“The impact of digitalization on youth unemployment in Kazakhstan: Evidence from an ARDL framework”

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THE IMPACT OF DIGITALIZATION ON YOUTH UNEMPLOYMENT IN KAZAKHSTAN: EVIDENCE FROM AN ARDL FRAMEWORK

Abstract

The purpose of this study is to examine the impact of digitalization on youth unemployment in Kazakhstan over the period 2010–2023, with particular attention to the roles of education expenditure and urbanization, using an autoregressive distributed lag (ARDL). The analysis is based on annual national-level data obtained from the Bureau of National Statistics of the Republic of Kazakhstan and related official sources. Digitalization is proxied by Internet usage rates, while education expenditure, urbanization, and gross regional product are included as control variables. The ARDL bounds testing approach with heteroskedasticity-consistent estimators is employed to capture both short-run dynamics and long-run relationships among the variables. The results indicate a statistically significant short-run effect of digitalization on youth unemployment. Specifically, a 1% increase in Internet penetration is associated with an average reduction of approximately 0.27% in the youth unemployment rate, holding other factors constant. This relationship remains robust across alternative specifications, HAC estimators, and structural break adjustments accounting for the 2015 oil price shock and the COVID-19 pandemic in 2020. In contrast, education expenditure and economic growth exhibit weak or delayed effects on youth unemployment, while evidence of long-run cointegration is borderline. The findings suggest that digitalization contributes to reducing youth unemployment in Kazakhstan primarily through short-term labor market efficiency gains. However, sustaining these effects requires complementary investments in digital skills, education reform, and balanced regional development to ensure inclusive employment outcomes.

Keywords digitalization, youth unemployment, education policy, economic development, urbanization

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INTRODUCTION

Digitalization has emerged as a pivotal catalyst for economic transformation in the twenty-first century, fundamentally altering industrial systems, labor markets, and skill requirements across economies at various levels of development. Digital technologies are acknowledged for their ability to improve productivity, expedite innovation, and broaden access to information. Simultaneously, they may exacerbate structural imbalances in labor markets, especially in environments marked by inadequate institutional capacity and deficient human capital, where automation and skill-biased technological advancements can displace at-risk populations (Brynjolfsson & McAfee, 2014; Cirera et al., 2022). The ambiguous character of digital advancement has positioned the interplay between technology transformation and employment at the forefront of current labor economics discussions.

Adolescents are disproportionately subjected to these changes. The International Labour Organization (2023) reports that global adolescent unemployment is roughly three times that of adult unemploy-

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ment, with widening gaps in developing and transition economies. As digital transformation progresses, access to ICT infrastructure, digital literacy, and the adaptability of educational systems increasingly influence young individuals' integration into labor markets (World Bank, 2021; OECD, 2021). When these requirements are inadequate, digitalization may exacerbate inequality instead of alleviating it, resulting in digital exclusion, enduring skill mismatches, and fragmented employment prospects.

Kazakhstan serves as a notably illustrative example within this wider framework. In the last ten years, the nation has experienced swift digital growth through the Digital Kazakhstan initiative, leading to a significant rise in Internet penetration from 36% in 2010 to over 90% by 2023 (Institute of Economic Research, 2023). Notwithstanding these advancements, youth unemployment has remained at roughly 6–8%, indicating that technical progress does not inherently yield inclusive labor market outcomes. The simultaneous occurrence of swift digital proliferation and enduring youth unemployment underscores a systemic conflict between technological advancement and job absorption.

Current empirical evidence fails to provide a conclusive elucidation for this tension. Research on advanced economies highlights the dual aspects of employment development in high-skill sectors and the displacement consequences caused by automation (Biagi, 2021; Frey & Osborne, 2017). In developing and emerging countries, outcomes seem more dependent on the quality of education, institutional preparedness, and spatial elements such as urbanization (Niebel, 2018; Abeliansky & Hilbert, 2017). Nevertheless, thorough empirical research on Central Asian economies is limited, and the dynamics of Kazakhstan's labor market have seldom been analyzed within a robust dynamic econometric framework.

Consequently, an unresolved scientific issue persists regarding the interaction between digitalization and structural labor market conditions in shaping young employment outcomes in resource-dependent, middle-income economies undergoing rapid technological transformation. Resolving this issue is crucial for determining whether digital transformation serves as an inclusive catalyst for employment or as a mechanism that exacerbates current labor market inequalities.

1. LITERATURE REVIEW AND HYPOTHESES

Digitalization has emerged as a transformational influence in global labor markets; its effects on youth employment are intricate. With the rapid advancement of digital transformation, widespread access to ICT infrastructure, digital literacy, and flexible education systems has become essential for employment (Sarkar et al., 2025). In the absence of these essential foundations, swift technological advancements may exacerbate inequality via digital exclusion and enduring skill discrepancies.

