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IMPACT OF TECHNOLOGY ADVANCEMENT ON ECONOMIC DEVELOPMENT OF KAZAKHSTAN: AN ARDL ASSESSMENT

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Original article

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ABSTRACT

One of the most important concerns for both industrialized and emerging nations will continue to be economic development. Since modern technologies have permeated practically every aspect of human existence, technological advancement plays a unique role in this regard. This study was carried out to evaluate the influence of technological development elements on the nation's economic development. ICT goods exports, research and development expenditure, scientific and technical journal articles, and patent applications were taken as independent factors, and GDP per capita was taken as dependent. The study employed the Autoregressive Distributed Lag model and covered the years 2000–2022. The study's conclusions demonstrate the long-term and short-term benefits of science-based and patent-based technology advancement for the nation's economic development. For scientists doing such research, the authors hope that this work will represent a fresh breakthrough.

Keywords: *technology, patents, digitalization, research and development, ARDL, economic development*

1. INTRODUCTION

Innovation in science and technology has long been a key factor in social advancement and economic prosperity, and both national strategies and institutional designs place significant emphasis on how to foster innovation. Technology has become an essential aspect of human life in the twenty-first century (Turkeeva & Umarova, 2020). Today, technology propels economic progress in both developed and developing nations (Elfaki & Ahmed, 2024). Economic development is no exception to the way technology drives change in everything from everyday routines to society functioning. The importance of technological information and knowledge has grown, and acquiring patents has gained international attention (Smith, 1986).

The data covered by a patent then serves as the basis for further research and development (Yoon & Lee, 2012). Innovation also stems from the findings of information research and development and has always been one of the primary forces behind economic expansion (Altynbekov et al., 2023; Yussupov et al., 2023). Today, one of the key determinants of worldwide competition is the effective exploitation of technology potential (Umarova et al., 2020). Since technology has permeated every aspect of human existence, it is vital that all citizens, regard-less of age, be able to use it at least at a fundamental level (Yahşi et al., 2025). At the same time, legal support for the introduction of technologies and innovations into production, state funding for research and development, the simplification of the patenting process for inventions and innovations, and the provision of high-quality education are all crucial and methodical processes for the overall development of the economy and technology (Satpayeva et al., 2022; Blind et al., 2022; Probst et al., 2023; Drakul, 2025).

The Republic of Kazakhstan's primary responsibilities in the framework of establishing a knowledge-based economy are the formation of a national innovation system and the creation of creative policies and initiatives (Satpayeva, 2017). In order to modify and enhance future policies, it is crucial to evaluate the extent to which technological advancement supports economic progress. In this study, the authors aim to evaluate the technological elements that impact economic development using econometrics. The findings of this study are anticipated to be helpful for researchers examining how technological advancements affect economic growth as well as for formulating socioeconomic policy recommendations for Kazakhstan.

The article's structure is as follows: Introduction, Literature Review, Study Limitations, Methodology and Materials, and Conclusion.

2. LITERATURE REVIEW

2. 1. PATENTS AND ECONOMIC DEVELOPMENT

Numerous elements impact the nation's economic progress (Kakizhanova et al., 2026). Furthermore, technology is becoming a crucial component of every aspect of human endeavor. The patent system, one of the most important institutional systems in contemporary economics, has been utilized to foster innovation for several decades (Ouyang et al., 2022). Future advancement is made possible by accumulating knowledge, which enables researchers and innovators to improve upon existing concepts or create new ones (Park et al., 2023). Science and technology are the main drivers of rising welfare, with economic expansion following closely behind. Economic expansion was a result of scientific and technological advancements, not the other way around (Mahdhi & Belgaroui, 2025). Economic expansion in its current form has the potential to impede technological advancement by slowing innovation and raising returns to scale (Budiandriani & Fahlevi, 2025). However, economic growth may be adversely affected by current technological advancements, particularly in the information technology sector (Ayres, 1996). The concentration of high-tech innovations is distributed differently across continents (Apriantoro et al., 2025). While there is growth, there are still countries in the world where people do not have access to what would seem to be a basic need – electricity (Desai et al., 2002). According to Yu & Jin (2024), innovations and inventions can be developed using research output, and this kind of technological advancement stimulates economic growth. Numerous global challenges have been worsened by the sharp rise in e-waste generation worldwide and the shorter lifespans of electronic devices (Yu et al., 2025). Technology revolution outcomes resulted in digital economy development and rapid technological advancements (Kashyap, 2018). Patents protect intellectual property, act as a storehouse of technical and business information, and foster innovation, company growth, and technological advancement (Mejia & Kajikawa, 2025).

