

REGIONAL GROWTH AND ENVIRONMENTAL POLICY IN KAZAKHSTAN'S CIRCULAR ECONOMY TRANSITION

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ABSTRACT

This study examines the determinants of regional economic performance in Kazakhstan in the context of its transition toward a circular economy. It focuses on the combined effects of environmental protection expenditure, small and medium-sized enterprise activity, and fixed capital investment. Using panel data for 16 regions from 2005 to 2024, the study applies two-way fixed effects models and a dynamic panel approach based on the Anderson-Hsiao estimator to account for growth persistence and potential endogeneity. The results show that the growth effects of environmental expenditure, SME activity, and fixed capital investment vary across model specifications. Environmental protection expenditure is positively associated with regional growth in static models, but this effect becomes insignificant once endogeneity is addressed. SME activity shows a negative association in static specifications, but a positive effect in dynamic IV estimates. Fixed capital investment is positively significant in static models, although its effect weakens in dynamic specifications. Overall, the findings suggest that institutional quality, regional heterogeneity, and policy coordination shape the economic outcomes of sustainability-oriented policies. By integrating environmental, entrepreneurial, and investment-related factors within a single empirical framework, the study offers new evidence on the context-dependent nature of regional growth in a transition economy and provides policy insights for designing regionally differentiated development strategies.

Keywords: *Circular economy, Environmental policy, Institutional capacity, Regional economic growth, SMEs, Fixed capital investment, Kazakhstan*

1. INTRODUCTION

The transition towards sustainable development has become one of the defining challenges in contemporary economic policy and research. In response, the circular economy has gained prominence as an alternative development model that seeks to reconcile economic progress with environmental sustainability through greater resource efficiency, waste reduction, and the regeneration of natural capital (Geissdoerfer et al., 2017; D'Amato et al., 2017; Alsharaideh et al., 2026). However, the economic consequences of environmental policies remain contested. While some studies argue that environmental regulation promotes innovation and long-term productivity,

others emphasise the costs associated with regulatory compliance and structural adjustment. Recent evidence suggests that the effectiveness of environmental policies depends largely on sectoral composition, technological capabilities, and institutional conditions (Benatti et al., 2024; Liu et al., 2023). Similarly, the growth effects of investment are not uniform across regions (Nguyen, 2026). Differences in governance quality, economic structure, and institutional capacity influence the extent to which both public and private investment translate into economic performance (Destefanis & Di Giacinto, 2025; Zhanseitov et al., 2020).

Small and medium-sized enterprises (SMEs) constitute another important determinant of regional development. Although SMEs are widely recognised for fostering entrepreneurship, innovation, and employment, their contribution to economic growth depends on the quality of the institutional environment and the availability of supportive entrepreneurial ecosystems (Keffala, 2025; Potter et al., 2025; Drakul, 2025). In regions characterised by institutional weaknesses, SME expansion may have limited productivity effects and may not generate sustained economic growth. Despite the growing body of research, important gaps remain. Existing studies typically examine environmental expenditure, investment, or SME activity in isolation, whereas relatively few consider these factors simultaneously within a dynamic analytical framework. Furthermore, evidence from transition economies remains limited, particularly regarding the interaction between circular economy policies and traditional drivers of regional growth. These shortcomings are especially relevant in Kazakhstan, where substantial regional disparities in economic structure, institutional capacity, and environmental governance may lead to heterogeneous development outcomes. Understanding these interactions requires an integrated framework that jointly evaluates environmental, entrepreneurial, and investment-related determinants of regional economic performance.

To address this gap, this study develops a comprehensive empirical framework for analysing regional economic growth during Kazakhstan's transition towards a circular economy. The circular economy dimension is captured through environmental protection expenditure, which serves as a proxy for the intensity of regional sustainability policies (Akilzhanova et al., 2025). Although this indicator does not fully reflect the multidimensional nature of the circular economy, it represents one of the few consistently available regional measures over a sufficiently long period. Similar proxy-based approaches have been adopted in previous studies where direct indicators of circular economy implementation, such as recycling rates, resource efficiency, material reuse, and waste recovery, are unavailable (Fan et al., 2022; Mukhiyayeva et al., 2025). Environmental protection expenditure is widely recognised as an important policy instrument supporting pollution mitigation, resource conservation, and sustainable regional development (Geissdoerfer et al., 2017; Hysa et al., 2020).

The empirical analysis investigates the joint effects of environmental protection expenditure, SME activity, and fixed capital investment on regional economic growth using panel data for 16 regions of Kazakhstan over the period 2005–2024. The baseline specification employs a two-way fixed effects model to control for unobserved regional heterogeneity and common time effects, while a dynamic Anderson-Hsiao estimator is used to account for growth persistence, potential endogeneity, and dynamic panel bias.

This study makes three principal contributions. First, it demonstrates that the growth effects of environmental protection expenditure vary across regions and depend on underlying structural and institutional characteristics. Second, it shows that the contribution of SMEs to regional growth is conditional upon the quality of the institutional environment. Third, by combining static and dynamic panel estimation techniques, the study provides new evidence on the determinants of regional growth during Kazakhstan's transition towards a circular economy.

Overall, the findings extend the literature by integrating environmental expenditure, entrepre-

neurial activity, and investment within a unified empirical framework and by providing new evidence on regional growth dynamics in a transition economy. The remainder of the paper is organised as follows. Section 2 reviews the relevant literature, Section 3 describes the data and methodology, Section 4 presents the empirical findings, Section 5 discusses the results, and the final section concludes with policy implications and directions for future research.

2. LITERATURE REVIEW

2. 1. ENVIRONMENTAL PROTECTION EXPENDITURE AND ECONOMIC GROWTH

The relationship between environmental protection expenditure and economic performance remains inconclusive. While environmental investments may enhance productivity by encouraging technological innovation and resource efficiency, they may also impose short-term compliance costs that constrain economic activity. Consequently, the growth effects of environmental policies depend on broader institutional, technological, and structural conditions.

Recent evidence supports this conditional relationship. [Fan et al. \(2022\)](#) show that environmental protection expenditure in China improves environmental quality and indirectly enhances productivity through institutional channels. Similarly, [Caglar and Yavuz \(2023\)](#) find that environmental expenditure contributes to sustainable development when complemented by renewable energy policies. [Sun et al. \(2024\)](#) identify significant spatial spillovers in the effectiveness of environmental policies, while [Akdag et al. \(2025\)](#) demonstrate that environmental fiscal instruments generate heterogeneous outcomes across countries. These findings are broadly consistent with the Porter Hypothesis ([Porter & van der Linde, 1995](#)), which argues that well-designed environmental regulation can stimulate innovation, although the resulting productivity gains depend on firms' and regions' absorptive capacity.

2. 2. ENVIRONMENTAL POLICY AND REGIONAL DEVELOPMENT IN KAZAKHSTAN

Empirical evidence on Kazakhstan remains relatively scarce. [Mukhiyayeva et al. \(2025\)](#) report that sustainability-oriented policies improve resource-use efficiency within a circular economy framework, although their effectiveness is constrained by institutional quality and the country's dependence on natural resources. Likewise, [Yessengeldin et al. \(2019\)](#) argue that legal uncertainty, weak regulatory enforcement, and governance challenges reduce the efficiency of environmental policy implementation. These findings suggest that environmental expenditure alone is unlikely to generate sustained economic growth without complementary institutional reforms and economic diversification.

2. 3. CIRCULAR ECONOMY AND SUSTAINABLE GROWTH

The circular economy has emerged as an important framework linking environmental sustainability with long-term economic development. Rather than focusing solely on waste reduction, it promotes resource efficiency, innovation, and sustainable production systems. [Hysa et al. \(2020\)](#) argue that circular economy strategies generate stronger economic outcomes when environmental, social, and economic objectives are pursued simultaneously. Similarly, [Georgescu et al. \(2025\)](#) emphasize that policy coordination and technological innovation are essential for successful circular economy implementation. However, transition economies often face structural constraints, including resource dependence, limited technological capabilities, and institutional weaknesses that may reduce the effectiveness of these strategies. Evidence from Kazakhstan further indicates that renewable energy investments can strengthen regional development by improving energy accessibility and supporting agricultural productivity ([Bolyssov et al., 2019](#)).