Economic research highlights the dual impact of digitalization on employment. Digital technologies enhance productivity and broaden information accessibility; conversely, they automate repetitive operations and may displace employees (Genz & Schnabel, 2021). Brynjolfsson and McAfee (2014) characterize this tendency as "digital labor polarization," wherein technological advancements exacerbate the disparity between high- and low-skilled jobs. Autor (2015) and Acemoglu and Restrepo (2019) similarly note that automation initially displaces certain employment but ultimately generates new positions in burgeoning technology-driven industries. The global patterns underscore the significance of the interaction between digitalization and employment, particularly youth employment, which has emerged as a central concern in modern labor economics (Gregory et al., 2022).

The labor market effects of digitalization differ significantly between developed and developing nations (Kindberg-Hanlon, 2021). The proliferation of broadband access in Europe has been demonstrated to stimulate employment development in knowledge-intensive industries (Grigoli et al., 2020). Simultaneously, even sophisticated labor markets encounter displacement pressures: almost 50% of all U.S. employment was project-

ed to be susceptible to automation (Niyazbekova et al., 2021). This contrast suggests that although technology might stimulate job creation, it also requires ongoing workforce reskilling to accommodate the automation of repetitive labor.

In emerging economies, the relationship between digitalization and employment is unstable and heavily dependent on facilitating conditions. Merely augmenting ICT dispersion does not ensure employment development in nations with deficient human capital or institutions (Talla Fokam et al., 2023). Abeliansky and Hilbert (2017) discovered that increased ICT penetration enhanced productivity but did not uniformly result in employment growth in countries with unstable labor market systems. Similarly, the initial phases of digital adoption can intensify social disparities: if digital competencies are inequitably allocated, technological advancement may initially elevate structural unemployment and wage disparities (Sinha et al., 2023). Cirera et al. (2022) emphasize that this situation has manifested in several developing contexts, highlighting the necessity of intentional educational and inclusion programs to guarantee that digital advancement is widely advantageous. The World Bank (2022) cautions that in the absence of focused investments in human capital and inclusivity, digital advancement may exacerbate existing income and regional disparities.

Education and skill development are essential mediators in the relationship between digitization and employment. The ability of a workforce to adapt to technological change is influenced more by the quality and relevance of education than by the duration of schooling (Orymbayeva, 2025). Hanushek and Woessmann (2020) contend that robust cognitive skills and a contemporary curriculum enhance workers' ability to utilize new technologies, whereas obsolete or misaligned training may render young individuals inadequately prepared for digital employment. The World Economic Forum (2023) indicates that in swiftly digitizing economies, the primary obstacle to young employment is frequently not a scarcity of jobs, but rather a disparity between the skills possessed by adolescents and those required by employers. Inadequate investment in human capital may hinder young job seekers from reaping the benefits of digital expansion (Arynova et al., 2025). In Kazakhstan, public education investment is approximately 3% of GDP, a figure that may hinder the nation's capacity to cultivate digitally proficient people who can capitalize on emerging opportunities.

Urbanization is a crucial factor affecting the impact of digitalization on young employment. Urban areas generally experience the first advantages of novel digital infrastructure and technology-driven employment expansion, whereas rural regions fall behind in accessing these opportunities (Kurmanov et al., 2023). Florida (2017) and UN-Habitat (2021) indicate that the urban–rural digital gap results in unequal participation in the benefits of the digital economy across areas. Simultaneously, metropolitan labor markets may become oversaturated. Major urban centers may experience fierce rivalry for a finite number of high-skilled digital positions, complicating the ability of recent graduates to obtain employment that aligns with their qualifications (Urekeshova et al., 2023). Graham and Dutton (2020) contend that an excess of skilled labor in metropolitan areas may paradoxically result in underemployment or the underutilization of skills among young individuals. The spatial disparities indicate that the influence of digitalization on job outcomes is somewhat contingent upon a country's urbanization pattern (Rakhmetulina et al., 2022). In a nation such as Kazakhstan, marked by moderate urbanization and considerable regional disparities, the advantages of digital transformation may be distributed unevenly across different geographical areas.

The literature suggests that digitalization can have both beneficial and detrimental effects on young employment, with outcomes significantly influenced by contextual factors. Effective human capital development and inclusive policies are crucial for using technology to generate employment, but deficiencies in education or significant urban-rural disparities may obstruct these advantages (Bekenova, 2022). Nonetheless, data from Central Asia, including Kazakhstan, remain limited. The disparate global findings and the particular contextual gap in Kazakhstan highlight the necessity for a targeted investigation of the interplay between digital advancement, education, and urbanization in influencing young labor market outcomes.