The patent database, as a source of technological information, is in demand among universities, research institutes, etc. (Pereira et al., 2015). Although some contend that invention is critical to the advancement of technology, other research indicates that patents are of limited importance (Hall, 2022). Chen et al.'s (2013) study revealed that National R&D productivity growth is mostly driven by patent-oriented R&D productivity growth, rather than by journal article-oriented R&D productivity development.

H_0: Patents are positively correlated to economic development in both the short and long run.

2. 2. DIGITAL TECHNOLOGY AND ECONOMIC DEVELOPMENT

The growth of the digital economy offers a chance to increase communication and fosters an open exchange of knowledge and insights (Barinov et al., 2020). Innovation in digital technology has emerged as a key driver of economic growth. Additionally, digital transformation raises R&D investment, improves internal control quality, eases financing limitations, and boosts core competitiveness – all of which have an impact on corporate digital technology innovation (Fang & Liu, 2024). A consensus regarding the substantial importance of digital technology innovation for economic and social growth has progressively emerged as a result of the industry and academia's extensive attention to this topic (Liu et al., 2023). In the modern global economy, digitalization is essential for improving communication between business partners, streamlining production processes, and cutting operating expenses (Vărzaru & Bocean, 2024). Hameed & Mubarak (2025) claim that sustainable development and digital technology can be carefully considered as precursors, and both ought to be important parts of any organizational plan. The digital economy is expanding and developing due to the unique significance of digital technology, and in many nations, it has been identified as the main force behind economic growth and development (Xia et al., 2024). Empirical evidence from Chinese cities provides verifiable proof of the digital economy's substantial impact on environmental quality, economic growth, and urban development (Jiang et al., 2021; Al-Zoubi, 2024). Technological solutions can be crucial for the orderly and seamless development of Kazakhstan's cities as well as for resolving environmental issues (Nurlanova et al., 2023; Tleuberdinova et al., 2024; Azhbenov et al., 2024). By using Heckman selection models, propensity score matching, and instrumental variable estimates, Chen & Xing (2025) found that the growth of the digital economy both directly and indirectly stimulates green innovation, which greatly boosts high-quality economic growth. Empirical evidence from Gao et al. (2024) demonstrates that, in the process of digital technology enabling high-quality development, maximizing factor allocation, green innovation, and entrepreneurial energy are essential.

H_1: Digital technology has significant positive effect on economic development in both the short and long term.

2. 3. TECHNOLOGY AND R&D EXPENDITURE

Discussions concerning the effects of technological advancement and innovation on economic growth and development have gained more attention since the 2000s due to the growing significance of the relationship between R&D spending and technology. According to İşcan & Öğrü (2021), policymakers may undoubtedly improve their nation's economic performance and prosperity by boosting R&D spending, patents, technology trade, and technological advancement in the twenty-first century. The impact of technological research and development on social structure has always stirred the academic community (DeLeon, 1982). Higher levels of R&D spending lead to a higher level of GDP per capita and a higher level of HDI (Kawahara et al., 2014). Now it has become an inalienable part of economic development (Appolloni et al., 2022; Seitkan et al., 2024). The main force behind developing sustainable inventions is now research and development, or R&D (Sarpong et al., 2023). Indeed, one of the main pillars of sustainable economic growth is research and development. Investment in research and development (R&D) is essential for companies, whether small or large, looking to expand their knowledge base, improve their ability to create, and engage in technological innovation, especially in today's fast-paced economy (Weiyu et al., 2022; Zaman & Tanewski, 2024). Ding et al.'s (2025) study suggests that government R&D expenditure on innovation has a positive effect on national innovative capacity. Research by Tung & Hoang (2024) showed that national R&D spending boosts economic growth both directly and indirectly.

H_2: Technology and R&D expenditure both have a positive effect on economic development in both the short and long term.

