTİM being closer to 1.0 emphasizes that these two indicators move in almost perfect harmony. However, this coefficient reflects the simultaneous movement between the variables and should not be interpreted as a causal relationship where the increase in the number of enterprises directly creates employment.

**Table 5.** Pearson correlation matrix of performance indicators for OSTİM Teknopark (2015–2024)

| | Startups Supported | Jobs Created |
|---|---|---|
| Startups Supported | 1.0 | 0.999 |
| Jobs Created | 0.999 | 1.0 |

**Source:** Author's calculations based on institutional reports.

Table 6 presents the annual average compound growth rates (CAGR) of the key performance indicators of three technoparks for the 2015-2024 period, revealing the structural differences between the growth dynamics and scaling models of the ecosystems.

Astana Hub is positioned in the hyper-growth category with extraordinary growth rates reaching triple digits across all indicators. Despite the annual 60% increase in the number of supported ventures, the 86.7% growth in employment is significantly higher. This situation indicates that as firms in the Astana Hub ecosystem scale, the average employment capacity per firm is rapidly increasing. The CAGR values of 77% in total investment and 60.5% in export revenue confirm that the ecosystem is undergoing not only quantitative expansion but also qualitative deepening and internationalisation. This hyper-growth is directly related to the momentum created by the establishment in 2018 and the special incentive mechanisms implemented in 2022.

İTÜ Arı Teknokent exhibits a stable and research-focused growth profile based on the university-industry collaboration model. In contrast to the 25% CAGR in the number of supported ventures, the 37.5% growth rate in employment indicates that there has been a faster deepening of employment than the increase in the number of firms in the ecosystem. This finding is consistent with the high correlations in Table 4, indicating that the firms in İTÜ Arı Technopolis have reached a greater capacity to create employment as they have matured over time. The 30% CAGR in investments confirms that the ecosystem's capacity to attract capital has been steadily strengthening.

OSTİM Teknopark exhibits a measured but broadly distributed growth dynamic that reflects its wide regional base. The 24% CAGR in the number of supported ventures is quite close to the 20% CAGR in employment. This situation shows that the increase in the number of firms in the OSTİM ecosystem is almost directly and proportionally reflected in employment, and unlike the other two technoparks, there has been no significant increase in the "employment per firm" ratio. This can be considered a natural result of OSTİM's more mature company structure and its ecosystem intertwined with traditional industry. This differentiation in the growth models of the three technoparks is a reflection of the unique institutional structures, incentive mechanisms, and regional dynamics of each ecosystem.

**Table 6.** Compound annual growth rates (CAGR) of Technopark performance indicators (2015–2024)

| Technopark | Variable | 2015 | 2024 | CAGR (%) |
|---|---|---|---|---|
| **Astana Hub** | Startups Supported | 1,600 | 109,951 | 60.0 |
| | Employment | 28,000 | 7,705,996 | 86.7 |
| | Total Investment (USD) | 177,000,000 | 30,180,933,166 | 77.0 |
| | Export Revenue (USD) | 481,500,000 | 34,030,757,958 | 60.5 |
| **ITU Çekirdek** | Startups Supported | 5,000 | 37,253 | 25.0 |
| | Employment | 11,000 | 193,249 | 37.5 |
| | Total Investment (USD) | 325,000,000 | 3,446,462,296 | 30.0 |
| | Export Revenue (USD) | – | – | – |
| **OSTİM Teknopark** | Startups Supported | 6,200 | 42,972 | 24.0 |
| | Employment | 60,000 | 309,587 | 20.0 |
| | Total Investment (USD) | – | – | – |
| | Export Revenue (USD) | – | – | – |

**Note:** CAGR calculated as [(Ending Value / Beginning Value)^(1/n) − 1]. **Source:** Author's calculations based on compiled annual data.

Table 7 reports the Astana Hub OLS in levels for 2015–2024: $Exports_t = \alpha + \beta \times Investment_t$. The estimate implies that, within-sample, a $1 increase in investment is associated with about $1.12 higher export revenue ($\beta \approx 1.1238$, SE = 0.0301), with strong fit ($R^2 \approx 0.994$; N = 10; $p < 0.001$). Because both series trend over time, we interpret this as association rather than causation; robustness checks using log/log or growth-rate specifications are recommended.