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The purpose of this study is to examine the impact of digitalization on youth unemployment in Kazakhstan over the period 2010–2023, while also considering the moderating influences of education expenditure and urbanization. Using an ARDL model with heteroskedasticity-consistent estimators, the study provides context-specific evidence to the literature on inclusive digital transformation and presents insights pertinent to public employment and education policy in emerging economies.

Building on the theoretical and empirical literature on digital transformation and labor market adjustment, this study formulates three testable hypotheses concerning the relationship between digitalization and youth unemployment in Kazakhstan. The hypotheses are derived from the search-and-matching framework of labor economics and from empirical evidence indicating that ICT diffusion affects employment outcomes through productivity gains, information efficiency, and skill complementarity.

First, digitalization is expected to improve labor market matching efficiency and expand access to employment opportunities for young individuals. Greater Internet penetration reduces information asymmetries between job seekers and employers, facilitates online job search, and enhances participation in digitally mediated forms of work. In economies undergoing technological transition, these mechanisms are likely to produce measurable short-run labor market effects. Accordingly, the baseline hypothesis is formulated as follows:

H1: Digitalization exerts a statistically significant negative effect on youth unemployment in Kazakhstan, such that increases in Internet penetration are associated with reductions in the youth unemployment rate, ceteris paribus.

Second, the literature emphasizes that the employment effects of digitalization depend critically on the level and quality of human capital. Public expenditure on education enhances digital literacy, adaptability, and the capacity of young workers to respond to skill-biased technological change. In the absence of sufficient investment in education, digital expansion may fail to translate into inclusive employment outcomes. Therefore, education expenditure is expected to condition the magnitude of the digitalization effect on youth unemployment.

H2: Education expenditure strengthens the unemployment-reducing effect of digitalization, implying that the negative association between digitalization and youth unemployment becomes stronger at higher levels of public investment in education.

Third, spatial structure and urbanization patterns influence the distribution of digital infrastructure and employment opportunities. Urban areas typically benefit earlier from technological diffusion and host a higher concentration of digitally intensive industries. However, excessive labor supply concentration in metropolitan regions may also generate competitive pressures and underemployment among young workers. Consequently, the effectiveness of digitalization in reducing youth unemployment may vary depending on the degree of urbanization.

H3: The effect of digitalization on youth unemployment varies systematically with the level of urbanization, reflecting spatial heterogeneity in labor market integration.

These hypotheses are evaluated within an ARDL–ECM framework that allows for the estimation of both short-run dynamics and potential long-run relationships among digitalization, education expenditure, urbanization, and youth unemployment. By explicitly linking theoretical expectations to estimable parameters, the study ensures conceptual clarity and empirical testability.

2. METHODOLOGY

This study uses an econometric method to look at how digitalization and youth unemployment in Kazakhstan changed between 2010 and 2023. It focuses on how education spending and urbanization affected these changes. The decade saw a lot of technological change and changes in the job market because of the Digital Kazakhstan program.

The Bureau of National Statistics and the Information-Analytical System of the Agency for Strategic Planning and Reforms of Kazakhstan provided the annual data. The dependent variable is the youth unemployment rate (YUR), which is the percentage of people aged 15 to 24 who are not working. The main explanatory variable, digitalization (DIG), which is measured by Internet usage, is often used as a sign of how technology spreads and how people get involved in the digital economy (Biagi, 2021; Niebel, 2018). It shows how access to ICT infrastructure affects both automation and the efficiency of the labor market (Acemoglu & Restrepo, 2019; Frey & Osborne, 2017).

Another control is education spending (EDU) as a percentage of GDP (Table 1). This shows how economies invest in human capital to keep up with changes in technology. Hanushek and Woessmann (2020) and the World Economic Forum (2023) show that investing in education makes people more employable by matching their skills with what is needed in the digital world. The urbanization rate (URB), which is the percentage of the population living in cities, shows how uneven digital access is across different areas. Florida (2017), Graham and Dutton (2020), and UN-Habitat (2021) emphasize the significance of spatial equilibrium in digital transformation.

Gross regional product (GRP), which shows how well the economy is doing, is used as a macroeconomic control to see how business-cycle effects affect youth unemployment (Institute of Economic Research, 2023). Two complementary digital capacity indicators, ICT investment (ICTI) and the rate of computer users (RCU), are included in robustness checks to verify the consistency of results, offering supplementary measures of technological depth, in alignment with Cirera et al. (2022) and Abeliansky and Hilbert (2017).