2. 4. INVESTMENT AND ECONOMIC GROWTH

Investment in fixed capital remains one of the principal drivers of economic growth. Nevertheless, its effectiveness depends on the institutional environment, technological capacity, and innovation performance. [Shakeyev et al. \(2023\)](#) demonstrate that fixed capital investment and research and development expenditure enhance productivity in Kazakhstan when accompanied by sufficient innovation capacity. Likewise, [Mitrofanova et al. \(2025\)](#) show that investment contributes to regional development primarily when integrated with innovation processes. These findings are consistent with the institutional theory of economic growth ([Acemoglu et al., 2005](#)), which suggests that weak institutions reduce investment efficiency through rent-seeking behaviour and resource misallocation.

2. 5. SMES, ENTREPRENEURSHIP, AND ECONOMIC GROWTH

The contribution of SMEs to economic growth remains a subject of debate. [Baumol \(1990\)](#) argues that the economic benefits of entrepreneurship depend not only on its scale but also on whether entrepreneurial activity is directed toward productive or unproductive purposes. Similarly, [Fritsch and Mueller \(2004\)](#) show that new firm formation may generate temporary adjustment costs before contributing to long-term growth. More recent studies confirm that the relationship between SME activity and economic performance is highly dependent on institutional quality, financial development, and the broader entrepreneurial ecosystem ([Gamidullaeva et al., 2020](#); [Batrancea et al., 2022](#); [Batrancea, 2022](#)).

2. 6. DYNAMIC GROWTH MODELS

Economic growth exhibits considerable persistence over time, making dynamic panel models particularly appropriate for empirical analysis. [Nickell \(1981\)](#) demonstrates that conventional fixed-effects estimators become biased when lagged dependent variables are included, whereas [Anderson and Hsiao \(1982\)](#) propose an instrumental-variable estimator that addresses this problem. Recent empirical studies continue to support the importance of growth persistence, suggesting that the effects of economic policies often materialize gradually rather than immediately ([Wen et al., 2022](#); [Karagiannis & Paleologou, 2025](#)).

2. 7. REGIONAL HETEROGENEITY

Regional disparities play a significant role in shaping economic performance, particularly in geographically large and economically diverse countries. Differences in industrial structure, institutional quality, and resource endowments lead to heterogeneous growth trajectories across regions. [Zhao et al. \(2024\)](#) demonstrate that urban-rural disparities substantially influence regional development, while [Fan et al. \(2022\)](#) and [Sun et al. \(2024\)](#) highlight the importance of spatial spillovers in both environmental policy effectiveness and regional economic performance.

2. 8. LITERATURE SYNTHESIS AND RESEARCH GAP

The existing literature indicates that the relationships between environmental protection expenditure, SME activity, investment, and economic growth are inherently context dependent. Environmental expenditure may enhance productivity through innovation and institutional improvement, yet its effectiveness varies according to governance quality, technological capability, and regional characteristics. Likewise, the economic contribution of SMEs depends on the institutional environment, while the returns to fixed capital investment are shaped by innovation capacity and economic structure.

Despite these advances, several important gaps remain. Most previous studies examine environmental policy, entrepreneurship, or investment separately, with relatively few analysing

their joint effects within a unified empirical framework. Moreover, evidence from transition economies remains limited, particularly at the regional level where substantial institutional and structural differences exist.

To address these gaps, this study develops an integrated empirical framework that jointly examines environmental protection expenditure, SME activity, and fixed capital investment while accounting for regional heterogeneity, growth persistence, and potential endogeneity. By focusing on Kazakhstan's regions during the country's transition towards a circular economy, the study provides new evidence on the determinants of regional economic performance in a transition economy.

3. METHODOLOGY

3.1. DATA AND EMPIRICAL DESIGN

The analysis is based on a balanced panel comprising 16 regions of Kazakhstan over the period 2005-2024, resulting in 320 region-year observations. The panel captures substantial regional variation in economic structure, institutional capacity, and environmental policy implementation, while the time dimension reflects both short-term fluctuations and medium-term developments associated with the transition towards a circular economy.

The dependent variable is the logarithm of gross regional product (GRP) per capita, which improves cross-regional comparability, mitigates heteroskedasticity, and allows estimated coefficients to be interpreted as elasticities (Wooldridge, 2010). The main explanatory variables include environmental protection expenditure, fixed capital investment, and the number of small and medium-sized enterprises (SMEs). Environmental protection expenditure serves as a proxy for the policy dimension of the circular economy transition, while fixed capital investment captures capital accumulation and SMEs reflect entrepreneurial activity and business development. Average wages are included to account for labour productivity and income levels, with employment and the unemployment rate incorporated as additional control variables. Population was initially considered but excluded from the final specifications because of multicollinearity and its limited explanatory contribution.

Although the circular economy is a multidimensional concept encompassing resource efficiency, recycling, waste recovery, and sustainable production, consistent regional indicators covering these dimensions are unavailable for Kazakhstan throughout the study period. Consequently, environmental protection expenditure represents the most reliable and policy-relevant proxy for sustainability-oriented regional intervention. Likewise, in the absence of comprehensive regional circular economy or sustainability indices, GRP per capita is employed as a consistent measure of regional economic performance during Kazakhstan's transition towards a circular economy.

3.2. BASELINE SPECIFICATION: TWO-WAY FIXED EFFECTS MODEL

The baseline is a two-way fixed effects (TWFE) model:

$$y_{it} = \beta X_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where y_{it} is log GRP per capita in region i at time t , X_{it} is a vector of explanatory variables, α_i are region-specific fixed effects, and γ_t are time-specific effects.

Identification is based on within-region variation. Regional fixed effects absorb time-invariant characteristics, such as geography, institutional legacy, and long-standing economic specialisation, while time fixed effects control for common macroeconomic shocks and national policy changes (Wooldridge, 2010; Baltagi, 2005).

The validity of the two-way fixed effects specification rests on the assumption that unobserved regional factors affecting economic performance are largely time-invariant and can therefore be captured by regional fixed effects. Time fixed effects further account for nationwide shocks, policy reforms, and macroeconomic developments that affect all regions simultaneously. As a result, the model identifies effects from changes within regions over time rather than from cross-sectional differences between regions. This approach helps reduce omitted variable bias arising from persistent regional characteristics that are difficult to observe directly.

Panel unit root tests based on Maddala and Wu (1999) and Choi (2001) reject the null hypothesis of a unit root, supporting the use of the variables in levels.

3. 3. ROBUST INFERENCE: DRISCOLL-KRAAY STANDARD ERRORS

3. 3. 1. ESTIMATION METHOD AND STANDARD ERRORS

Standard errors are estimated using the Driscoll-Kraay procedure, which is robust to heteroskedasticity, serial correlation, and cross-sectional dependence (Driscoll & Kraay, 1998; Pesaran, 2004). Given the structure of the panel, with a relatively small cross-section ($N = 16$) and a longer time dimension ($T = 20$), this estimator is preferred to conventional cluster-robust alternatives, which generally perform better with a larger number of cross-sectional units and rely on stronger assumptions about the error structure.

3. 3. 2. MODEL SPECIFICATION AND ROBUSTNESS CHECKS

Several model specifications are estimated to assess the stability of the baseline results. Extended models include digitalisation, measured by internet usage, and innovation activity to examine whether the main relationships remain robust when broader explanatory variables are introduced. Since these variables are available only for selected regions and years, the effective sample is reduced to 224 and 192 observations, respectively. These reduced-sample specifications also serve as checks for potential sample selection effects.