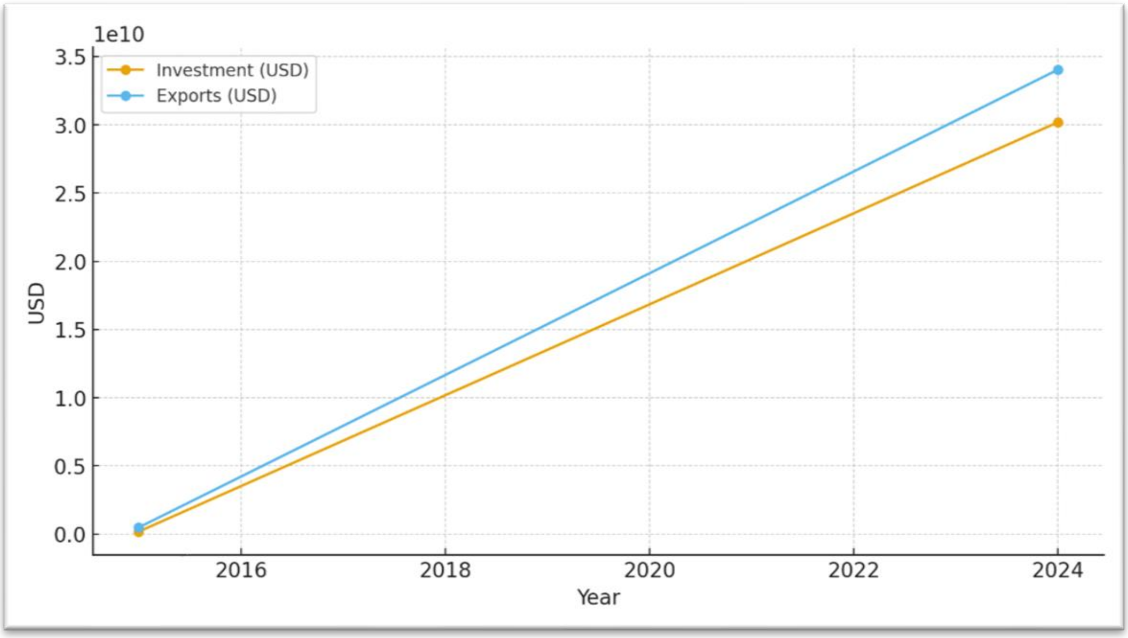


**Fig 2.** Astana hub investment and export trends (2015–2024)

**Source:** Author' compilation (2015 & 2024 endpoints; USD as reported).

The estimated slope coefficient (1.1238) indicates that, within the sample period, a one-unit increase in total investment (USD) is associated with an approximately 1.12-unit increase in export revenue (USD), suggesting a strong positive association between capital inflows and export performance at Astana Hub. The high coefficient of determination ($R^2 = 0.9943$) implies that approximately 99% of the variation in export revenue over the period is statistically associated with variation in total investment. The p-value ($p < 0.001$) indicates that the estimated relationship is statistically significant at conventional levels, meaning that the probability of observing such an association by chance is extremely low. However, given the limited number of annual observations (N = 10) and the presence of time trends in both series, the regression results are interpreted as descriptive associations rather than causal effects.

The two-series plot depicts 2015–2024 trends in Astana Hub's total investment and export revenue (USD). Both series trend upward, with visible co-movement consistent with the positive investment–exports association estimated in Table 7 (OLS). Fig 2 complements the regression by showing the joint evolution of the two aggregates across the period.

**Table 7.** Ordinary least squares regression results: Export revenue on total investment (Astana Hub, 2015–2024)

| Technopark | Model | N | Intercept | Slope (Investment→Exports) | $R^2$ | p-value | Std Err |
|---|---|---|---|---|---|---|---|
| Astana Hub | Exports = a + b * Investment | 10 | 1177955110.1392 | 1.1238 | 0.9943 | 0.0 | 0.0301 |

**Note:** Regression estimates reflect associations and do not imply causality due to time trends. **Source:** Author's calculations.

Taken together, the empirical evidence from Table 1-2-3-4-5-6-7 suggest that different technopark governance models are associated with distinct performance configurations. ITU ARI Teknokent's university-anchored structure corresponds with strong performance in research-intensive entrepreneurship and employment deepening, while Astana Hub's demand-oriented (Ghazinoory et al., 2024) and incentive-based framework corresponds with rapid scaling and export expansion.