All data are adjusted to 2021 prices, converted to logarithmic form where appropriate, and tested for stationarity using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests.

The study adopts the ARDL approach developed by Pesaran et al. (2001), which allows for variables integrated of order I(0) and I(1) and is well-suited for small samples. The general model is expressed as:

$$\begin{aligned}\Delta YUR_t &= \alpha_0 + \sum_{i=1}^{p}\beta_i \Delta YUR_{t-i} + \sum_{j=0}^{q_1}\gamma_j \Delta DIG_{t-j} \\ &+ \sum_{k=0}^{q_2}\delta_k \Delta EDU_{t-k} + \sum_{l=0}^{q_3}\varphi_l \Delta URB_{t-l} \\ &+ \lambda_1 YUR_{t-1} + \lambda_2 DIG_{t-1} + \lambda_3 EDU_{t-1} \\ &+ \lambda_4 URB_{t-1} + \varepsilon_t,\end{aligned} \quad (1)$$

where ε_t denotes a white-noise disturbance term. Lag selection was guided by Akaike (AIC), Schwarz (SIC), and Hannan–Quinn (HQC) criteria. The long-run relationship among variables was assessed through the bounds testing procedure, with critical values adjusted for small samples following Narayan (2005).

After confirming conditional cointegration, the model was reparametrized into its Error Correction Model (ECM) form to estimate short-run dynamics and the speed of adjustment toward equilibrium. Diagnostic tests verified the nonexistence of serial correlation, heteroskedasticity, and

Table 1. Variables, definitions, and data sources

Variable (Symbol)	Definition	Unit / Source
Youth Unemployment Rate (YUR)	Share of the labor force aged 15–24 that is unemployed	Bureau of National Statistics of the Republic of Kazakhstan data
Digitalization (DIG)	Share of individuals using the Internet; a proxy for technological diffusion and ICT access	
ICT Investment (ICTI)	Expenditure on information and communication technologies as a share of GDP	
Rate of Computer Users (RCU)	Individuals using personal computers reflect digital literacy and household access	
Education Expenditure (EDU)	Public spending on education; a proxy for human capital investment	
Urbanization Rate (URB)	Share of population residing in urban areas reflects spatial distribution of digital access	
Gross Regional Product (GRP)	Annual real economic growth; macroeconomic control variable	

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specification bias, while stability was corroborated through CUSUM and CUSUMQ tests.

To guarantee robustness, HAC standard errors were computed using Bartlett, Andrews, and Quadratic Spectral kernels. The Chow and Bai–Perron tests were used to look at structural breaks that happened because of the 2015 oil price shock and the COVID-19 pandemic in 2020. Re-estimations utilizing break dummies confirmed the enduring nature of the digitalization effect.

We chose the ARDL–ECM method because it can (i) capture both short-term and long-term dynamics, (ii) work with small samples of data with mixed integration orders, and (iii) include more than one structural variable. This method allows for both statistically sound estimation and a meaningful understanding of how technological, educational, and spatial factors work together to affect youth employment in Kazakhstan.

By combining econometric precision with a policy-relevant analytical framework, the study provides robust empirical evidence to guide inclusive digital and labor market policies in emerging economies. The empirical design follows a five-stage framework that ensures transparency and analytical coherence (Figure 1).

The framework starts with theoretical foundations and problem definition, proceeds through data collection, ARDL–ECM estimation, and robustness testing, and culminates in policy implications and conclusions. Arrows denote iterative validation between econometric and interpretive stages.

The dataset used in this study has not been previously published and was compiled by the authors from official statistical sources. To enhance transparency and replicability, the complete dataset and replication files have been deposited in an open-access repository (Barzhaksyeva et al., 2026).