2. 4. OVERVIEW OF THE KAZAKH CASE

In recent years, Kazakhstan has taken a course towards developing domestic science-intensive production, developing and mastering new information technologies aimed at obtaining competitive products, and ensuring the interests of national economic security and the development of the industrial and scientific-technical potential of the republic (Rakhmetulina et al., 2022; Alzhanova et al., 2023). In these conditions, innovation processes are being activated, new technological structures introduced, new stages in the manufacturing industry mastered, national scientific and technical potential developed, the gap between science and production bridged, advanced foreign technology transferred, and international standards introduced. GDP growth and the economic efficiency of industrial companies are inextricably linked to the introduction of innovative technologies and fresh scientific discoveries by domestic scientists into production (Umarova et al., 2020). Despite the fact that R&D investment in Kazakhstan is increasing, it is still far behind developed countries (Baidalina et al., 2024). The weak link between science and domestic industrial organizations, the low rate of science commercialization, and scientists' low wages remain ongoing and unresolved issues (Kangalakova et al., 2024; Satpayeva et al., 2025). As a result, many scientists teach at universities to supplement their income (Nurgaliuly & Smagulova, 2025). Although conditions for the inventive and technological development of science are being created across the country, their efficiency remains limited. The level of funding for science remains low, and the tightening of criteria, as well as the increased responsibilities of scientists, makes it impossible to maintain the necessary level of economic development assistance (Dnishev et al., 2022).

Thus, since a country's technological growth is inextricably linked to science, the authors endeavored to identify factors related to both technology and science that span decades.

3. STUDY LIMITATIONS

The authors subjected the model to a number of tests to ensure its reliability and validity, given that the statistical data used in the study spans 23 years (2000-2022). The study variables must meet specific stationarity requirements in order to use the ARDL model. Alimi (2014) states that I(0)/I(1), I(0), or I(1) should be the variables. The Dickey-Fuller (1979) test was used to assess this. The optimal lag length was determined using the Akaike Information Criterion (AIC) (Akaike, 1974). Residuals were examined for normalcy using the Jarque-Bera test (1980). The Breusch (1978) and Godfrey (1978) tests were employed to detect serial correlation. Heteroscedasticity was examined using the Breusch-Pagan-Godfrey (1979) test. The cumulative sum of recursive residuals (CUSUM) and cumulative sum of squares of recursive residuals (CUSUMSQ) tests were used to evaluate the stability of the model (Brown et al., 1975).

4. METHODOLOGY AND MATERIALS

4. 1. DATA

This study examines how the Republic of Kazakhstan's GDP per capita is affected by important technology development factors. Data from the World Data Bank (WDI) covering the years 2000–2022 are used in the study. The study uses ICT goods exports, research and development spending, scientific and technical journal articles, and patent applications as explanatory factors. Table 1 lists the definitions and measurement units of all the indicators utilized in the study.

