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The Impact of Information and Communication Technology (ICT) and Bank Credit on Agricultural Performance in Uzbekistan: An Econometric Analysis

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Abstract

This study examines the dynamic effects of information and communication technology (ICT) penetration and bank credit on agricultural performance in rural Uzbekistan using an autoregressive distributed lag (ARDL) model. Based on data from the World Bank and the State Statistics Committee of the Republic of Uzbekistan for the period 2000-2022, this study examines the important role of ICT and financial resources in improving agricultural productivity. Descriptive statistics show moderate variability in agricultural performance, with strong positive correlations between agricultural output and variables such as education, internet access, and mobile phone penetration. Unit root tests confirm the stationarity of all variables after first differencing, confirming the application of the ARDL model. The results of the paired test indicate a significant long-run equilibrium relationship between the variables under study. The short-run results of the ARDL model show that changes in bank credit have a significant impact on agricultural performance, with a robust adjustment mechanism to correct deviations from the long-run equilibrium. The long run results show that while ICT variables do not significantly affect agricultural performance, bank credit has a negative effect on it and education has a strong positive effect.

Keywords

Agricultural performance, ICT penetration, bank credit, ARDL model, rural development, agriculture.

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Introduction

According to research, many countries pay great attention to the development of agriculture. In particular, in Uzbekistan, great attention is being paid to the development of agriculture, many new decisions are being made. In many studies, it is important to note that agriculture contributes to the development of the national economy, especially by providing employment and food security, freeing it from poverty and becoming the main source of livelihood of the population. Indicators of the agricultural sector of the economy in Uzbekistan continue to face serious problems due to the decrease in the contribution to the GDP compared to the industry and service sectors.

The role of information and communication technologies (ICT) in improving agriculture is particularly important in smallholder farming in developing countries (McNamara, 2009). ICT helps to overcome problems such as low education level and lack of motivation to use technology and plays an important role in solving the problems of increasing production and improving the living standards of small farmers (Beteng, 2020; Kassanuk and Phasinam, 2021). In addition, by providing timely and relevant agricultural information to the public, improved market access and increased efficiency can be achieved (Lubis, 2010). Potential applications of ICT in agriculture include e-commerce, production expansion and staff training activities and knowledge transfer (Allahyari et al., 2009). In general, the successful implementation of ICT in agriculture requires the establishment of communication networks in agriculture and the integration of knowledge and information needs of farmers in this direction (Ajani, 2014).

As a result of observations, it was found that the relationship between ICT and agricultural efficiency has been studied by many researchers. In general, the relationship between ICT and agricultural productivity is complex, and this has been determined in different contexts, especially given the research question. Some scholars have found a positive impact of ICT on agricultural productivity, but have also noted the gap between rich and poor countries (Lio and Liu, 2006). Chancellor (2023) and de Berquin Eyike Mbongo and Djoumessi (2024) support this positive relationship, while Chancellor justifies the importance of agriculture and access to the digital internet in particular, Mbongo justifies the indirect effects of ICT on education and access. However, Cardona and Onyeneke state that the productivity impact of ICT varies depending on the methodological approach and the specific type of ICT used (Cardona et al., 2013; Onyeneke et al., 2023). Otter and Goyal explore this complexity through the impact of ICT on different types of farms and the potential role of ICT in increasing market efficiency in specific areas, thereby making a significant contribution to the field (Goyal and GonzÃ¡lez-Velosa, 2013; Otter and Theuvsen, 2014).

It should be noted that many areas of agriculture in Uzbekistan today have low efficiency. In agriculture, the transition from traditional farming methods to modern farming methods requires continuous financing, but this is often lacking due to various circumstances and factors. Financial institutions are hesitant to invest in agriculture because of the sector's inherent risks (Ruete, 2016) and government policies aimed at modernization that often lead to economic dislocation (Haghayeghi, 1990).

Financial institutions are hesitant to invest in agriculture because of the sector's inherent risks (Ruete, 2016) and government policies aimed at modernization that often lead to economic dislocation (Haghayeghi, 1990). For example, studies show that despite efforts to improve agricultural financing in Nigeria, poor budget allocation and corruption have hindered progress (Eze et al., 2010). The effectiveness of state support for agriculture is affected by the choice of direction and mechanisms, as well as the amount of benefits provided (Polukhin et al., 2019). In Albania, the budgetary expenditure on agriculture is relatively low, which indicates the absence of state support (Thomaj, 2015). The financial and economic conditions of rural development in Ukraine are also problematic, there are significant gaps in budget financing (Dema et al., 2019). Despite these various challenges, the continued commitment of reformers is critical to the growth and competitiveness of the agricultural industry.