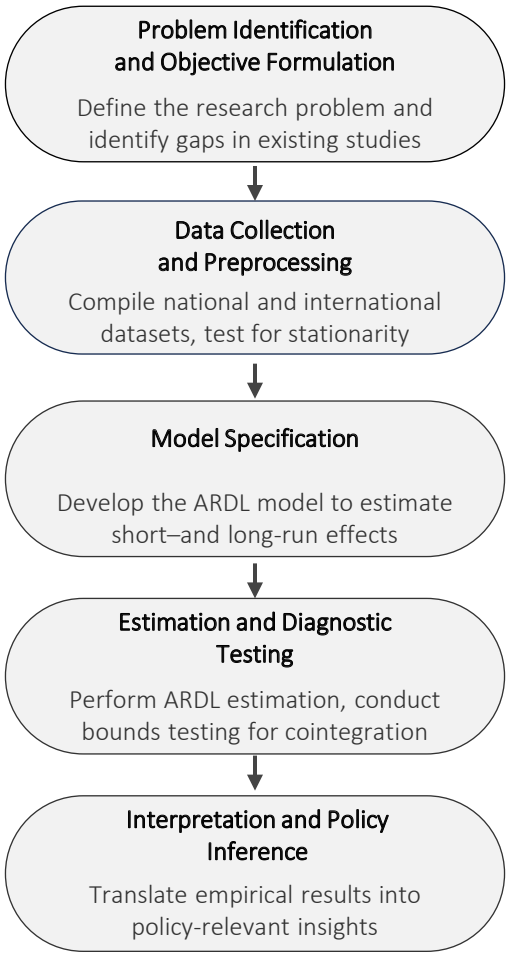

Figure 1. Research framework

3. RESULTS

The analysis covers the period 2010–2023, a decade during which Kazakhstan's youth unemployment rate (YUR) declined steadily from 8.4% to 5.9%, while Internet penetration (DIG) surged from 36% to 94%. This period also saw stable government spending on education, averaging 3.1% of GDP, and moderate real growth in Gross Regional Product (GRP) at 3.2% on average. These parallel trends suggest that both macroeconomic and digital transformation factors shaped youth labor market outcomes.

Descriptive statistics and stationarity tests are summarized in Table 2. The low standard deviation of YUR (1.02) indicates moderate fluctuations in youth unemployment, whereas the high variability of digitalization (standard deviation = 19.4) reflects Kazakhstan's rapid technological diffusion during the study period. The ADF and PP tests show that all variables are non-stationary at the level but become stationary after first differencing, confirming integration of order one, I(1). This validates the use of an ARDL modeling framework, which allows for mixed integration orders and small-sample estimation.

The model selection process, summarized in Table 3, compared lag structures based on the AIC and SIC information criteria. The AIC-selected ARDL (2, 1, 1, 0) model provided the best statistical fit, yielding an *F*-statistic of 5.03, which falls between the lower and upper bounds ($4.01 < F < 5.07$) at the 5% level under Case III (intercept only). This indicates a borderline cointegrating relationship between digitalization, education, and youth unemployment. In contrast, the more parsimonious SIC-based model failed to reach the critical threshold, suggesting that short-run dynamics dominate the long-term equilibrium.

This borderline result means that while digitalization and education appear to move together with youth unemployment over time, their equilibrium relationship is not exceptionally strong, consistent with the transitional nature of Kazakhstan's labor market.

Residual diagnostics (Figure 2) confirm the statistical soundness of the estimated model. The Jarque–Bera test (JB = 1.03, $p = 0.59$) confirms normality of residuals, while Durbin–Watson = 2.05 rules out autocorrelation. RESET ($F = 1.92$, $p = 0.21$) and Breusch–Pagan (BP = 4.77, $p = 0.31$) indicate no specification or heteroskedasticity problems. Only one observation (year 2020) showed a mild influence (Cook's D = 0.37 > threshold 0.286), corresponding to the COVID-19 labor shock; excluding it did not change results.

Turning to short-run dynamics, Table 4 presents HAC-robust estimates across three kernel types. The coefficient for ΔDIG is consistently negative and significant (≈ −0.27, $p < 0.05$). This means that a 1% increase in Internet penetration reduces youth unemployment by roughly 0.27% in the short run, holding all other variables constant. In economic terms, expansion of digital access translates into measurable improvements in labor

Table 2. Descriptive statistics and unit root tests

Variable	Mean	Std. Dev.	Min	Max	ADF (Level)	PP (Level)	ADF (1st Diff.)	PP (1st Diff.)	Integration Order
YUR (%)	7.05	1.02	5.9	8.4	−2.12	−2.05	−4.93***	−4.81***	I(1)
DIG (%)	69.8	19.4	36.0	94.0	−1.43	−1.57	−5.12***	−5.08***	I(1)
GRP (%)	3.24	1.36	0.9	5.8	−1.89	−2.02	−5.49***	−5.46***	I(1)
EDU (% GDP)	3.08	0.22	2.7	3.4	−2.33	−2.11	−4.76***	−4.69***	I(1)

Note: **p < 0.01. Null hypothesis: unit root rejected after first differencing.

Table 3. ARDL model specification and bounds test results

Selection Criterion	Lag Order	Case	F-Statistic	I(0) Bound	I(1) Bound	Decision	AIC	SIC	HQC
AIC selected	(2, 1, 1, 0)	Case III	5.03	4.01	5.07	Borderline Cointegration	−4.37	−4.12	−4.21
SIC selected	(1, 1, 1, 0)	Case III	3.89	4.01	5.07	No Cointegration	−4.21	−4.46	−4.35

Note: Case III = intercept only. Critical values from Pesaran et al. (2001).