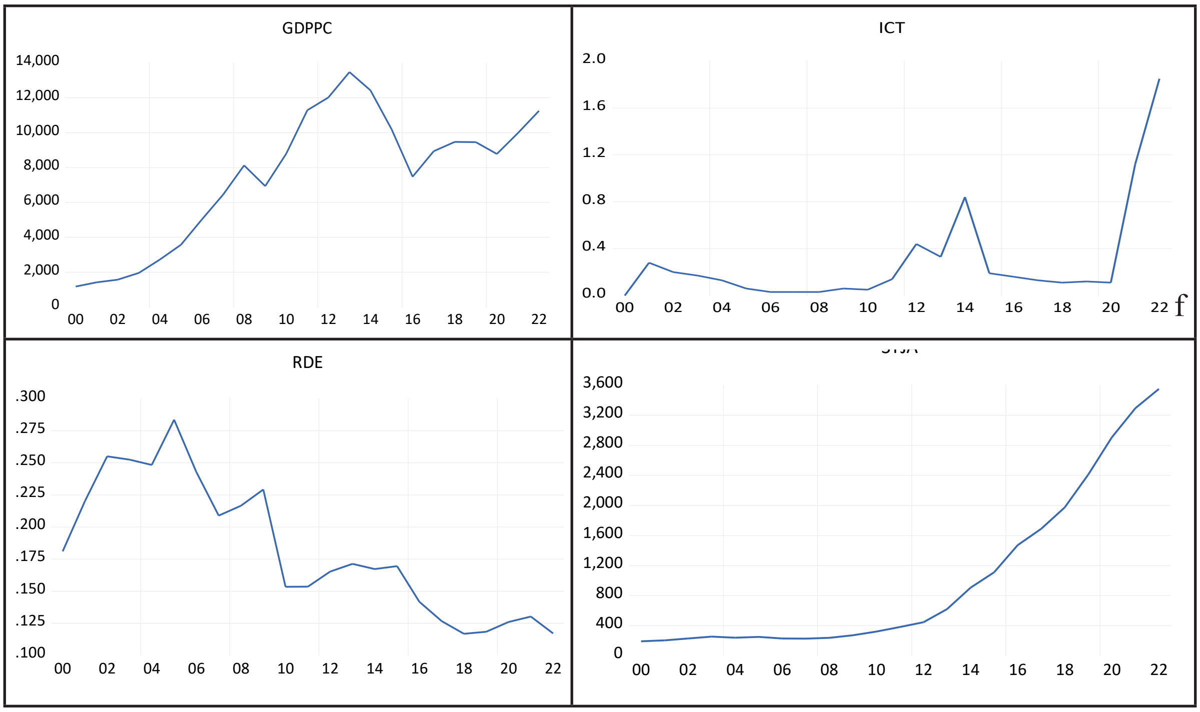
Table 1. Model Variables and sources

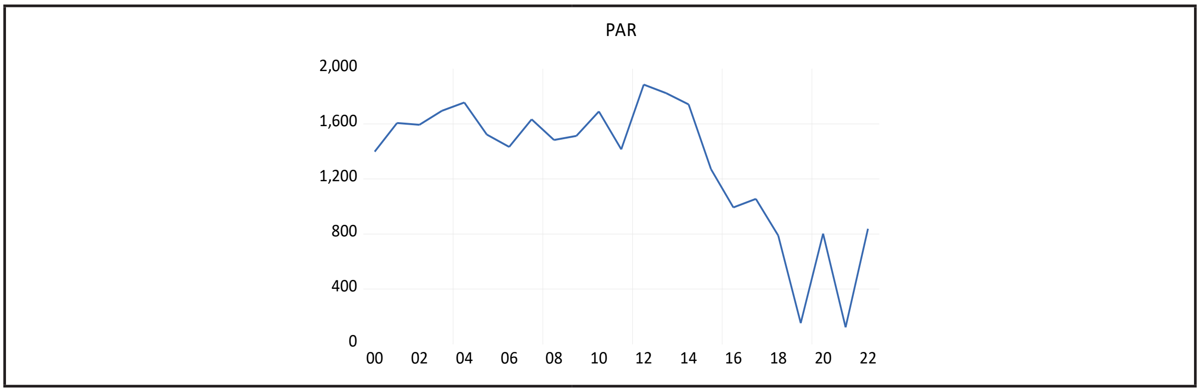
Variables	Definitions	Sources
GDPPC	GDP per capita (US dollars)	World Development Indicators (WDI) (2025), National Bureau of Statistics: https://stat.gov.kz/ru/industries/economy/national-accounts/publications/367840/
ICT	ICT goods exports (% of total goods exports)	World Development Indicators (WDI) (2025)
RDE	Research and development expenditure (% of GDP)	World Development Indicators (WDI) (2025), Tradingeconomics: https://tradingeconomics.com/kazakhstan/research-and-development-expenditure-percent-of-gdp-wb-data.html
STJA	Scientific and technical journal articles	World Development Indicators (WDI) (2025)
PAR	Patent applications, residents	World Development Indicators (WDI) (2025), Kazakhstan Patents base: https://kz.patents.su/; WIPO: https://www.wipo.int/edocs/statistics-country-profile/en/kz.pdf

Source: Compiled by the authors

The following graph displays the dynamic change in each of the indicators provided in the table for the years 2000–2022.

Figure 1. Evolution of all variables for Kazakhstan (2000–2022)





Source: Compiled by the authors

It is evident from the examination of the graph in Figure 1 that the variables being studied are appropriate for analysis. The graph's distinct, steady, and consistent time patterns suggest that variations in the variables are appropriate for additional research.

4. 2. METHODS

This study investigates the relationship between GDP per capita and the following factors for the years 2000–2022, taking into account the findings of the literature review in the previous section: ICT goods exports, Research and development expenditure, Scientific and technical journal articles, and Patent applications, residents. The following formula defines GDPPC:

$$GDPPC = f\,(ICT, RDE, STJA, PAR) \tag{1}$$

As previously stated, Table 1 lists the definitions and measurement units of all indicators.

