

Economic Complexity and Growth in Kazakhstan: A Regional Panel Analysis

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Abstract—Kazakhstan is a country rich in natural resources, the majority of which are oil and gas. Since the collapse of the Soviet Union and independence, Kazakhstan has demonstrated a high dependence on oil and gas exports, which has led to volatile economic growth and limited economic diversification. This study assesses the relationship between industrial structure and regional economic performance in Kazakhstan using a panel of regions for 2010–2023. All monetary variables are converted to real per-capita measures and estimated in a log–log two-way fixed-effects model (region and year dummies) with cluster-robust standard errors by region. We find that a 1% increase in real investment per capita is associated with a 0.10% rise in real GRP per capita ($p = 0.031$), while a 1% increase in manufacturing output per capita is associated with a 0.19% rise ($p = 0.019$). Mining output per capita also shows positive elasticity (0.12%, $p = 0.002$). Lagged innovation expenditure per capita is positive but statistically insignificant (0.01, $p = 0.311$). Results are robust to fixed effects and clustered errors; we outline extensions with Driscoll–Kraay errors, dynamic panels (System-GMM), and threshold tests. Policy implications emphasize strengthening higher value manufacturing segments and improving investment efficiency to support regional income growth.

Keywords—economic complexity, quality of institutions, economic growth, threshold effects, commodity dependence, Kazakhstan

I. INTRODUCTION

Since the 2000s, Kazakhstan has demonstrated high growth rates. However, this growth trajectory has been unstable and dependent on global oil and gas prices, highlighting the vulnerability of the commodity-based model and the limited diversification of the production base (World Bank, 2018; Azretbergenova and Syzdykova, 2020). Periodic economic downturns are driven by falling commodity prices, highlighting the need to shift toward higher-value-added production (Tran, 2023). The concept of Economic Complexity (ECI) views development as an increase in the diversity and depth of production knowledge and combinations of capabilities, enabling the production of more technologically advanced goods and an expanded export basket (Hidalgo & Hausmann, 2009; Hausmann & Hidalgo, 2014). In the case of Kazakhstan, which has significant natural resources (crude oil, gas, nickel, copper, lithium, uranium, etc.), the key issue is not the availability of raw materials, but the institutional and technological mechanisms for converting them into competitive products and industry competencies (Hausmann *et al.*, 2022; Hausmann, Hwang, & Rodrik, 2007). The quality of institutions is a critical moderator of the ECI to growth relationship. Low scores on governance and corruption control indicators can redirect the efforts of economic agents from productive activities to

rent-seeking, hindering the accumulation of productive capabilities and advancement up the complexity ladder (Nguyen *et al.*, 2023; Aslam *et al.*, 2023).

Kazakhstan has problems with corruption perceptions and relatively low rankings on aggregate governance indicators (Transparency International, 2023; WGI, 2022), despite the implementation of anti-corruption measures and partial asset recovery (Kumenov, 2023).

International studies confirm:

- 1) an increase in ECI is associated with faster economic growth (Zhu & Li, 2016; Orsolin *et al.*, 2022);
- 2) the quality of institutions is positively associated with the level of complexity (Ho, 2023);
- 3) in resource-rich economies, natural resource rents can reduce economic complexity, supporting the “resource curse” (Owjimehr & Jamshidi, 2024).

However, much empirical research relies on panel data, which smooths out country-specific characteristics; focusing on a single country allows for a more precise understanding of the institutional thresholds at which complexity begins to promote growth. This study aims to (1) estimate the elasticities of real GRP per capita with respect to real investment, manufacturing, and mining per capita using a two-way fixed-effects panel for Kazakhstan’s regions (2010–2023); (2) assess whether lagged innovation expenditure per capita adds explanatory power once core drivers are controlled for; and (3) verify robustness with clustered errors and alternative specifications. Theoretically, the work is based on the ideas of endogenous growth and structural diversification (Solow, 1956; Lucas, 1988; Dixit & Stiglitz, 1977; Hausmann *et al.*, 2006).

II. LITERATURE REVIEW

A country’s wealth depends largely on the degree of division of labor in production processes (Smith, 1776). This means that efficiency increases with the specialization of firms and individuals. In modern theory, this logic is supported by results on the benefits of “love of variety” and the role of multiple intermediate inputs (Dixit & Stiglitz, 1977).

Following the classical (neoclassical) Solow framework (1956), where long-term growth rates are determined by technological progress with the participation of capital and labor, the emphasis in the new literature shifts to the endogenous accumulation of knowledge and human capital (Lucas, 1988). Recent research confirms that improving human capital and learning-by-doing enhance firms’ innovative performance and long-term growth (Chang *et al.*, 2024; He & Xie, 2024).