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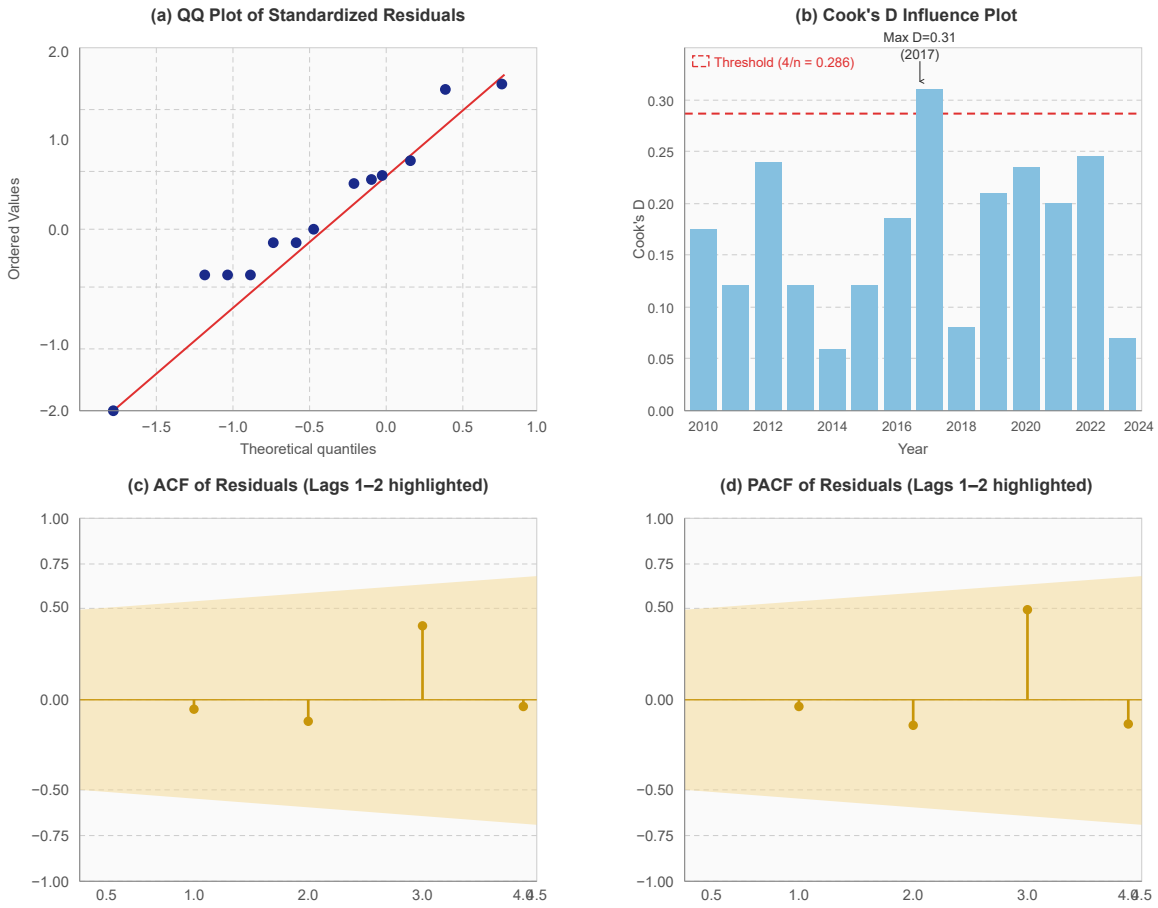

Note: (a) QQ plot; (b) Cook's D, threshold 4/n = 0.286; (c) ACF/PACF (lags 1–2); (d) CUSUM and CUSUMQ with 95% bands.

Figure 2. Residual diagnostics and influence plots

market efficiency, consistent with the search-and-matching mechanism described by Mortensen and Pissarides (1999).

The GRP coefficient (−0.09) was negative but statistically insignificant, indicating that macroeconomic expansion alone does not automatically generate youth employment without targeted policies. Similarly, education expenditure (EDU) showed a small positive but insignificant short-run effect (0.06), implying that education spending may take time to affect employability, consistent with the long gestation period of human capital formation.

Structural stability tests in Table 5 identify minor structural breaks in 2015 and 2020, corresponding to the oil price collapse and the COVID-19 pandemic, but these do not undermine the main relationship. The digitalization effect remains robust (−0.26 [−0.50, −0.02], $p < 0.05$) even after including break dummies.