First difference was used to construct a linear ARDL model, and both short- and long-term evaluations of the relationship between the variables were carried out. Table 6 displays the results of the boundaries test, which evaluates long-term associations. Equation 2 defines the ARDL process in a linear autoregressive model with distributed lags:

$$\begin{aligned} \Delta GDPPC_t = \beta_0 &+ \sum_{k=1}^{m} \beta_1 \Delta GDPPC_{t-k} + \sum_{k=0}^{n} \beta_2 \Delta ICT_{t-k} + \sum_{k=0}^{p} \beta_3 \Delta RDE_{t-k} \\ &+ \sum_{k=0}^{q} \beta_4 \Delta STJA_{t-k} + \sum_{k=0}^{r} \beta_5 \Delta PAR_{t-k} + \gamma_0 GDPPC_{t-i} + \gamma_1 ICT_{t-i} \\ &+ \gamma_2 RDE_{t-i} + \gamma_3 STJA_{t-i} + \gamma_4 PAR_{t-i} + \varepsilon_t \end{aligned} \tag{2}$$

5. EMPIRICAL RESULTS AND DISCUSSION

5. 1. DESCRIPTIVE STATISTICS

The values of the time series variables listed in Table 1 were employed in the investigation. Table 2 below details the descriptive statistics values for each variable included in the model. The mean, median, skewness and kurtosis, Jarque-Bera, and probability are used to analyze the variables in the study.

Table 2. Values of descriptive statistics of the displayed series

Values	GDPPC	ICT	RDE	STJA	PAR
Mean	7501.951	0.286087	0.182408	1018.937	1313.826
Median	8781.508	0.130000	0.169510	381.9800	1483.000
Maximum	13478.46	1.850000	0.283610	3550.750	1886.000
Minimum	1180.044	0.000000	0.116830	192.9700	122.0000
Std. Dev.	3839.282	0.432537	0.052099	1091.687	494.0429
Skewness	-0.371634	2.548439	0.342389	1.180229	-1.155399
Kurtosis	1.915060	8.951249	1.823335	3.005135	3.483411
Jarque-Bera	1.657477	58.83738	1.776233	5.339632	5.341242
Probability	0.436600	0.000000	0.411430	0.069265	0.069209
Sum	172544.9	6.580000	4.195390	23435.55	30218.00
Sum Sq. Dev.	3.24E+08	4.115948	0.059715	26219184	5369725.

Source: Author`s calculation

Based on the indicators' descriptive statistics, the GDPPC median is 8781.508 US dollars, and the standard deviation is 3839.282 US dollars. Since the likelihood of the relationship is 0.436600 and the Jarque-Bera statistic is 1.657477, both greater than 0.05, it can be said that the time series is uniformly distributed. Furthermore, all variables are evenly distributed, with the exception of the RDE indicator. The skewness coefficient for ICT is 2.548439, and the median of ICT goods exports is 0.13% of total goods exports. It is evident from the results in Table 2 that the time series for all variables except GDPPC and PAR exhibit positive skewness, since skewness coefficients are greater than zero. A distribution is considered approximately normal if its excess kurtosis is close to zero, indicating similarity to the normal distribution.

5. 2. UNIT ROOT TEST

It is vital to ascertain whether the time series are stationary before examining the long-term relationships between them. The levels or differences of variables deemed stationary in this study were tested using Augmented Dickey-Fuller (ADF) unit root tests. While some variables must be stationary at the first difference of I(1), others can be employed at the level of I(0). The outcomes of the Augmented Dickey-Fuller (ADF) unit root tests for the level and first difference series are displayed in Table 3. If the ADF result is lower than the 1%, 5%, and 10% absolute critical levels, the null hypothesis of nonstationary-which is tested by ADF-is rejected.

The results show that all explanatory factors are stationary at first difference only in the case of the absence of Trend and Intercept. Consequently, the ARDL model is estimated using these variables for this case.

Table 3. ADF unit root tests

Variables	Intercept			Trend and intercept			None		
	Level	First diff.	Order of Integration	Level	First diff.	Order of Integration	Level	First diff.	Order of Integration
GDPPC	-1.403 (0.562)	-3.224** (0.033)	I(1)	-1.281 (0.866)	-3.212 (0.109)	>I(1)	0.780 (0.875)	-2.999*** (0.004)	I(1)
ICT	0.219 (0.966)	-3.436** (0.021)	I(1)	-0.394 (0.981)	-3.922** (0.030)	I(1)	0.913 (0.897)	-3.348*** (0.002)	I(1)
RDE	-0.788 (0.803)	-4.82*** (0.001)	I(1)	-3.399* (0.083)	-4.61*** (0.008)	I(0)	-0.718 (0.394)	-4.548*** (0.000)	I(1)
STJA	-0.029 (0.946)	-1.203** (0.653)	>I(1)	1.107 (0.999)	-2.541 (0.307)	>I(1)	0.311 (0.766)	-0.444* (0.051)	I(1)
PAR	-0.164 (0.929)	-7.70*** (0.000)	I(1)	-1.523 (0.788)	-7.799** (0.000)	I(1)	-1.098 (0.238)	-7.591*** (0.000)	I(1)