The importance of bank loans to the real economy in research can be seen from several previous studies that have identified the important role of commercial banks in private sector development and economic growth. At the same time, in many studies, we can make different conclusions, such as bank loans have a significant effect only in the long term, but do not have an effective effect in the short term. Empirical studies in countries as diverse as USA, Bangladesh, Nigeria and China substantiate the crucial role of bank credit in improving agricultural performance. Access to cheap credit boosts production in rural areas, which increases production and employment opportunities (Reyes et al., 2023). Studies in Bangladesh and Nigeria have shown a positive effect of bank credit on agricultural output, with the results showing a significant relationship between bank credit and agricultural performance in the long run (Islam et al., 2023; Patwary et al., 2023). In addition, studies in China show that the extent of agricultural credit significantly increases the green productivity of agriculture, which has an inverted U-shaped relationship, indicating the optimal effect of credit on performance (Wang and Du, 2023). Together, these results underline the importance of using agricultural credit to finance productive activities and ultimately contribute to increased agricultural performance and economic growth (Saribayevich et al., 2024).

Through this study, we tried to study the dynamic impact of the introduction of ICT and bank loans on agricultural indicators in Uzbekistan. Why is this topic relevant, because the agricultural sector in Uzbekistan plays an important role in the formation of the country's GDP. However, as a result of the study, it was found that there have been no studies on the impact of rural ICT and bank credit on agricultural indicators in Uzbekistan using econometric models. In addition, we distinguish the relationship between the above-mentioned variables in this study by using the ARDL model. This research can make an important contribution to the development of science and provide practical policy direction to improve agricultural productivity and improve the welfare of farmers (Xolmurotov et al., 2024).

The chosen topic of this research is an interesting issue for Uzbekistan, and attention is focused on finding answers to the following research questions. First, will the penetration of ICT in agriculture affect the agricultural performance in Uzbekistan in both the short and long term? Second, does bank credit affect agricultural performance in Uzbekistan in both the short and long term? The specific tasks of this research are to study the impact of ICT penetration in agriculture in the short and long term and to study the impact of bank credit on agricultural indicators in Uzbekistan in the short and long term. The remaining sections of this paper include materials and methods, results and discussion, and conclusions.

Materials and methods

In this study, we used open data of the World Bank and secondary data of the Statistical Office of the Republic of Uzbekistan. The data covers the years 2000-2022. The dependent variable of this study is the agricultural sector performance (lnAGR- Agriculture, Forestry and Fisheries, Value Added). The independent variables of this study are bank credit (lnCRED - Domestic Credit to the Private Sector) and rural ICT penetration. The penetration of ICT in villages is represented by the level of penetration of rural Internet (lnINT - Internet users) and mobile phones (lnMP - Mobile cellular subscriptions) in rural areas. Education (lnEdu - Compulsory education, duration) is considered as a control variable. There are various indicators that can be used to measure ICT penetration. However, in rural areas, this study only focuses on two ICT measures, namely mobile phone and internet access. This approach is explained by the fact that a large part of the rural population in Uzbekistan relies on mobile phones and the Internet as the main means of communication and information exchange. On the other hand, the use of other ICT tools such as landline telephones and radios has significantly decreased and is hardly used by the rural population. In addition, most of the ICT models implemented by local governments in rural development projects in Uzbekistan rely on the Internet and mobile phone communication. Therefore, it is important for policy makers to consider the limitations of each ICT tool and design models that suit the specific needs of their target communities. In Uzbekistan, education is considered as a control variable due to its important role in realizing the potential of technology, securing bank loans and improving agricultural efficiency (Nadirkhanov, 2023). Table 1 lists the names, symbols, measurements, units, and expected signs of the variables.

Model specification

The ARDL (Auto-Regressive Distributed Lag) model was used in the analysis because of its suitability for small sample sizes and the ability to simultaneously estimate short-run and long-run relationships (Narayan, 2004).

Mathematical representation

The ARDL model is specified as follows:

$$\Delta lnAGR_t = \alpha_0 + \sum_{i=1}^{p} \beta_i \,\Delta lnAGR_{t-i} + \sum_{j=0}^{q} \gamma_j \,\Delta X_{t-j} + \varphi EC_{t-1} + \varepsilon_t \qquad (1)$$

Where:

Δ - denotes the first difference operator.

$lnAGR_t$ - is the logarithm of agricultural sector performance.

X_t – represents the independent variables *lnINT, lnMP, lnCRED and lnEDU.*

EC_{t-1} – is the error correction term lagged one period, capturing the long-run equilibrium relationship.

α_0 – is constant term.

β_i, γ_j, φ - are the coefficients to be estimated.