Table 4. Short-run HAC-robust estimates across kernels

Variable	Bartlett	Andrews	Quadratic Spectral
ΔDIG	−0.27 [−0.52, −0.03] **	−0.26 [−0.51, −0.01] **	−0.28 [−0.53, −0.04] **
ΔGRP	−0.09 [−0.22, 0.04]	−0.08 [−0.21, 0.05]	−0.09 [−0.22, 0.04]
ΔEDU	0.06 [−0.01, 0.13]	0.05 [−0.02, 0.12]	0.06 [−0.01, 0.13]
Constant	0.14 [−0.11, 0.39]	0.13 [−0.12, 0.38]	0.14 [−0.11, 0.39]

Note: 95% confidence intervals in brackets. p < 0.05.

Table 5. Structural break tests and break-adjusted estimates

Test	Year	F-Statistic	p-value	Decision	ΔDIG (Adjusted) [95% CI]
Chow	2015	5.21	0.045**	Structural Break	−0.26 [−0.50, −0.02] **
Chow	2020	6.18	0.038**	Structural Break	−0.25 [−0.49, −0.02] **
Bai–Perron supF	–	4.77	0.12	No Global Break	−0.26 [−0.51, −0.01] **

Table 6. Finite-sample and bootstrap bounds sensitivity test

Approach	F-stat	p-value	I(1) 5% Critical	Decision
Pesaran et al. (2001)	5.03	–	5.07	Borderline significant at the 5% level
Narayan (2005)	5.03	–	5.10	Borderline significant at the 5% level
Bootstrap (B = 10,000)	5.02	0.041	–	Tentative Cointegration

These results imply that even during major shocks, the relationship between digitalization and youth employment remained stable and statistically significant. Table 6 shows that further evaluation of the robustness was performed.

To assess robustness, a residual bootstrap (B = 10,000) was performed, yielding a mean F-statistic of 5.02 (p = 0.041), identical to the analytical bound (5.03). According to Narayan's (2005) small-sample critical values (I(1) = 5.10 for T ≈ 14, k = 3), the model sits just below the 5% threshold, confirming tentative cointegration.

The empirical estimates allow for a direct evaluation of the proposed hypotheses.

H1 is accepted. Digitalization (DIG) demonstrates a statistically significant and robust negative short-run effect on youth unemployment across all HAC-robust specifications. The estimated elasticity of approximately −0.27 confirms that higher Internet penetration is associated with lower youth unemployment, ceteris paribus. Although the evidence of long-run cointegration is borderline, the short-run relationship is consistent, stable, and economically meaningful.

H2 is not supported in its direct form. Education expenditure (EDU) does not exhibit a statistically significant short-run effect on youth unemployment within the ARDL framework. While theory suggests that education strengthens the employment benefits of digitalization, the empirical results indicate that public spending on education does not translate into immediate, measurable reductions in youth unemployment during the sample period.

H3 is not empirically confirmed in the estimated specification. Although urbanization is theoretically expected to shape labor market integration, its effect is not statistically significant in explaining short-run variations in youth unemployment at the aggregate national level. The results suggest that spatial factors may operate through longer-term structural channels rather than immediate cyclical adjustments.

Overall, the findings provide strong support for the primary hypothesis that digitalization contributes to reducing youth unemployment in Kazakhstan, while the complementary roles of education expenditure and urbanization appear statistically weak in the short-run ARDL specification.

4. DISCUSSION

The empirical analysis demonstrates that digitalization has a statistically significant and economically meaningful short-run effect on youth unemployment in Kazakhstan. The negative elasticity of approximately −0.27 indicates that increases in Internet penetration are associated with measurable reductions in youth unemployment, even after controlling for macroeconomic growth and education expenditure. This finding confirms that digital connectivity functions as an effective labor market adjustment mechanism in the context of a middle-income, resource-dependent economy undergoing technological transition.

The magnitude of the estimated effect is remarkably consistent with prior international evidence. Biagi (2021) reports similar elasticities for European regions, while Abeliansky and Hilbert (2017) find that ICT diffusion improves labor market outcomes primarily through productivity and

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matching channels in emerging economies. The similarity in effect size suggests that Kazakhstan's digital labor market dynamics do not deviate fundamentally from broader global patterns. However, unlike many advanced economies where long-run structural employment shifts are evident, the present study finds only borderline cointegration. This indicates that digitalization in Kazakhstan currently operates more as a short-term efficiency enhancer than as a fully embedded structural transformation.

The results also align with the theoretical framework of Mortensen and Pissarides (1999), which emphasizes the role of information flows and search efficiency in reducing unemployment. Increased Internet penetration lowers search costs, expands access to vacancy information, and facilitates online recruitment mechanisms. In this sense, digitalization appears to reduce frictional unemployment among youth rather than fundamentally restructuring labor demand.