Additional specifications exclude wages to assess potential multicollinearity and to isolate the independent effects of capital accumulation and institutional variables, as wages may partly capture overlapping productivity dynamics.

$$y_{it} = \rho y_{i,t-1} + \beta X_{it} + \alpha_i + \gamma_t + \varepsilon_{it} \quad (2)$$

This captures path dependence and allows short-run and longer-run effects to be distinguished. Including a lagged dependent variable in a fixed effects model introduces Nickell bias (Nickell, 1981), which is addressed in the next subsection.

3. 4. ENDOGENEITY AND THE CHOICE AGAINST GMM

Generalized Method of Moments estimators (Arellano & Bond, 1991; Blundell & Bond, 1998) are a common solution to dynamic panel bias but are known to perform poorly when N is small, as instrument proliferation can lead to weak identification (Roodman, 2009). In this dataset, system GMM produced excessively high Hansen test p-values, indicating instrument proliferation and a lack of validity. Given , GMM estimates are not considered reliable, and the analysis instead uses the Anderson–Hsiao estimator.

3. 5. ANDERSON–HSIAO ESTIMATOR

The Anderson-Hsiao (AH) instrumental variable estimator (Anderson & Hsiao, 1982) first-differences the model:

$$\Delta y_{it} = \rho \Delta y_{i,t-1} + \beta \Delta X_{it} + \Delta \varepsilon_{it} \quad (3)$$

and instruments the lagged differenced dependent variable with its second lag. AH is consistent under standard assumptions and remains stable in small- settings (Hsiao, 2014), avoiding the instrument proliferation that constrains GMM in this dataset.

Diagnostic tests are consistent with the presence of endogeneity and with adequate instrument strength, supporting the use of AH as a robustness check on the dynamic estimates.

3. 6. SPATIAL DEPENDENCE AND MODEL SELECTION

Moran's I is computed for both the raw data and the residuals of the TWFE model. The results indicate weak spatial dependence in the raw data, but no statistically significant spatial autocorrelation in the model residuals. This suggests that the observed spatial patterns are mainly driven by structural regional heterogeneity, which is absorbed by the fixed effects, rather than by spatial spillovers.

Accordingly, spatial autoregressive (SAR) and spatial error (SEM) models are not estimated, and the TWFE model is retained as the primary specification. The spatial diagnostics are reported as a robustness check rather than as a structural test, since fixed effects may absorb part of the underlying spatial dependence.

This decision is also supported by methodological considerations. Spatial panel models require the prior specification of a spatial weight's matrix defining the relevant channel of inter-regional interaction, such as geographic proximity, economic complementarity, or institutional linkages. In the Kazakhstani regional context, there is no clear theoretical consensus on the appropriate spatial structure. Given the small cross-sectional dimension ($N = 16$) and the absence of significant residual spatial autocorrelation, the additional complexity and parameter uncertainty introduced by spatial modelling are not supported by the data.

3. 7. IDENTIFICATION STRATEGY AND LIMITATIONS

Identification is based on within-region variation over time. The two-way fixed effects specification controls for time-invariant regional heterogeneity and common time shocks, thereby reducing omitted variable bias (Wooldridge, 2010; Baltagi, 2005). This approach assumes that, conditional on fixed effects and observed covariates, the remaining variation in the explanatory variables is exogenous.

However, strict exogeneity cannot be fully guaranteed. Reverse causality may arise if higher GRP per capita increases environmental expenditure or wages, while measurement error in regional indicators, particularly SME activity and environmental expenditure, may lead to attenuation bias. To address these concerns, the dynamic specification accounts for growth persistence, while the Anderson-Hsiao estimator uses internal instruments to address the endogeneity of the lagged dependent variable (Nickell, 1981; Anderson & Hsiao, 1982; Hsiao, 2014).

Accordingly, the results should be interpreted as conditional associations rather than strictly causal effects. The small cross-sectional dimension of the panel ($N = 16$) limits the feasibility of high-dimensional GMM estimators and external instrumental-variable strategies. In addition, the absence of significant residual spatial autocorrelation suggests that the analysis primarily captures internal regional dynamics rather than interregional spillover effects.

4. RESULTS

Descriptive statistics for the variables used in the empirical analysis are presented in Table 1. The dataset covers 16 regions over the period 2005–2024, resulting in 320 observations. Most variables are expressed in natural logarithms to ensure comparability and reduce scale differences across regions.

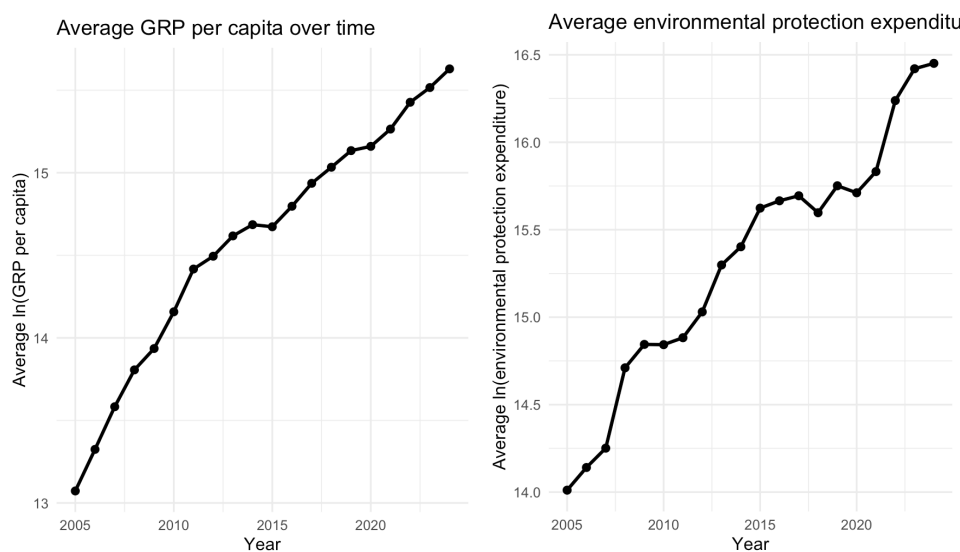
Table 1. Descriptive statistics of variables

Variable	Mean	SD	Min	Max	Obs
ln_food_output	17.75	1.14	14.84	20.03	320
ln_env_protection_exp	15.32	1.42	11.36	17.88	320
ln_fixed_capital_investment	12.78	0.92	10.01	15.28	320
ln_employment	13.07	0.46	12.05	14.05	320
ln_population	13.71	0.43	12.80	15.03	320
ln_grp_pc	14.58	0.94	12.00	16.91	320
ln_number_of_smes	10.89	0.68	9.53	12.82	320
ln_avg_wage	11.65	0.75	10.02	13.36	320
unemployment_rate	5.61	1.19	4.10	9.80	320

Source: Authors' calculations based on data from the Bureau of National Statistics of the Republic of Kazakhstan

Table 1 reports summary statistics for all variables across the full sample of 320 region-year observations. GRP per capita exhibits substantial cross-regional variation, while environmental protection expenditure also displays considerable dispersion, indicating differences in the intensity of regional environmental policy. Fixed capital investment and average wages show moderate variation, whereas employment, population, SMEs, and the unemployment rate remain comparatively stable across regions. Overall, the observed variation provides sufficient within-region and cross-sectional heterogeneity to support two-way fixed effects estimation.