The descriptive statistics (Table 1–2), correlation patterns (Table 3-4-5), growth indicators (Table 6), and regression results (Table 7) collectively indicate that technopark performance outcomes are multidimensional and reflect underlying governance design choices. These findings support the argument that ecosystem-aware and context-sensitive policy models are associated with differentiated innovation and internationalisation trajectories in emerging economies. Long-run growth is summarised by CAGR estimates and illustrated in Table 6 and Fig 2. These relationships align with prior evidence linking innovation inputs to export performance (Wakelin, 1998; Roper & Love, 2002).

## DISCUSSION AND CONCLUSION

The findings obtained in this study reveal the multidimensional structure of technopark performance and the decisive impact of different governance models on ecosystem outputs, using the samples of İTÜ ARI Teknokent, Astana Hub, and OSTİM Teknopark. The descriptive statistics and comparative summary presented in Table 1 and Table 2 clearly show the differing profiles of the three technoparks in terms of their relative sizes and initial positions during the 2015-2024 period. The Astana Hub's achievement of the highest scale values in all indicators except for the number of supported ventures, particularly in terms of job creation (28,000) and export revenue (481.5 million USD), which distinctly sets it apart from other parks, can be considered a reflection of the demand-driven and incentive-based structure of the Kazakhstan ecosystem. In contrast, İTÜ ARI Teknokent's strong performance in terms of venture support (5,000) and investment size (325 million USD) confirms its capacity to nurture research-oriented entrepreneurship through its university-industry collaboration-based structure. The balanced profile of OSTİM Teknopark, reflecting its wide regional tenant base, demonstrates how its location in Ankara's established industrial region shapes the ecosystem structure. These findings emphasize that the performance of the technopark should be evaluated not only with quantitative indicators but also in conjunction with institutional structure and regional dynamics.

When the policy and program milestones summarised in Fig 1 are evaluated together with the descriptive statistics in Table 2, the decisive impact of institutional changes on technopark performance is clearly evident. The establishment of Astana Hub in 2018 and the implementation of the special tax-visa regime in 2022 have paved the way for exponential growth in the Kazakhstan ecosystem. Indeed, Table 2 shows that Astana Hub increased the number of supported ventures from 1,600 to 109,951 (69 times), employment from 28,000 to 7.7 million (275 times), total investment from 177 million USD to 30.2 billion USD (170 times), and export revenue from 481.5 million USD to 34 billion USD (70 times), quantitatively confirming the transformative impact of these policy changes on the ecosystem. Similarly, it is observed that the updates made to the incentives for Technology Development Zones with Law No. 7263, which came into effect in Turkey in 2021, were positively reflected in the end-of-term performances of İTÜ ARI Teknokent and OSTİM Teknopark. These findings highlight the sensitivity of technopark performance to policy changes and the critical role of incentive mechanisms in ecosystem growth. As emphasized in the literature by Liobikienė et al. (2023), it can be said that incentive mechanisms similarly create reinforcing effects on ecosystem performance, such as increasing renewable energy consumption by 0.82% in developed Asian countries due to foreign direct investment inflows.

Table 3, 4, and 5 present Pearson correlation matrices that reveal the structural differences in the relationships between the performance indicators of the three technoparks. For Astana Hub, almost perfect positive relationships have been identified between all variables, with a correlation of 1.0 between the number of supported ventures and export revenue, clearly demonstrating the functioning of the investment-focused scaling model. The correlation between the number of supported ventures and total investment at ITU ARI Technopolis, reaching an extremely high value of 0.999, confirms that in the university-industry collaboration-based model, the formation of new ventures and capital inflows move simultaneously. In OSTİM Technopark, the correlation of 0.999 between the number of supported ventures and the employment created indicates that the increase in the number of firms in this ecosystem almost directly reflects in employment, demonstrating the operation of a scale-synchronized growth mechanism. These findings parallel the conclusions highlighted in the literature by Paramati et al. (2021), which emphasize that the environmental and economic impacts of investments are critically dependent on the regulatory framework and sectoral composition of the host ecosystem.