Notes:1) *, **, *** denote statistically significant at the 10%, 5% and 1% levels, respectively
p-value is inside brackets

Source: Author`s calculation

The ARDL model must be used to verify whether there is a long-term relationship between Kazakhstan's GDP per capita and the primary explanatory elements of technological progress suggested in the study, as the results of the unit root tests are in line with the initial hypotheses.

5. 3. GRANGER CAUSALITY TEST

Before making suggestions, it is crucial to determine the causal relationship between the core factors. The Granger test is used to examine the relationship between GDPPC and the chosen variables. The test results are shown in Table 4. These findings show that ICT, RDE, STJA, PAR, and GDPPC emissions are causally related. Changes in one variable can have a substantial effect on another, as they show that the regressors are interconnected. These findings demonstrate how important these elements are to economic growth.

Table 4. Granger noncausality tests for the vector autoregressive model (1) (2000-2022)

Direction of causality	F-statistic	Prob.
GDPPC		
ICT does not Granger Cause GDPPC	4.61842	0.1061
RDE does not Granger Cause GDPPC	1.63500	0.2259
STJA does not Granger Cause GDPPC	0.37715	0.6918
PAR does not Granger Cause GDPPC	2.16962	0.1467

Source: Author`s calculation

5. 4. CO-INTEGRATION TEST

Due to the small sample size, the long-term association between variables was examined using the ARDL model. In order to ascertain the effect of technological advancement on the Republic of Kazakhstan's economy, this study employs the ARDL bounds testing approach to examine the long-term relationship between a few chosen factors and GDP per capita. Determining the lag length prior to conducting the cointegration test is crucial. The lag length criterion is determined using LR, FPE, AIC, SC, and HQ. Table 5 displays the outcomes of the chosen lag, which indicates that the chosen lag length is 2 since it has more stars and is utilized in the study.

Table 5. Selection order criteria

ARDL(1, 2, 2, 0, 1)						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	-468.8130	NA	2.72e+13	45.12505	45.37375	45.17902
1	-367.6082	144.5783*	2.08e+10	37.86745	39.35962*	38.19129
2	-337.3022	28.86283	2.06e+10*	37.36212*	40.09777	37.95582*

Source: Authors' analysis results

5. 5. RESULTS OF LONG- AND SHORT-RUN RELATIONSHIPS

The first difference was used in the study to estimate the ARDL linear model (Equation 2). Table 7 shows the findings of both long-term and short-term investigation of the relationships between the variables. Since the F-statistic for ARDL (Table 6) (7.220921) is statistically significant at the 1–10 percent levels and surpasses the upper limit of 4.44, the results of the cointegration F-test show that the chosen variables are cointegrated and that there is a long-term relationship among them in the case of Kazakhstan.

Table 6. Results of cointegration test

Model	F Statistics	Critical Bounds	Decision
ARDL(1, 2, 2, 0, 1)	7.220921	3.01-4.44	Cointegration

Critical bounds are reported at 1% (***) and 10% (**) level of significance

Source: Authors' analysis results

Table 7. Results of ARDL Estimation (2000-2022)

Model 1- results of ARDL (1, 2, 2, 0, 1) estimation Δ(GDPPC)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
Short Run				
GDPPC(-1)*	-0.274342**	0.098510	-2.784917	0.0177
ICT(-1)	-4683.764***	1296.242	-3.613340	0.0041
RDE(-1)	-12539.39	7516.584	-1.668230	0.1235
STJA**	1.016682**	0.442679	2.296657	0.0423
PAR(-1)	3.292542**	1.250904	2.632131	0.0233
Δ(ICT)	1113.028	636.7630	1.747947	0.1083
Δ(ICT(-1))	4590.588***	1066.479	4.304433	0.0012
Δ(RDE)	-24440.57**	8412.542	-2.905254	0.0143
Δ(RDE(-1))	-15490.36*	7466.473	-2.074656	0.0623
Δ(PAR)	1.261092	0.789084	1.598173	0.1383
Long Run				
ICT	-17072.70*	7762.205	-2.199465	0.0501
RDE	-45707.10**	18094.55	-2.526015	0.0282
STJA	3.705889***	0.840499	4.409153	0.0010
PAR	12.00158***	2.440706	4.917258	0.0005
Diagnostic	F-statistics		P-value	
Serial correlation	0.376617		0.6965	
Heteroscedasticity	1.508046		0.2639	
Jarque-Bera	0.804884		0.6687	

1) coefficients are statistically significant at ***1%, **5%, *10% level of significance.