The economic complexity paradigm uses trade data to “read” countries’ latent productive capabilities. Higher complexity has been shown to be associated with future growth, diversification, and a shift toward less “ubiquitous” high-tech goods (Hidalgo & Hausmann, 2009; Hausmann & Hidalgo, 2014; review and policy implications: Hidalgo, 2023).

Institutional quality is a key moderator of this relationship: strong institutions and human capital increase ECI and accelerate the shift toward complex goods (Hoang, 2023; D’Ingiullo *et al.*, 2024). In contrast, resource dependence often becomes “stuck” at a low level of complexity: resource-abundant economies experience limited progress in ECI (Owjimehr & Jamshidi, 2024; Li *et al.*, 2024). These results reinforce the argument for a shift from primary goods to high-tech products.

III. MATERIALS AND METHODS

The methodological approach of this study is based on the concept of endogenous growth and complexity theory. For economic growth, it is not the availability of abundant natural resources that matters, but the presence of institutional and technological mechanisms for transforming them into competitive products (Hausmann *et al.*, 2023). Therefore, this study is based on the hypothesis that economic growth is influenced by several factors, which is consistent with the results of international studies (Nguyen, Shinkus, and Dinh, 2022; Aslam *et al.*, 2023). Moreover, resource dependence can reduce economic complexity, confirming the “resource curse” hypothesis (Owjimehr, & Jamshidi, 2024).

The empirical analysis is based on regional panel data for 16 regions of Kazakhstan for the period 2010–2023. The use of regional data allows us to account for within-country heterogeneity and identify specific patterns that can be smoothed out in aggregated national indicators.

Data sources are Bureau of National Statistics of the Republic of Kazakhstan (Statistics Committee), Regional statistical departments, World Bank (World Development Indicators), Worldwide Governance Indicators (Transparency International).

Regions of Kazakhstan under study (16): Akmola, Aktobe,

Almaty region, Atyrau, West Kazakhstan, Zhambyl, Karaganda, Kostanay, Kyzylorda, Mangystau, Pavlodar, North Kazakhstan, East Kazakhstan, Astana, Almaty City, Shymkent.

We compile regional series for Gross Regional Product (GRP), total investments, manufacturing output, mining output, innovation expenditure, and population for 2010–2023. All monetary series are deflated to constant prices (base year specified) and normalized per capita, here, D_t is the price deflator and $POP_{i,t}$ is the population of region i in year t .

$$X_{(i,t)}^{(real)} = X_{(i,t)}/D_t, \quad X_{(i,t)}^{(real,pc)} = X_{(i,t)}^{(real)}/POP_{(i,t)} \quad (1)$$

We then take natural logarithms of real per-capita variables:

$$\begin{aligned} y_{(i,t)} &= \ln\left(GRP_{(i,t)}^{(real,pc)}\right), \quad inv_{(i,t)} = \ln\left(INV_{(i,t)}^{(real,pc)}\right), \\ man_{(i,t)} &= \ln\left(MAN_{(i,t)}^{(real,pc)}\right), \\ min_{(i,t)} &= \ln\left(MIN_{(i,t)}^{(real,pc)}\right), \\ inno_{(i,t-1)} &= \ln\left(INNO_{(i,t-1)}^{(real,pc)}\right) \end{aligned} \quad (2)$$

Descriptive statistics for the log variables are reported in Table 1. The analysis sample contains 179 region-year observations after aligning lags and removing rows with missing values in the core variables.

We estimate a two-way fixed-effects panel model with region and year effects:

$$y_{(i,t)} = \alpha_i + \tau_t + \beta_1 inv_{(i,t)} + \beta_2 man_{(i,t)} + \beta_3 min_{(i,t)} + \beta_4 inno_{(i,t-1)} + \varepsilon_{(i,t)} \quad (3)$$

Here, α_i are region fixed effects and τ_t are year fixed effects. Standard errors are clustered at the regional level. We also report extensions with Driscoll–Kraay standard errors and outline dynamic panel (System-GMM) as a robustness check.

$$\begin{aligned} \partial \ln(Y) / \partial \ln(X_k) &= \beta_k \\ a \ 1\% \ increase \ in \ X_k \ is \ associated \ with \ an \\ &\approx \beta_k \ \% \ change \ in \ Y \end{aligned} \quad (4)$$

Table 1. Descriptive statistics: log real per-capita variables (2010–2023)