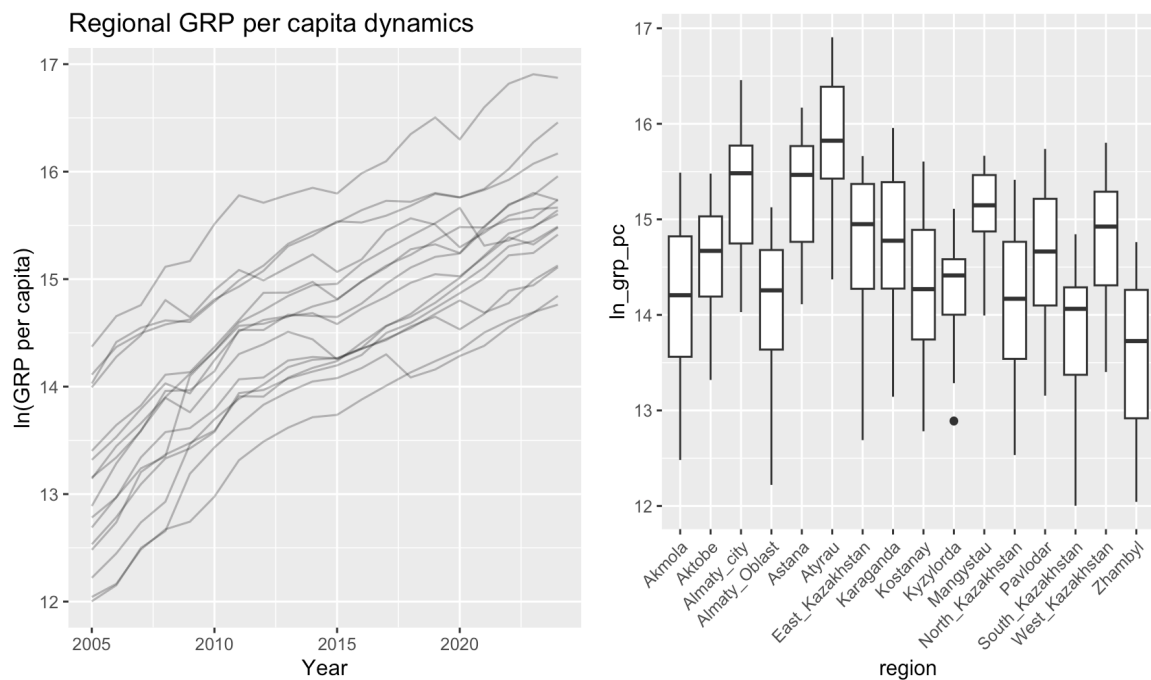
Figure 1. Average GRP per capita (left) and environmental protection expenditure (right) over time



Source: Authors' Calculations

Both variables exhibit sustained upward trajectories across the full study period from 2005 to 2024. The parallel growth in GRP per capita and environmental protection expenditure provides preliminary visual evidence of a positive association between regional income levels and environmental policy intensity, though the presence of regional heterogeneity in growth rates cautions against treating this as a uniform relationship. These trends motivate formal econometric analysis of the conditional relationship between the two variables.

Figure 2. Regional dynamics and distribution of GRP per capita (left: regional trends over time; right: distribution across regions)



Source: Authors' Calculations

The figure indicates a general upward trajectory in GRP per capita across regions, accompanied by widening dispersion over time. This pattern points to increasing regional heterogeneity and potential divergence in economic performance, underscoring the importance of controlling for regional effects in the empirical analysis.

4. 1. PANEL UNIT ROOT TESTS

Table 2. Unit Root Tests

Variable	Test	Statistic	p-value	Conclusion
ln(GRP per capita)	Maddala–Wu	53.921	0.009	Stationary
ln(GRP per capita)	Choi Pm	2.740	0.003	Stationary
Δ ln(GRP per capita)	Maddala–Wu	146.68	<0.001	Strongly stationary

Source: Authors' Calculations

Before estimation, panel unit root tests are conducted to ensure that the dependent variable is stationary and that the regression results are not spurious. Two complementary procedures are applied to the log-transformed GRP per capita series: the [Maddala and Wu \(1999\)](#) chi-squared test, which combines p-values from individual augmented Dickey-Fuller regressions, and the [Choi \(2001\)](#) Pm statistic, which provides an asymptotically normal alternative under the same null hypothesis of a unit root.

Both tests reject the null hypothesis at conventional significance levels. For ln (GRP per capita) in levels, the Maddala-Wu statistic is 53.921 ($p = 0.009$), while the Choi Pm statistic is 2.740 ($p = 0.003$). These results confirm that the series is stationary in levels, eliminating the need to first-difference the dependent variable before estimation.

As an additional check, the first-differenced series is also tested and found to be strongly stationary, with the Maddala-Wu statistic increasing to 146.68 ($p < 0.001$). Overall, the results indicate that spurious regression is not a concern and support the use of both the two-way fixed effects and Anderson-Hsiao specifications.

4. 2. CORRELATION MATRIX

Table 3. Correlation matrix

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) ln_food_output	1.00						
(2) ln_env_protection_exp	0.01	1.00					
(3) ln_fixed_capital_inv	0.20	0.54	1.00				
(4) ln_employment	0.56	-0.05	0.13	1.00			
(5) ln_grp_pc	0.16	0.57	0.87	-0.13	1.00		
(6) ln_number_of_smes	0.67	0.13	0.56	0.74	0.35	1.00	
(7) unemployment_rate	-0.49	-0.46	-0.59	-0.23	-0.66	-0.48	1.00

Source: Authors' Calculations

Table 3 presents the pairwise Pearson correlation coefficients for the variables used in the empirical analysis. The strongest bivariate relationship is observed between GRP per capita and fixed capital investment ($r = 0.87$), suggesting that economically stronger regions tend to attract higher capital inflows and maintain greater levels of physical investment.

Environmental protection expenditure is moderately and positively correlated with GRP per capita ($r = 0.57$) and fixed capital investment ($r = 0.54$). This indicates that regions with stronger economic capacity allocate more resources to environmental policy, which is consistent with the literature on income-related environmental spending.

Among the structural variables, employment and SME density show a strong positive correlation ($r = 0.74$), suggesting that labour absorption and business activity tend to develop together across Kazakhstan's regions. Food output is also positively correlated with employment ($r = 0.56$) and SME density ($r = 0.67$), reflecting the labour-intensive and enterprise-based nature of regional food production.

The unemployment rate is negatively correlated with almost all economic indicators, particularly GRP per capita ($r = -0.66$), fixed capital investment ($r = -0.59$), and environmental protection expenditure ($r = -0.46$). This pattern is consistent with standard macroeconomic expectations, where weaker labour market conditions are associated with lower economic and institutional capacity.

Although some correlations are relatively high, particularly between GRP per capita and fixed capital investment, they do not indicate severe multicollinearity. Moreover, the two-way fixed effects specification reduces the risk that cross-sectional correlations in the raw data distort the panel regression estimates.

Table 4. Variance Inflation Factors (VIF)

Variable	VIF
ln_env_protection_exp	1.67
ln_fixed_capital_investment	4.91
ln_employment	4.53
ln_number_of_smes	5.72
ln_avg_wage	8.64
unemployment_rate	2.74

Source: Authors' Calculations

To further assess multicollinearity, variance inflation factors (VIFs) were calculated for all explanatory variables. The highest VIF value is 8.64 for average wages, while all remaining vari-

ables exhibit values below 6. Although the VIF for average wages exceeds the more conservative threshold of 5, it remains below the widely accepted threshold of 10. Therefore, multicollinearity is not considered severe and does not compromise the reliability of the estimated coefficients.