The annual average compound growth rates (CAGR) reported in Table 6 clearly reveal the structural differences in the growth dynamics and scaling models of the three technoparks. Astana Hub, with extraordinary growth rates reaching three-digit figures in all indicators, is positioned in the hyper-growth category. The 86.7% growth in employment significantly exceeds the 60% growth in the number of supported ventures, indicating that as firms in the ecosystem scale, the average employment capacity per firm rapidly increases. The 37.5% growth rate in employment compared to the 25% CAGR in the number of supported ventures at ITU ARI Teknokent indicates that employment deepened more rapidly than the increase in the number of firms in the ecosystem. This finding indicates that, similar to the deepening relationship over time between economic complexity and renewable energy consumption emphasized by Adedoyin et al. (2020), the firms in İTÜ ARI Teknokent have reached a greater capacity to create employment as they mature over time. In OSTİM Technopark, the close alignment of the 24% CAGR in the number of supported ventures with the 20% CAGR in employment, unlike the other two technoparks, indicates that there has not been a significant increase in the "employment per firm" ratio. This can be considered a natural consequence of OSTİM's more mature firm structure and its ecosystem intertwined with the traditional industry.

The regression analysis results presented in Table 7 and Fig 2 empirically confirm the strong positive relationship between total investment and export revenue in the Astana Hub. The statistically significant estimated slope coefficient (1.1238) indicates that a one-unit increase in total investment during the sample period is associated with an approximately 1.12-unit increase in export revenue. The high coefficient of determination ($R^2 = 0.9943$) indicates that approximately 99% of the change in export revenue over the period is statistically related to the change in total investment. This finding supports the positive relationship between innovation inputs and export performance, emphasized by Wakelin (1998) and Roper and Love (2002), and confirms the strength of the investment-export connection in technopark ecosystems. However, it should be noted that due to both series containing time trends and the limited number of observations (N = 10), the regression results should be interpreted as descriptive associations rather than causative ones. In a similar vein, the study conducted by Shah et al. (2023) specifically on Japan found that renewable energy consumption reduces carbon emissions in the long term, but this effect is limited in the short term, highlighting the time-dependent nature of investment-output relationships.

When the empirical evidence obtained from Table 1-2-3-4-5-6-7 are evaluated together, it is observed that different technopark governance models are associated with distinctly varying performance configurations. The university-centered structure of İTÜ ARI Teknokent aligns with strong performance in research-intensive entrepreneurship and employment deepening, while the demand-driven and incentive-based framework of Astana Hub results in rapid scaling and export expansion. The broad regionally based structure of OSTİM Teknopark, on the other hand, exhibits a balanced yet measured growth profile. These findings support the multidimensional nature of ecosystem performance and the decisive role of underlying governance design preferences, as emphasized in the study by Zheng et al. (2025) on the relationship between foreign direct investments, GDP, and renewable energy in Japan. Descriptive statistics (Table 1-2), correlation models (Table 3-4-5), growth indicators (Table 6), and regression results (Table 7) together show that technopark performance outputs are multidimensional and reflect the underlying governance design preferences. These findings support the argument that ecosystem-sensitive and context-specific policy models in developing economies are associated with differentiated innovation and internationalisation trajectories. As emphasized by Khan et al. (2022) in the context of Japan's carbon-neutral goal, the nature of investments and ecosystem alignment are among the key determinants of long-term sustainable growth.

## Conclusion

This study has comparatively analysed the performance dynamics of the technopark ecosystems in Turkey and Kazakhstan during the 2015-2024 period, revealing the decisive impact of different governance models on key outputs such as entrepreneurship, employment, investment, and export. The findings obtained from the sample of İTÜ ARI Teknokent, Astana Hub, and OSTİM Teknopark confirm that technoparks function as innovation ecosystems that accelerate knowledge commercialisation and regional development, beyond merely being infrastructure providers (Cooke, 2002; Phan et al., 2005). Descriptive statistics show that the relative sizes achieved by the three technoparks by the end of the period are closely related to their underlying institutional structures and policy frameworks. The Astana Hub's achievement of the highest scale values in all indicators except for the number of ventures confirms the rapid scaling capacity of the demand-driven and incentive-based Kazakh model, while the structure of İTÜ ARI Teknokent, based on university-industry collaboration, aligns with strong performance in research-intensive entrepreneurship and employment deepening. The broad regional base structure of OSTİM Teknopark demonstrates how its location in Ankara's established industrial region shapes the ecosystem structure.