2) compiled by the authors

Source: Authors' analysis results

The findings presented in Table 7 show that, ceteris paribus, the ICT and RDE variables have a negative long-term effect on changes in GDPPC in Kazakhstan (corresponding coefficients of -17072.70 and -45707.10). In contrast, STJA and PAR are positively correlated with Δ(GDPPC) with corresponding values of 3.705889 and 12.00158.

According to the empirical data, STJA and Δ(GDPPC) have a positive short-term relationship in Kazakhstan (coefficient = 1.016682). The model's findings support the notion that Δ(RDE) and Δ(GDPPC) are negatively correlated (-24440.57).

Furthermore, the lagged variable PAR(-1) exhibits a positive relationship with Δ(GDPPC) (3.292542), and ICT(-1) has a negative relationship with Δ(GDPPC) (-4683.764) if the coefficient of the lagged variable GDPPC(-1) in the period t-1 in the short run turns out to be negative (-0.274342). The short-term change in Δ(RDE) has a significant and negative correlation with Δ(GDPPC), with a corresponding coefficient of -24440.57. In the near term, the lagged variables Δ(RDE(-1)) and Δ(ICT(-1)) have a negative (-15490.36) and positive (4590.588) correlation with Δ(GDPPC), respectively.

To verify the stability of the linear ARDL model, diagnostic tests were conducted (Table 7). These included tests for heteroscedasticity, serial correlation, and normality. For this model, the null hypotheses of homoscedasticity, normalcy, and no serial correlation cannot be disproved. This suggests that serial correlation and heteroscedasticity are absent from the ARDL model. The diagnostic test results are shown in Table 7. For the ARDL model, the probability value is 0.6965 and the serial correlation is 0.376617.

This study concludes that there is no serial correlation in the model and the null hypothesis is accepted. The model is homoscedastic, as indicated by the heteroscedasticity tests' F-statistic of 1.508046 and probability of 0.2639, both of which are higher than the 0.05% significance threshold. Given that the F-statistic is 0.804884 and the probability value is 0.6687, both of which are higher than the 5% significance level, the model accepts the null hypothesis of the normality test and determines that the residuals are normally distributed. Lastly, the robustness of the ARDL model was demonstrated by the successful completion of the diagnostic tests for serial correlation with the Lagrange multiplier, the Jarque-Bera normalcy test, and the heteroscedasticity test.

5. 6. ROBUSTNESS ANALYSIS

The dependability of the long-run estimations derived from the ARDL estimation was verified by utilizing estimating techniques such as FMOLS, DOLS, and CCR. Table 8 shows the estimated outcomes of using DOLS, FMOLS, and CCR. It is demonstrated that the DOLS, CCR, and FMOLS results exhibit dependable and consistent characteristics, ultimately yielding findings that align with those of the ARDL estimations. This information specifically shows that GDPPC rises with the growth of ICT and RDE, while it falls with the growth of STJA and PAR. Consequently, conclusions based on the results obtained can be drawn with a high level of confidence.

Table 8. Results of FMOLS, DOLS and CCR estimations (2000-2022)

Dependent Variable: GDPPC						
Independent Variable	FMOLS		DOLS		CCR	
	Coeff.	t-Stat.	Coeff.	t-Stat.	Coeff.	t-Stat.
ICT	-1413.435	-0.793487	-1935.61***	-3.031950	-487.3008	-0.378431
RDE	-47883.9***	-3.835818	-63690.6***	-4.262077	-67244.2***	-6.354591
STJA	3.800016***	5.690868	4.765461***	3.523432	1.037945	0.924634
PAR	9.669348***	5.954420	11.81804***	5.897732	5.014718***	2.910470
R^2	0.471937		0.771832		0.637829	
Adj.R^2	0.383926		0.657748		0.552612	