4.3. BASELINE TWFE RESULTS

Table 5. Main results: Two-way fixed effects estimations

Variable	(1) TWFE	(2) TWFE + DK	(3) Digitalization	(4) Innovation	(5) No wage
ln_env_protection_exp	0.045** (0.014)	0.045* (0.025)	0.016 (0.022)	0.021 (0.018)	0.037** (0.014)
ln_fixed_capital_investment	0.151*** (0.036)	0.151*** (0.033)	0.047 (0.052)	0.003 (0.050)	0.217*** (0.035)
ln_employment	0.183* (0.104)	0.183** (0.085)	0.305 (0.187)	0.491** (0.204)	-0.010 (0.101)
ln_number_of_smes	-0.233*** (0.059)	-0.233** (0.083)	-0.476*** (0.089)	-0.618*** (0.123)	-0.269*** (0.062)
ln_avg_wage	0.943*** (0.186)	0.943*** (0.169)	0.826*** (0.242)	0.948*** (0.225)	-
unemployment_rate	0.127*** (0.025)	0.127*** (0.030)	-0.207*** (0.040)	-0.135* (0.080)	0.131*** (0.026)
internet_usage	-	-	-0.002 (0.001)	-	-
innovation_activity	-	-	-	0.003 (0.004)	-

Source: Authors' Calculations

Table 6. Model statistics

Statistic	(1)	(2)	(3)	(4)	(5)
Observations	320	320	224	192	320
Fixed Effects	Region & Year	Region & Year	Region & Year	Region & Year	Region & Year
R ²	0.432	0.432	0.302	0.316	0.379
Adjusted R ²	0.350	0.350	0.173	0.173	0.293

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Standard errors in parentheses

Source: Authors' Calculations

The baseline two-way fixed effects model (Model 1) identifies fixed capital investment and average wages as the strongest determinants of regional economic performance. Fixed capital investment has a positive and highly significant effect (0.151, $p < 0.01$), confirming the importance of capital accumulation for regional productivity. Average wages exhibit the largest coefficient (0.943, $p < 0.01$), reflecting the close relationship between labour income and regional output. Environmental protection expenditure is positively associated with GRP per capita (0.045, $p < 0.05$), suggesting that greater investment in environmental policy accompanies stronger regional economic performance. In contrast, SME activity is negatively related to growth (-0.233, $p < 0.01$), indicating that a higher concentration of small firms may characterise less productive regional economies. Employment is only weakly significant (0.183, $p < 0.10$), whereas unemployment shows an unexpected positive coefficient (0.127, $p < 0.01$). This result should be interpreted cautiously, as it likely reflects structural characteristics of resource-rich regions rather than a positive effect of unemployment on economic growth.

Model 2 applies Driscoll-Kraay standard errors to account for heteroskedasticity, serial correlation, and cross-sectional dependence. Although coefficient estimates remain unchanged, standard errors increase slightly. Environmental protection expenditure becomes marginally significant ($p < 0.10$), while employment gains significance at the 5% level. Fixed capital investment, wages, SMEs, and unemployment retain both their magnitude and statistical significance, indicating that the baseline findings are robust to alternative error specifications. Overall, Models 1 and 2 consistently identify capital accumulation and wage dynamics as the principal drivers of regional economic performance.

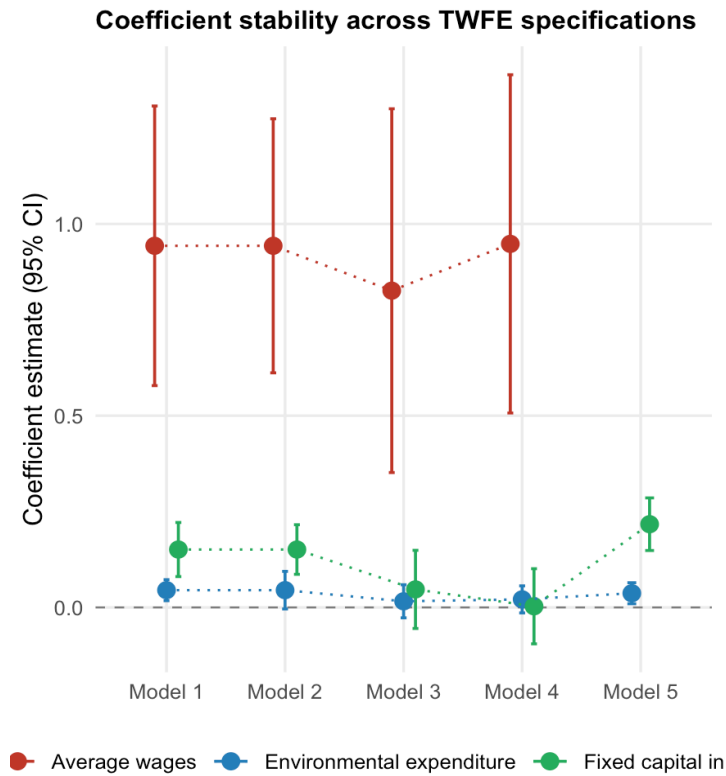
Model 3 extends the baseline specification by including internet usage as a proxy for digitalisation. Owing to data limitations, the estimation sample decreases from 320 to 224 observations. Internet usage is not statistically significant, providing no evidence of an independent contribution of digitalisation to regional output. The unemployment coefficient changes sign and becomes negative, suggesting that the restricted sample reflects a different regional composition rather than a structural change in the underlying relationship.

Model 4 incorporates innovation activity, further reducing the sample to 192 observations. Innovation does not have a statistically significant contemporaneous effect on GRP per capita, implying that its contribution to regional growth may materialise only over a longer horizon. The inclusion of innovation substantially weakens the effect of fixed capital investment, which becomes insignificant, whereas employment becomes positively significant. Average wages remain highly significant across all specifications. The negative effect of SME activity becomes stronger, reinforcing the finding that higher SME density is associated with lower regional productivity. Environmental protection expenditure also loses statistical significance, indicating that its estimated effect is sensitive to model specification and sample composition.

Model 5 excludes average wages to examine whether wage dynamics mask the effects of other explanatory variables. Removing wages restores the statistical significance of environmental protection expenditure, whose coefficient returns to a level close to that observed in the baseline model. The coefficient on fixed capital investment increases substantially, suggesting that wages partly capture the returns to capital accumulation in more prosperous regions. Employment becomes insignificant, confirming the close relationship between employment and wage levels as alternative indicators of regional productivity. The negative effect of SME activity and the positive association between unemployment and GRP per capita remain robust, while the full sample of 320 observations is restored.

Overall, the results indicate that fixed capital investment and wage dynamics are the most stable determinants of regional economic performance. In contrast, the estimated effects of environmental protection expenditure, SME activity and unemployment vary across specifications, highlighting the importance of model choice, sample composition, and regional heterogeneity when assessing the determinants of economic growth in Kazakhstan.

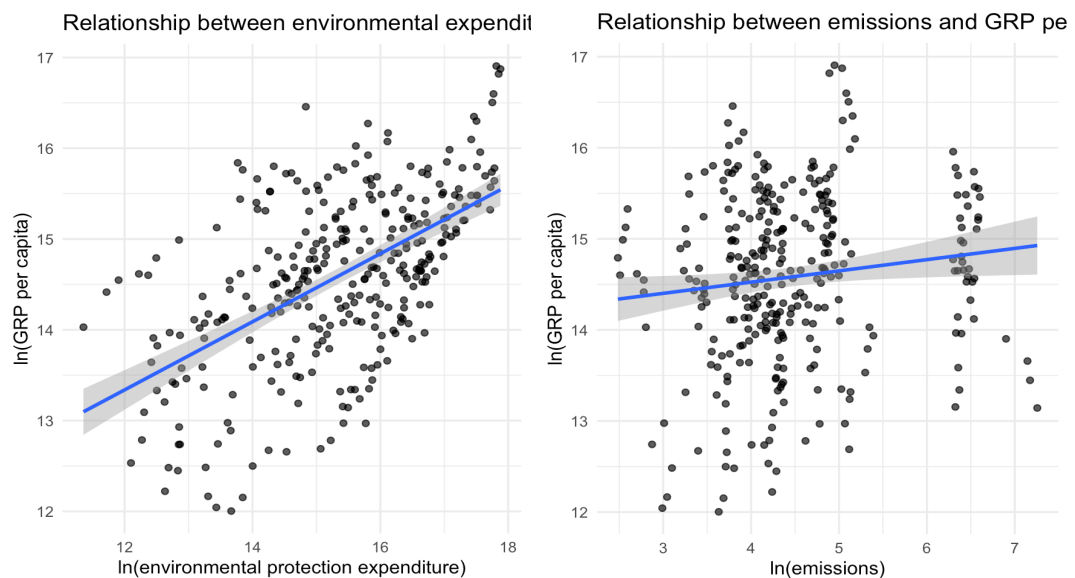
Figure 3. Coefficient stability across two-way fixed effects specifications (with 95% confidence intervals)



Source: Authors' Calculations

Figure 3 illustrates that average wages and fixed capital investment produce the most stable estimates across specifications, with confidence intervals that remain consistently away from zero. The environmental protection expenditure coefficient, by contrast, displays greater sensitivity to specification changes: significant in the baseline and wage-excluded models but losing precision in the reduced-sample specifications. This pattern reflects conditional rather than unconditional robustness and is discussed in detail in the model-by-model analysis below.