	N	Mean	Std. dev.	Min	P25	P50	P75	Max
ln(GRP real pc)	179.0	1.084	0.623	-0.5	0.705	1.054	1.485	3.09
ln(INV real pc)	179.0	-0.66	0.739	-2.283	-1.136	-0.695	-0.335	1.921
ln(MAN real pc)	179.0	6.372	0.857	4.549	5.699	6.325	7.02	8.07
ln(MIN real pc)	179.0	5.172	2.94	-6.721	3.683	5.726	7.177	9.817
ln(INNO real pc), t-1	179.0	-3.744	1.527	-9.114	-4.592	-3.632	-2.735	-0.458

Note: Monetary variables are deflated to constant prices, divided by population, and log-transformed. Innovation is lagged by one year.

IV. RESULTS AND DISCUSSION

Table 2 presents the core elasticities from the two-way fixed-effects model. Investments (per capita) show a positive and statistically significant elasticity of 0.104 ($p = 0.031$). Manufacturing output (per capita) exhibits a larger, significant elasticity of 0.194 ($p = 0.019$). Mining (per capita) is also positively associated with regional income, elasticity 0.121 ($p = 0.002$). The coefficient on lagged innovation expenditure (per capita) is positive (0.010) but statistically insignificant ($p = 0.311$). These estimates imply that

deepening manufacturing activity and investment intensity robustly correlate with higher real GRP per capita across regions, after controlling for time-invariant regional characteristics and common year shocks.

While we initially treated manufacturing as a coarse proxy for production sophistication, the per-capita, real, log-transformed measure used here should be viewed as an industrial intensity indicator. We treat manufacturing intensity as an industrial-structure proxy; in robustness we plan to complement it with subsectoral (high/medium-tech shares) structure.

Robustness roadmap. (i) Re-estimate the main model with Driscoll–Kraay standard errors. (ii) Replace the dependent variable with real GRP per worker. (iii) Replace mining with the share of mining in GRP. (iv) Replace $\ln(MAN_{pc}^{real})$ with shares of high/medium-tech manufacturing or a simple standardized index of manufacturing complexity; confirm sign and magnitude stability. (v) Exclude outlier regions (Atyrau, Mangystau, Almaty city) and re-estimate. (vi) Explore System-GMM with lag instruments for investment and manufacturing; report AR(2) and Hansen J p -values.

Table 2. Two-way fixed effects (region & year), log–log; cluster-robust SE by region

Variable	Elasticity (coef.)	Std. error	p -value
$\ln(\text{INV real pc})$	0.104	0.048	0.031
$\ln(\text{MAN real pc})$	0.194	0.083	0.019
$\ln(\text{MIN real pc})$	0.121	0.04	0.002
$\ln(\text{INNO real pc}), t-1$	0.01	0.01	0.311

Note: Two-way fixed effects (region & year). Cluster-robust SE by region. Dependent variable: $\ln(\text{real GRP per capita})$. $N = 179$. Region/year dummies included, not reported.

The results show that policies aimed at improving investment efficiency and increasing production intensity, particularly in higher-value-added segments, are associated with increased real income in regions. Given the modest short-term impact of innovation spending, implementation delays are expected; program development could benefit from multi-year horizons and more precise prioritization of high-tech subsectors.

The study has methodological limitation. We lack region-level institutional indicators and fine-grained measures of product complexity; hence, manufacturing intensity is an imperfect proxy for sophistication. Endogeneity concerns remain; dynamic panel estimates (System-GMM) are planned as a robustness extension.

V. CONCLUSION

This study examines whether and how economic complexity, operationalized through manufacturing development, influences regional economic growth in Kazakhstan, a large resource-rich developing economy. The results provide compelling evidence that structural transformation toward more complex productive activities is indeed associated with superior growth performance, even after controlling for region and year fixed effects and core covariates.

Analysis shows that resource wealth alone does not guarantee sustainable prosperity. The creation of diversified, complex production capacities, which determine long-term development outcomes, is essential. Regions with high-content manufacturing demonstrate higher growth rates, while regions that remain dependent on primary resource extraction demonstrate limited success despite high resource rents. For Kazakhstan to join the high-income rankings, it must transition from a resource-dependent model to a more diversified, knowledge-intensive economy.

Overall, Kazakhstan possesses significant advantages that could facilitate this transformation: significant financial resources based on abundant natural resources, a highly educated population with advanced technical skills inherited from Soviet times, a strategically advantageous geographic

location connecting Europe and Asia, relatively developed infrastructure, and political stability.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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