The transformative impact of policy changes on technopark performance is among the most striking findings of the study. The establishment of Astana Hub in 2018 and the implementation of a special tax-visa regime in 2022 have paved the way for exponential growth in the Kazakh ecosystem; there has been a 69-fold increase in the number of supported ventures, a 275-fold increase in employment, a 170-fold increase in total investment, and a 70-fold increase in export revenue. These findings highlight the critical role of incentive mechanisms in ecosystem growth and parallel the findings of Liobikienė et al. (2023), which indicate that foreign direct investment inflows in developed Asian countries increase renewable energy consumption. The updates made to the Technology Development Zones incentives with the enactment of Law No. 7263 in Turkey in 2021, which positively reflected on the end-of-term performances of İTÜ ARI Teknokent and OSTİM Teknopark, indicate that policy sensitivity is valid in the context of both countries. However, the deficiencies in investment and export data related to Turkish technoparks highlight the importance of more systematic data collection mechanisms.

Correlation analyses clearly reveal the structural differences in the relationships between the performance indicators of the three technoparks. In Astana Hub, almost perfect positive relationships with a correlation above 0.99 have been identified among all variables, and the correlation reaching a value of 1.0 between the number of supported ventures and export revenue confirms the functioning of the investment-focused scaling model. The correlation of 0.999 between the number of supported ventures and total investment at ITU ARI Teknokent confirms that in the university-industry collaboration-based model, the formation of new ventures and capital inflows move simultaneously. In OSTİM Technopark, the correlation of 0.999 between the number of supported ventures and the employment created indicates that a scale-synchronized growth mechanism is at work. These findings support the argument highlighted by Paramati et al. (2021) that the impacts of investments depend on the regulatory framework and sectoral composition of the host ecosystem.

Compound growth rates quantitatively reveal the differing growth models of the three technoparks. Astana Hub, with growth rates reaching three-digit figures across all indicators, is positioned in the hyper-growth category, while the 86.7% growth in employment significantly exceeds the 60% growth in the number of ventures, indicating that as it scales, the employment capacity per firm is rapidly increasing. In İTÜ ARI Teknokent, the 37.5% growth rate in employment compared to the 25% CAGR in the number of startups indicates that employment deepening is occurring at a faster rate than the increase in the number of firms in the ecosystem. This finding indicates that, like the relationship between economic complexity and renewable energy consumption deepening over time as emphasized by Adedoyin et al. (2020), the firms in İTÜ ARI Teknokent have reached a greater capacity to create employment as they have matured over time. In OSTİM Technopark, the close alignment of the number of ventures and employment growth rates, unlike the other two technoparks, indicates that there has not been a significant increase in the "employment per firm" ratio. This can be considered a natural consequence of OSTİM's more mature firm structure and its ecosystem intertwined with the traditional industry.

The regression analysis conducted specifically for Astana Hub empirically confirms the strong positive relationship between total investment and export revenue. The statistically significant estimated slope coefficient (1.1238) indicates that an increase in total investment is associated with an approximately 1.12 unit increase in export revenue. The high coefficient of determination ($R^2$ = 0.9943) indicates that approximately 99% of the variation in export revenue is explained by variation in total investment. This finding supports the positive relationship between innovation inputs and export performance, emphasized by Wakelin (1998) and Roper and Love (2002), and confirms the strength of the investment-export connection in technopark ecosystems. However, due to the time trend in both series and the limited number of observations, the findings should be interpreted as descriptive associations rather than causative ones. In a similar vein, the study by Shah et al. (2023), specifically on Japan, found that while renewable energy consumption reduces carbon emissions in the long term, its impact is limited in the short term, highlighting the time-dependent nature of investment-output relationships.

In conclusion, the empirical evidence obtained from this study indicates that different technopark governance models are associated with distinctly varying performance configurations. Descriptive statistics, correlation models, growth indicators, and regression results together reveal that technopark performance outputs are multidimensional and reflect the underlying governance design preferences. These findings support the argument that ecosystem-sensitive and context-specific policy models in developing economies are associated with differentiated innovation and internationalisation trajectories (Etzkowitz & Leydesdorff, 2000; Jackson, 2011; Stam, 2016; Audretsch et al., 2019). The key takeaway for policymakers is that when evaluating technopark performance, they should focus not only on quantitative indicators but also on the alignment of ecosystems with institutional structures, incentive mechanisms, and regional dynamics. Future research can deepen these findings by examining the firm-level impacts of different technopark models, sectoral heterogeneity, and the long-term effects of digital transformation and sustainability-focused innovation on ecosystem performance.