Figure 4. Relationship between environmental protection expenditure and GRP per capita (left) and emissions and GRP per capita (right)



Source: Authors' Calculations

The scatterplots reveal a clear positive association between environmental protection expenditure and GRP per capita, supporting the view that environmental investment may complement economic growth. By contrast, the relationship between emissions and GRP is weaker and more dispersed, suggesting that environmental pressure does not follow a straightforward linear pattern with economic development.

4. 4. DYNAMIC PANEL MODEL (TWO-WAY FE + DRISCOLL-KRAAY)

Dynamic specification is estimated to account for persistence in regional economic performance. A lagged dependent variable is introduced to capture temporal dependence and inertia in GRP per capita. The model retains the baseline set of controls and applies two-way fixed effects with Driscoll–Kraay standard errors to address cross-sectional dependence and serial correlation.

Table 7. Dynamic two-way fixed effects model with Driscoll-Kraay standard errors

Variable	Coefficient	Std. Error	t-stat	p-value
lag(ln_grp_pc, 1)	0.714	0.044	16.390	0.000***
ln_env_protection_exp	0.024	0.010	2.395	0.017**
ln_fixed_capital_investment	0.046	0.028	1.641	0.102
ln_employment	-0.014	0.081	-0.170	0.865
ln_number_of_smes	0.065	0.047	1.383	0.168
ln_avg_wage	0.402	0.144	2.783	0.006***
unemployment_rate	0.052	0.023	2.264	0.024**

Source: Authors' Calculations

Table 8. Model statistics

Statistic	Value
Observations	304
Fixed Effects	Region & Year
R ²	0.702
Adjusted R ²	0.657

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Source: Authors' Calculations

The lagged dependent variable has a positive and highly significant coefficient (0.714, $p < 0.001$), indicating strong persistence in regional economic performance. This suggests that about 71% of current GRP per capita is determined by its previous-period value, pointing to substantial structural inertia in regional growth patterns. As a result, regional development appears to be strongly path-dependent, meaning that short-term policy measures may have limited immediate impact. Environmental protection expenditure remains positive and statistically significant in the dynamic model (0.024, $p < 0.05$), although its effect is much smaller than in the static specifications. This reduction is expected, as the inclusion of the lagged dependent variable accounts for past income levels. Therefore, the coefficient mainly reflects the additional contemporaneous effect of environmental spending beyond prior economic performance, while part of the relationship found in the static models likely captures accumulated long-term effects.

Average wages continue to show a positive and significant association with GRP per capita (0.402, $p < 0.01$), confirming their continued importance in regional income generation after accounting for persistence. The unemployment rate is also positive and significant (0.052, $p < 0.05$), which is consistent with the explanation provided in Section 4.2 regarding structural fea-

tures of Kazakhstan's regional labour markets. Fixed capital investment, although significant in the static models, becomes statistically insignificant in the dynamic specification (0.046, $p > 0.10$). This implies that its effect is largely captured by the lagged dependent variable. In other words, investment does not appear to produce immediate gains in GRP per capita but instead contributes gradually through the accumulation of productive capacity over time.

Employment and the number of SMEs are statistically insignificant ($p > 0.10$), suggesting that they do not exert a clear short-run effect on GRP per capita once dynamic adjustment is considered. This indicates that regional growth is driven more by productivity improvements than by simple increases in employment or firm numbers. The dynamic model also shows a considerably better fit than the static specifications, with $R^2 = 0.702$ and adjusted $R^2 = 0.657$. This indicates that the model explains a larger share of variation in regional economic performance, mainly due to the inclusion of the lagged dependent variable and the strong persistence it captures.

4. 5. SPATIAL DEPENDENCE (MORAN'S I)

To assess the presence of spatial dependence in regional data, Moran's I statistic was calculated both for the raw variable and for the residuals of the two-way fixed effects (TWFE) model. This allows distinguishing between inherent spatial clustering and residual spatial autocorrelation after controlling for regional and temporal heterogeneity.

Table 9. Moran's I test's results

Test specification	Moran's I	Expected value	Std. deviate	p-value	Interpretation
Raw data (ln_grp_pc / or proxy)	0.1665	-0.0667	1.3086	0.0953	Weak / marginal spatial dependence
TWFE residuals	-0.0892	-0.0667	-0.126	0.5501	No spatial autocorrelation

Source: Authors' Calculations

These results indicate that the spatial clustering observed in the original data is attributable to persistent structural differences across regions rather than genuine spatial dependence. Accordingly, the two-way fixed effects specification adequately accounts for this regional heterogeneity. Consequently, there is no empirical basis for estimating spatial econometric models, such as the Spatial Autoregressive (SAR) or Spatial Error Model (SEM), as their application would unnecessarily increase model complexity without improving model performance.

4. 6. SYSTEM GMM

Since no evidence of residual spatial dependence was detected, a dynamic specification was subsequently estimated using the System GMM (Blundell–Bond) estimator to account for potential endogeneity and dynamic panel bias. Nevertheless, the estimation results were not considered reliable. Specifically, the Sargan/Hansen test produced exceptionally high p -values (close to 1), indicating instrument proliferation and weak instrument identification arising from the relatively small cross-sectional dimension of the dataset ($N = 16$). This limitation is widely recognised in the dynamic panel literature, where System GMM is known to perform poorly in panels with a limited number of cross-sectional units.

4. 7. ROBUSTNESS ANALYSIS: ANDERSON-HSIAO IV ESTIMATOR

To further address potential endogeneity and dynamic panel bias (Nickell bias), an additional robustness analysis is conducted using the Anderson-Hsiao instrumental variable estimator. This approach first transforms the model through first differencing and subsequently instruments the lagged dependent variable with its second lag, producing a consistent estimator in

the presence of endogeneity. Unlike System GMM, the Anderson-Hsiao estimator avoids the problem of instrument proliferation and is therefore particularly appropriate for panels with a relatively small number of cross-sectional units ($N = 16$).

Table 10 - Anderson-Hsiao IV Estimator results

Variable	Estimate	Std. Error	t-value	p-value	Significance
Lagged GRP (Δy_{t-1})	0.740	0.226	3.281	0.00116	**
Environmental expenditure	-0.004	0.019	-0.219	0.826	
Investment	-0.026	0.050	-0.517	0.605	
Wage	0.419	0.157	2.662	0.00822	**
SMEs	0.221	0.068	3.266	0.00122	**
Unemployment	-0.051	0.035	-1.443	0.150	

Source: Authors' Calculations

Table 11. Model statistics

Test	Statistic	p-value	Interpretation
Weak instruments (F)	29.89	<0.001	Strong instruments
Wu-Hausman	23.03	<0.001	Endogeneity confirmed
Sargan	N/A	N/A	Exactly identified

Source: Authors' Calculations

The Anderson-Hsiao estimator provides further evidence supporting the robustness of the empirical findings. The coefficient on the lagged dependent variable remains positive and statistically significant (0.740, $p < 0.01$), confirming the strong persistence of regional economic performance over time. Its slightly larger magnitude compared with the TWFE estimate is consistent with the expected correction for Nickell bias.