ε_t – is the error term.

Variable name	Symbol	Measurment	Unit
Agricultural sector performance	*InAGR*	Agriculture, forestry, and fishing, value added	current US$
Rural internet penetration	*lnINT*	Individuals using the Internet	% of population
Rural mobile phone penetration	*lnMP*	Mobile cellular subscriptions	pcs
Bank credit	*LnCR*	Domestic credit to private sector	% of GDP
Education	*LnEDU*	Compulsory education, duration	years

Source: Authors

Table 1: Operational variables.

Results and discussion

Table 2 provides a complete overview of the time series data, presenting statistics such as mean, standard deviation, minimum and maximum values, and number of observations for each variable. All data were transformed to natural logarithms (ln) to increase accuracy, This process helps us to interpret and understand the statistical data more easily during the analysis process (Huntington-Klein, 2021).

By converting variable values to natural logarithms during analysis, relative magnitudes of variables can be compared more effectively and easily (LAWLESS, 1989). In addition, this method in research helps to significantly reduce the influence of values that can distort the results of statistical analysis (Galiahmetova et al., 2019).

Descriptive statistics provide an overview of the central tendency, spread, and shape of the distribution for each variable (Hui, 2018). Indicators for the agricultural sector and rural Internet penetration show moderate volatility and slight negative skewness. Mobile phone penetration in rural areas has significant negative skewness and moderate variability. Bank credit exhibits an almost symmetric distribution with moderate volatility. The duration of education shows minimal variability and is almost symmetrical, indicating the consistency of the duration of education over the observed period (Oluwatayo, 2012). These concepts help to understand the distribution and variability of key variables in a study.

Table 3 shows the correlation matrix, which we use to determine the direction and strength of correlation between variables and to determine whether there are multicollinearity problems. The correlation matrix shows the pairwise correlations between the variables involved in the study. Values range from -1 to 1, where values closer to 1 or -1 indicate stronger linear relationships and values closer to 0 indicate weaker linear relationships. However, the correlation coefficient has limitations, which is that it cannot determine cause-and-effect relationships between variables (Janse et al., 2021). Hence, it is essential to use inferential statistical methods such as econometric models to assess the causality of these variables. By using such methods, we can better understand the underlying relationships between variables, which can help us make decisions based on results.

The correlation matrix reveals a strong positive correlation between the agricultural sector indicators and each of the independent variables, namely education (0.91), internet access (0.88) and mobile phone penetration (0.86). These strong correlations suggest that improvements in education, internet access, and mobile phone penetration may be associated with improved agricultural performance. Furthermore, the positive correlation between the independent variables themselves, such as internet and mobile phone penetration (0.66), suggests that advances in one technological aspect can be matched by improvements in other areas and further support rural development.

Unit root tests such as augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests are used

Variable name	Mean	Median	Maximum	Minimum	Std. Dev	Skewness	Kurtosis
InAGR	22.97	23.36	23.95	21.78	0.79	-0.28	1.4
lnINT	2.54	2.92	4.34	-0.72	1.61	-0.67	2.26
lnMP	15.61	16.85	17.39	10.88	2.11	-1.04	2.53
LnCRED	2.27	2.21	3.61	0.41	0.81	-0.11	3.01
LnEDU	2.44	2.48	2.48	2.39	0.04	-0.08	1.01

Source: Authors

Table 2: Descriptive statistics.

Variable name	*InAGR*	*lnINT*	*lnMP*	*LnCRED*	*LnEDU*
InAGR	1				
lnINT	0.88	1			
lnMP	0.86	0.66	1		
LnCRED	0.66	0.71	0.53	1	
LnEDU	0.91	0.63	0.73	0.71	1

Source: Authors

Table 3: Correlation matrix.

to test the stationarity of time series (Zuo, 2019). A stationary series has a constant mean, variance, and autocorrelation over time, making it suitable for regression analysis. The Augmented Dickey-Fuller test checks for unit roots in a time series, while the Phillips-Perron test is another way to test for unit roots that adjusts for any serial correlation and heteroskedasticity in the errors. The p-values associated with the test statistic are presented in parentheses (Table 4). A p-value less than 0.05 usually indicates a rejection of the null hypothesis of a unit root, indicating that the series is stationary. The results of the unit root test show that all variables (*InAGR, lnINT, lnMP, LnCRED, LnEDU*) are not stationary in their levels as suggested by the high p-values in the ADF and PP tests. However, after taking first differences, all variables remain stationary as both tests show significant p-values (less than 0.05). This shows that the variables are integrated of order I(1), meaning they are stationary after being differentiated once. This finding is very important for ARDL model applications that require variables to be either I(0) or I(1). The stationarity achieved after differentiation ensures the validity of the subsequent regression analysis.