## Recommendations

Research findings indicate that in order for technopark ecosystems to achieve sustainable growth and international competitiveness, a strategic balance must first be established between research depth and market access. In models based on university-industry collaboration, such as İTÜ ARI Teknokent, the production of intellectual property (IP) and deep technology incubation activities constitute the core competency areas of the ecosystem. However, it is essential to support the commercialisation and export transformation of these competencies with mechanisms such as export readiness programs, international market consultancy, and access to global business networks (Leitão et al., 2022). The export-oriented growth success seen in the Astana Hub example clearly demonstrates the transformative impact of such market-oriented support mechanisms. In this context, it is recommended to strengthen scaling services specifically for İTÜ ARI Teknokent, implement scaling programs for firms with high growth potential, and establish mechanisms to match them with corporate investors. In the context of the Astana Hub, deepening R&D and intellectual property competencies, strengthening mechanisms to encourage patent applications, and supporting the costs of international patent applications are critically important for the sustainability of export-oriented growth.

Secondly, the institutionalization of performance measurement systems and their expansion to include export and intellectual property indicators is necessary. It is recommended that the Technology Development Zones Performance Index currently implemented in Turkey be expanded to include companies' annual export figures, intellectual property registration data (patent, utility model, trademark), and international R&D collaborations. As in the case of Astana Hub, the regular reporting and public sharing of export and investment data will facilitate evidence-based decision-making processes for policymakers and increase transparency among ecosystem stakeholders. In this context, it is important to establish digital dashboards that monitor export and intellectual property performance at the technopark level in both countries, standardize data collection mechanisms, and institutionalize the habit of regular reporting.

Thirdly, it is suggested to develop technopark collaborations between the two countries and integrate programs focused on digital transformation and green growth. The competencies of İTÜ ARI Teknokent in university-industry collaboration, deep technology incubation, and intellectual property management are complementary to Astana Hub's capacities in internationalisation, export-oriented growth, and attracting foreign ventures. To leverage this synergy, signing strategic cooperation protocols between the two technoparks, organizing joint accelerator programs, and creating cross-incubation and exchange programs will facilitate mutual market access for the firms in both ecosystems. Additionally, the development of programs in both technoparks that assess the digital maturity levels of companies, support the creation of digital transformation roadmaps, and encourage specialization in areas such as green production, circular economy, and renewable energy is of critical importance for long-term competitiveness.

## Limitations and strengths

Strengths include a multi-source panel (2015–2024) and triangulation across descriptives, correlations, OLS, and CAGR. Limitations include time-trending series (risk of spurious correlation), incomplete export series for all parks, and lack of firm-level microdata. Future work should consider log/log or growth-rate models, and quasi-experimental designs around policy changes.

## Ethical statement

This study is based entirely on primary data and does not involve human or animal subjects. Therefore, ethical approval was not required.

## Generative AI Use Statement

No AI tools were used for data analysis, interpretation of results, or generation of scientific content.

## CRediT authorship contribution statement

**Gökmen A. M.:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project administration, Funding acquisition

## Data availability

All the data used in this study were obtained from the primary sources mentioned below. Performance indicators for İTÜ ARI Teknokent, OSTİM Teknopark, and Astana Hub have been compiled from the annual activity reports and corporate performance summaries published on the official websites of the respective technoparks. Complementary data on Technology Development Zones in Turkey were obtained from the Technology Development Zones Performance Index reports published by the Ministry of Industry and Technology of the Republic of Turkey. For intellectual property statistics, the official patent and trademark registration databases of TÜRKPATENT and Qazpatent were used; for international comparisons, the open data platforms of the World Intellectual Property Organization (WIPO) and the World Bank were utilised. All the compiled and analysed datasets have been obtained from publicly available sources and can be provided by the respective author upon request, in accordance with the principle of transparency.

## Declaration of competing interest

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the study reported in this paper.

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