1) coefficients are statistically significant at ***1%, **5%, *10% level of significance.
2) compiled and calculated by the authors

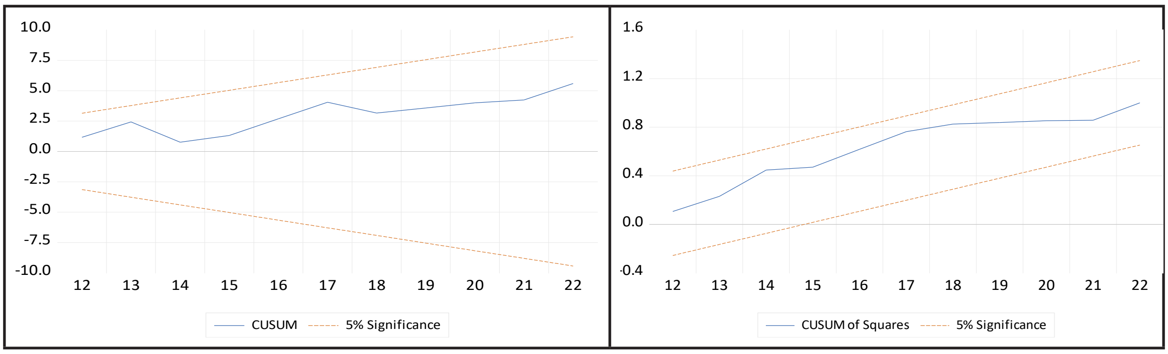
Source: Authors' calculation

The results of FMOLS, DOLS, and CCR are corroborated by the long-run nonlinear ARDL findings for GDPPC, STJA, PAR, ICT, and RDE.

5. 7. STABILITY TESTS

To determine whether the coefficients of the built model stay constant over time, Figure 2 displays the findings of the CUSUM and CUSUM-squared tests, which are markers of model stability. The reliability of the model is demonstrated by the tests' failure to surpass the critical threshold values at the 5% significance level. The long-term dynamics of the regression are also examined using this test.

Figure 2. CUSUM and CUSUM squares tests



Source: Author`s calculation

6. CONCLUSION

The study examined how a nation's economic development is affected by technological development variables. Determining which of these factors had an impact and to what degree over what time frame was the study's purpose.

For this purpose, the authors used factors such as GDP per capita, ICT goods exports, Research and development expenditure, Scientific and technical journal articles and Patent applications covering the period 2000-2022. The authors proposed hypotheses H0-H2 based on modeling, with hypothesis H0 being fully validated. Both in the short and long term, Kazakhstan's economic development benefits from the volume of patent applications. The study concluded that exports of ICT items had a negative effect on GDP per capita, hence rejecting hypothesis H1 in both the short and long term. The favorable impact of Scientific and technical journal articles on economic development is proven, but the negative effect of R&D spending (as a percentage of GDP) on GDP per capita disproves H2. As a result, the authors believe that the Republic of Kazakhstan will gain from the creation of knowledge-intensive and patent-oriented technologies that promote economic development.

Some policy implications

It is clear that in order to attain economic and technological success based on scientific principles, sustained supported for science is essential in Kazakhstan, which is now working to advance its scientific capabilities. First and foremost, "continuous," not temporary funding, is required for the advancement of patent-oriented science. Since "defeats" in science are equivalent to "victories," science should not be dependent on money from three-year grants and programs.

We suppose it would be beneficial to provide medium- or long-term grants under the framework of patent-required scientific grant funding. Funds devoted to science have a detrimental effect on economic development for a number of reasons:

- Every scientific endeavor requires publishing articles in journals that are included in international databases. Since publications must be published within the three-year grant period, researchers need to submit their work to expensive, quick-publishing journals to meet deadlines. This has a detrimental effect on science investment in terms of financial leakage. However, scientific articles in indexed databases continue to yield a return by increasing engagement and synchronization with global trends. In this regard, it is necessary to study in which areas such articles are needed, and which areas can develop without international publications, where domestic articles are sufficient.
- Lack of continuity in scientific results: instead of studying a major problem over many years and finding a solution, short-term grants lead to “overlap” or “duplication”.
- Since science and higher education are currently managed by the same ministry in the Republic of Kazakhstan, scientific research institutes remain overshadowed by universities. Establishing a separate ministry for science could help address scientific issues at a more fundamental level.

7. DECLARATIONS

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Competing Interests

The authors declare that they have no competing interests.

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