Among the explanatory variables, average wages and SME activity retain positive and statistically significant coefficients, indicating that higher income levels and greater business activity contribute positively to regional economic growth once dynamic adjustment is considered. By contrast, environmental protection expenditure and fixed capital investment are not statistically significant in the first-difference specification, suggesting that their effects materialise gradually over longer periods rather than through immediate changes in regional output.

The diagnostic statistics provide strong support for the validity of the Anderson-Hsiao specification. The first-stage F-statistic (29.89) exceeds conventional critical values, confirming instrument relevance and eliminating concerns regarding weak instruments. The Wu-Hausman test rejects the exogeneity of the lagged dependent variable, thereby providing empirical justification for adopting an instrumental variable approach. The absence of a Sargan test is expected because the model is exactly identified and should not be interpreted as a methodological limitation. By construction, the second lag of GRP per capita satisfies the exclusion restriction, as it is correlated with the first-differenced lagged dependent variable while remaining uncorrelated with the first-differenced error term under the standard assumptions of [Anderson and Hsiao \(1982\)](#) and [Hsiao \(2014\)](#).

Despite these advantages, the Anderson-Hsiao estimator has certain limitations. Because it relies on first differencing and a relatively limited set of instruments, it is generally less efficient than System GMM in large samples. Furthermore, it primarily captures short-run dynamic relationships and may therefore understate longer-term adjustment processes. Nevertheless, given the relatively small cross-sectional dimension of the present dataset ($N = 16$), the Ander-

son–Hsiao estimator provides a conservative yet statistically reliable robustness check while avoiding the instrument proliferation and over-identification problems encountered with the System GMM estimator.

5. DISCUSSION

5.1. STRUCTURAL INTERPRETATION OF REGIONAL GROWTH DYNAMICS

The empirical findings indicate that regional economic performance in Kazakhstan is influenced by a combination of structural, institutional, and policy-related factors rather than by any single determinant. The baseline two-way fixed effects model identifies average wages and fixed capital investment as the most consistent determinants of GRP per capita, with coefficients of 0.943 ($p < 0.01$) and 0.151 ($p < 0.01$), respectively.

The strong relationship between wages and regional income suggests that economic disparities across Kazakhstan are driven primarily by differences in labour productivity, industrial structure, and the concentration of high-value-added activities rather than by labour market participation alone. Likewise, the significance of fixed capital investment highlights the importance of capital accumulation as a key driver of regional development, supporting theories of structural transformation and long-run economic growth.

However, these relationships are not entirely stable across model specifications. Environmental protection expenditure is positive and statistically significant in the baseline model ($\beta = 0.045$, $p < 0.05$), but its effect weakens or becomes statistically insignificant in alternative specifications and subsamples. Similarly, SME activity exhibits a consistently negative and statistically significant coefficient in the static models, becomes insignificant in the dynamic specification, and turns positive under the Anderson–Hsiao estimator. These results suggest that the effects of environmental policy and entrepreneurship depend on both model specification and regional context, reinforcing the institutional perspective that regional development outcomes are shaped by governance quality and structural conditions (Acemoglu et al., 2005). Comparable evidence from Central Asia also indicates that coordinated institutional arrangements and integrated policy implementation contribute to stronger policy coherence and greater societal resilience (Yermekbayeva et al., 2026).

5.2. NEGATIVE SME COEFFICIENT: STRUCTURAL INTERPRETATION AND PRODUCTIVITY CONSTRAINTS

One of the most notable findings is the consistently negative and statistically significant coefficient on SME activity across the static TWFE specifications, ranging from -0.233 to -0.618 and remaining significant at the 1% level in four of the five estimated models.

Baumol (1990) argues that entrepreneurial activity does not necessarily promote economic growth, particularly in weak institutional environments where entrepreneurship may be directed towards rent-seeking or other low-productivity activities. This perspective is especially relevant for transition economies, where institutional constraints frequently limit firms' ability to generate productivity improvements. Likewise, Henrekson and Sanandaji (2014) contend that conventional indicators such as SME density may fail to capture productive entrepreneurship and may even exhibit a negative association with economic performance.

Short-run market dynamics provide an additional explanation for the observed relationship. Fritsch and Mueller (2004) demonstrate that new firm entry may initially reduce regional output through competitive displacement effects, while its positive contribution emerges only over longer periods. In the context of Kazakhstan, where many SMEs operate in relatively

low-value-added sectors, an increase in the number of firms may therefore reflect economic fragmentation rather than productivity-enhancing expansion.

Recent empirical evidence supports this interpretation. [Potter et al. \(2025\)](#) report that the presence of small firms does not necessarily stimulate regional economic growth once structural factors are considered, while [Keffala \(2025\)](#) finds that the growth-enhancing role of SMEs in developing economies depends critically on institutional quality. Similarly, [Szerb et al. \(2019\)](#) show that necessity-driven or low-quality entrepreneurship is associated with weaker regional performance where entrepreneurial ecosystems remain underdeveloped. [Matenda and Sibanda \(2023\)](#) likewise conclude that entrepreneurial activity alone is insufficient to improve per capita output without stronger entrepreneurial capabilities and supportive institutional conditions.

5. 3. DYNAMIC ADJUSTMENT AND THE ANDERSON-HSIAO CORRECTION

The dynamic and instrumental variable estimates provide additional insight into the relationship between SME activity and regional economic growth. Once temporal dependence is incorporated into the model, the SME coefficient becomes statistically insignificant ($0.065, p > 0.10$). However, under the Anderson-Hsiao IV estimator, it becomes positive and statistically significant ($0.221, p < 0.01$). Two complementary explanations may account for this pattern.

First, the static and dynamic estimators capture different aspects of the underlying data. The static TWFE model measures contemporaneous within-region variation after controlling for regional fixed effects, whereas the Anderson-Hsiao estimator, based on first differences, isolates short-run within-region changes while correcting for the endogeneity of the lagged dependent variable. Consequently, the contrasting estimates suggest that structural inefficiencies dominate the cross-sectional relationship, whereas the productive contribution of SMEs becomes more apparent when analysing changes within regions over time.

Second, the reversal in the coefficient's sign may indicate that the static TWFE estimates are affected by endogeneity bias, which the Anderson-Hsiao estimator partially addresses. Under this interpretation, the Anderson-Hsiao coefficient provides a more reliable estimate of the marginal within-region effect of SME activity on economic growth.

Overall, the relationship between SME activity and regional growth proves highly sensitive to the treatment of dynamics and endogeneity. This finding highlights the importance of dynamic modelling in regional growth analysis and is consistent with evidence that regional development trajectories exhibit strong path dependence and are shaped by governance quality and institutional continuity ([Karagiannis & Paleologou, 2025](#)).

More broadly, the differences between the static TWFE and Anderson-Hsiao estimates observed for environmental protection expenditure, SME activity, and fixed capital investment can be attributed to three complementary mechanisms. First, endogeneity may bias the static TWFE estimates through reverse causality where higher GRP per capita stimulates environmental spending or SME formation or through omitted variables that distort the estimated relationships. The Anderson-Hsiao estimator partially mitigates this issue by instrumenting the lagged dependent variable, thereby producing estimates that more closely reflect marginal within-region effects.

Second, the two estimators capture different adjustment horizons. The static TWFE specification reflects long-run within-region associations, whereas the Anderson-Hsiao estimator, estimated in first differences, focuses on short-run dynamic responses. Consequently, variables whose effects accumulate gradually, such as environmental expenditure and capital investment, are expected to display weaker contemporaneous effects in the Anderson-Hsiao specification.