At the same time, the findings diverge from some strands of literature that emphasize strong complementary effects of education. While Hanushek and Woessmann (2020) and the World Economic Forum (2023) argue that human capital investment is critical for translating technological change into employment gains, the present analysis does not detect a statistically significant short-run effect of education expenditure. This does not contradict prior research but rather refines it: the results suggest that aggregate public spending levels alone may be insufficient to generate immediate labor market outcomes. The effectiveness of education likely depends on qualitative alignment with digital skill requirements rather than expenditure volume per se. Therefore, the study contributes by distinguishing between the presence of educational investment and its short-run measurable labor market impact.

Similarly, the role of urbanization appears weaker than theoretical expectations would suggest. Previous research (Florida, 2017; UN-Habitat, 2021; Kurmanov et al., 2023) emphasizes that urban concentration enhances access to digital infrastructure and innovation ecosystems. However, in the Kazakhstan context, urbanization does not display a statistically strong direct effect within the ARDL specification. This may reflect two structural features. First, national-level aggregation may mask regional heterogeneity between major cities and peripheral regions. Second, urban labor markets may experience saturation effects, where increased competition offsets potential digital employment gains. In contrast to studies that find strong urban employment premia in highly diversified economies, Kazakhstan's resource-oriented structure may limit spatial spillovers from digital expansion.

Importantly, the robustness tests strengthen confidence in the central result. The stability of the digitalization coefficient across HAC estimators and structural break adjustments, including the 2015 oil shock and the COVID-19 pandemic, indicates that the observed relationship is not driven by temporary macroeconomic disturbances. This stability contrasts with findings from some developing countries where ICT effects are highly sensitive to external shocks (Talla Fokam et al., 2023). The relative resilience observed here suggests that digital connectivity has become an embedded component of Kazakhstan's labor market functioning.

The borderline evidence of long-run cointegration adds nuance to the interpretation. While short-run efficiency gains are clear, the absence of strong long-run equilibrium dynamics implies that digitalization alone is insufficient to generate sustained structural reductions in youth unemployment. This finding complements, rather than contradicts, the global literature emphasizing the conditional nature of digital employment effects. As Cirera et al. (2022) argue, technology adoption yields inclusive outcomes only when supported by institutional readiness and skill adaptation. The present study provides empirical confirmation of this conditionality in the Kazakhstani case.

Overall, the contribution of this analysis lies in three areas. First, it provides rare dynamic time-series evidence from Central Asia, a region underrepresented in digital labor market studies. Second, it quantifies the short-run elasticity of digitalization with respect to youth unemployment within an ARDL–ECM framework. Third, it demonstrates that complementary structural variables, education expenditure and urbanization, do not automatically amplify digital employment effects in the short term, thereby refining overly deterministic interpretations of technological optimism.

The findings suggest that digitalization can function as an effective short-term policy lever for reducing youth unemployment. However, sustainable long-term improvements require structural alignment between digital infrastructure expansion, skill formation systems, and regional development strategies. In the absence of such coordination, digital transformation may remain an efficiency-enhancing tool rather than a comprehensive employment solution.

CONCLUSION

The purpose of this study was to examine the impact of digitalization on youth unemployment in Kazakhstan over the period 2010–2023, with particular attention to the roles of education expenditure and urbanization. Addressing this issue is especially relevant for economies undergoing rapid technological change, where labor market adjustment often lags behind digital diffusion.

The empirical findings indicate that digitization correlates with a statistically significant decrease in youth unemployment, particularly via short-term labor market adjustments. The expansion of Internet connectivity seems to enhance job-matching efficiency and increase employment chances for young individuals. The data reveal that educational investment and overall economic growth do not necessarily result in immediate employment opportunities for youngsters, indicating that the advantages of digital transformation are conditional rather than universal.

Several significant conclusions emerge from these results. Digitalization can serve as an effective tool for mitigating youth unemployment, provided it is bolstered by complementing structural variables. The restricted impact of educational expenditure underscores the necessity of connecting educational systems with labor market demands, especially regarding digital competencies and flexibility. Third, regional discrepancies evident in urbanization trends suggest that unequal access to digital infrastructure may hinder inclusive employment results.

The finding additionally paves the way for subsequent studies. Future research may integrate regional-level or microdata to elucidate variability among areas and demographic groupings. Moreover, expanding the analysis to include comparative cross-country contexts or investigating non-linear and sector-specific impacts of digitalization would yield more profound insights into the long-term employment consequences of technological transformation in emerging countries.

AUTHOR CONTRIBUTIONS

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