Third, first differencing increases the influence of measurement error relative to the underlying

signal, creating attenuation bias that tends to shrink estimated coefficients towards zero. This effect is particularly relevant for variables measured less precisely at the regional level, including environmental expenditure and SME activity. Taken together, these mechanisms explain why the Anderson–Hsiao estimates differ from the static TWFE results and caution against relying on any single estimator as definitive.

5. 4. ENVIRONMENTAL EXPENDITURE: CONDITIONAL AND SPECIFICATION-SENSITIVE EFFECTS

The estimated effect of environmental protection expenditure is consistently positive but varies considerably across model specifications. The coefficient is positive and statistically significant in the baseline model (0.045, $p < 0.05$), remains positive but smaller in the dynamic specification (0.024, $p < 0.05$), and becomes statistically insignificant under the Anderson–Hsiao estimator (-0.004 , $p = 0.83$).

This pattern is broadly consistent with the Porter hypothesis, which argues that environmental regulation can enhance innovation and productivity, although only under favourable institutional and technological conditions (Porter & van der Linde, 1995). Previous empirical studies similarly demonstrate that the economic effects of environmental policy depend on technological capabilities and institutional quality (Rubashkina et al., 2015; Benatti et al., 2024).

The instability of the estimated coefficient further suggests that environmental protection expenditure influences economic performance primarily through indirect channels, including improvements in institutional quality and governance, rather than through immediate increases in regional output. This interpretation is supported by Fan et al. (2022), who show that local environmental expenditure strengthens governance quality and regulatory effectiveness even when short-run growth effects remain limited. Likewise, Gorus (2024) finds that stricter environmental regulation may generate temporary adjustment costs and reduce short-term economic growth where innovation-absorption capacity is insufficient.

5. 5. WAGES AS THE DOMINANT CORRELATE OF REGIONAL PERFORMANCE

Average wages emerge as the most stable and economically important determinant across all estimated specifications. The coefficient remains large and highly significant in the static models (ranging from 0.826 to 0.948) and continues to be positive and statistically significant in both the dynamic specification (0.402, $p < 0.01$) and the Anderson–Hsiao model (0.419, $p < 0.01$). These results suggest that wage dynamics play a central role in regional income formation, most likely reflecting underlying differences in labour productivity, human capital, and industrial composition across regions.

The omission of wages from Model 5 substantially increases the coefficient on fixed capital investment from 0.151 to 0.217, indicating that wages capture an important share of productivity-related variation that would otherwise be attributed to capital investment.

5. 6. UNEMPLOYMENT AND LABOUR MARKET STRUCTURE

The positive and statistically significant coefficient on unemployment in the baseline specification (0.127, $p < 0.01$) appears counterintuitive at first glance. However, it can be explained by the structural characteristics of Kazakhstan's regional labour markets. In resource-dependent and regionally imbalanced economies, relatively high unemployment rates may coexist with high income levels because capital-intensive industries generate substantial output while employing comparatively few workers. As a result, economically advanced regions may simultaneously record high GRP per capita and elevated measured unemployment.

The sign reversals observed in Models 3 and 4, together with the loss of statistical signifi-

cance under the Anderson–Hsiao specification (-0.051 , $p = 0.150$), suggest that the positive association identified in the static models reflects structural differences across regions rather than a causal within-region relationship. This interpretation is consistent with the wage curve literature, which documents an inverse relationship between wages and unemployment across regional labour markets (Blanchflower & Oswald, 1994).

5. 7. SPATIAL DIAGNOSTICS AND MODEL VALIDITY

The Moran's I statistic calculated from the residuals of the TWFE model ($I = -0.0892$, $p = 0.55$) is statistically insignificant, indicating that the spatial clustering observed in the raw data is largely explained by regional fixed effects. Consequently, there is no empirical justification for estimating spatial econometric models in the present analysis.

As discussed in the methodology, however, this result should not be interpreted as conclusive evidence that spatial dependence is absent. Regional fixed effects may absorb part of any underlying spatial structure, thereby reducing detectable residual autocorrelation. Within these limitations, the diagnostic supports the use of the TWFE specification without indicating a need for additional spatial modelling.

5. 8. SYNTHESIS

Taken together, the empirical findings indicate that regional economic growth in Kazakhstan is driven by a combination of structural productivity factors, institutional conditions, and dynamic adjustment processes. The results further demonstrate that distinguishing between short-run and long-run relationships, as well as between cross-sectional and within-region variation, is essential for interpreting the estimated effects.

The consistently negative SME coefficient in the static models points towards structural inefficiencies and relatively low productivity, whereas its positive coefficient under the Anderson–Hsiao estimator suggests that SMEs may contribute positively to regional growth once dynamic adjustment and endogeneity are appropriately addressed. Similarly, the effects of environmental protection expenditure appear conditional upon model specification and institutional context rather than universally positive. In contrast, average wages remain the most stable predictor of regional economic performance across all specifications, while unemployment primarily reflects structural labour market characteristics rather than cyclical economic conditions.

Overall, the findings support the broader conclusion that the effectiveness of regional development policies depends critically on the institutional and structural environment in which they are implemented.

6. CONCLUSION

This study examined the relationship between environmental protection expenditure, SME activity, fixed capital investment, and regional economic growth in Kazakhstan during the country's transition towards a circular economy. Using a balanced panel dataset covering 16 regions over the period 2005-2024 and combining static two-way fixed effects models with Driscoll-Kraay standard errors and the dynamic Anderson–Hsiao instrumental variable estimator, the analysis demonstrates that regional growth is shaped by persistent structural conditions and that the estimated effects of key policy variables depend on model specification and dynamic adjustment.

Three principal findings emerge. First, environmental protection expenditure does not exert a uniform effect on regional economic growth. Although it is positively associated with GRP per capita in the baseline specification, its effect weakens across alternative models, indicating

that the effectiveness of sustainability-oriented policies depends on regional structural characteristics and institutional capacity.

Second, the relationship between SME activity and regional growth is highly specification dependent. SME activity exhibits a negative association with regional income in the static models but becomes positive under the Anderson–Hsiao estimator, highlighting the importance of accounting for endogeneity and dynamic adjustment when evaluating entrepreneurship policies.

Third, fixed capital investment contributes positively to regional growth in the static specifications but loses statistical significance in the dynamic models, suggesting that part of its estimated impact reflects the persistence of regional income rather than an immediate within-region growth effect.

The comparison of static and dynamic estimators demonstrates that the determinants of regional growth are conditional rather than universal. Furthermore, the spatial diagnostics provide no evidence of statistically significant residual spatial autocorrelation, although this should not be interpreted as conclusive evidence that regional spillover effects are entirely absent.

Several limitations should be acknowledged. Environmental protection expenditure serves only as a proxy for the policy dimension of the circular economy, while the absence of regional indicators of institutional quality prevents the explicit modelling of institutional interactions. Moreover, the single-country focus limits the external validity of the findings, and alternative dynamic panel estimators were not pursued because of instrument proliferation concerns associated with small- N panel datasets. Although the results are likely to be most relevant for transition and resource-dependent economies with structural characteristics like Kazakhstan, broader generalisation requires comparative cross-country evidence.

From a policy perspective, the findings suggest that environmental expenditure should be aligned more closely with regional industrial structures and institutional capacity to minimise short-term adjustment costs and maximise long-term benefits. Policies supporting SMEs should focus on productivity-enhancing measures, including improved access to finance, innovation incentives, and business formalisation. Likewise, investment policies should be complemented by governance reforms that strengthen project selection, implementation quality, and regional absorptive capacity. Given that these policy effects operate over different adjustment horizons, their effectiveness should be assessed over the medium and long term rather than within a single annual budget cycle.

Future research should incorporate direct regional measures of institutional quality, extend the analysis to comparative cross-country settings, and evaluate alternative dynamic panel estimators as longer panel datasets become available.

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