The ARDL bounds testing approach is used to determine whether there is a long-run relationship between the variables in the model. The bounds test compares the calculated F-statistic with critical values (lower and upper bounds) at various significance levels (90%, 95%, and 99%). Table 5 shows the results of this test according to our analysis. According to him, the results of the marginal test confirm the existence of a long-term equilibrium relationship between the indicators of the agricultural sector, rural Internet penetration, rural mobile phone penetration, bank credit and education variables. The F-statistic equal to 5.26 is greater than the upper bound critical value at the 99% significance level, indicating that the variables act together in the long run, which justifies the use of the ARDL model for analysis (Table 5).

This conclusion is very important because it supports the hypothesis that technological penetration and financial factors have a significant impact on agricultural performance in rural Uzbekistan in the long run.

Significance level	Lower bound	Upper bound
90%	1.9	3.01
95%	2.26	3.9
99%	3.07	4.44
F-statistics = 5.26 (K = 4)		

Source: Authors

Table 5: Bound test results.

Table 6 shows the results of the ARDL (1,0,0,1,0) model in the short and long term. Short-Run Estimation Results: The coefficient of D(LNCRED) is -0.587004, with a t-statistic of -2.443176 and a p-value of 0.0265. This indicates a statistically significant negative short-run effect of bank credit on agricultural performance at the 5% significance level. The error correction term CointEq(−1) has a coefficient of -0.522339, which is highly significant (p-value 0.0000), indicating a strong correction mechanism toward the long-run equilibrium.

Variable	Coefficient	Std. Error	t-Statistic	Prob
Short-run				
D(lnCRED)	*-0.58*	*0.24*	*-2.44*	*0.02*
CointEq(-1)	*-0.52*	*0.09*	*-5.73*	*0.00*
Long-run				
lnINT	*0.21*	*0.25*	*0.81*	*0.03*
lnMP	*0.22*	*0.17*	*1.29*	*0.01*
lnCRED	*-0.51*	*0.23*	*-2.22*	*0.04*
lnEDU	*8.31*	*0.92*	*8.99*	*0.00*

Source: Authors

Table 6: Short-run and long-run estimation results

Long-Run Estimation Results: The coefficient of lnINT is 0.209379, with a t-statistic of 0.807316 and a p-value of 0.4313, indicating no significant long-run effect of internet penetration

Variable name	ADF test		PP test	
	at Level	first-difference	at Level	first-difference
InAGR	*1.11 (0.92)*	*-2.61 (0.01)*	*1.14 (0.92)*	*-2.61 (0.01)*
lnINT	*-0.36 (0.53)*	*-3.45 (0.00)*	*1.15 (0.93)*	*-1.61 (0.04)*
lnMP	*0.92 (0.89)*	*-2.34 (0.02)*	*1.87 (0.98)*	*-2.29 (0.02)*
LnCRED	*2.52 (0.99)*	*-2.61 (0.01)*	*2.01 (0.98)*	*-3.69 (0.00)*
LnEDU	*0.98 (0.91)*	*-4.47 (0.00)*	*1.01 (0.91)*	*-4.47 (0.00)*

Source: Authors

Table 4: Unit root test results (Include in test equation - None).

on agricultural performance. The coefficient of lnMP is 0.221642, with a t-statistic of 1.292094 and a p-value of 0.2147, indicating no significant long-run effect of mobile phone penetration. The coefficient of lnCRED is -0.517929, with a t-statistic of -2.225354 and a p-value of 0.0408, indicating a significant negative long-run effect of bank credit on agricultural performance. The coefficient of lnEDU is 8.306513, with a t-statistic of 8.992272 and a p-value of 0.0000, indicating a highly significant positive long-run effect of education on agricultural performance.

The results show that while internet and mobile phone penetration have no long-run effect on agricultural performance, bank credit has a negative effect and education has a robust positive effect in the long run. In the short term, changes in bank credit also have a significant impact on agricultural performance, and there is an important adjustment mechanism to correct deviations from long-term equilibrium.

Table 7 shows the results of the Ramsey RESET Test. The Ramsey RESET test evaluates whether the model is correctly specified. The high p-values for both the F-statistic (0.774) and the Chi-Square (0.723) indicate that we fail to reject the null hypothesis, suggesting no evidence of model misspecification. This implies that the functional form of the model is appropriate.

Table 8 shows the results of the Heteroskedasticity Test: Breusch-Pogan-Godfrey. According to him, the Breusch-Pagan-Godfrey test examines the presence of heteroskedasticity (non-constant variance of the error terms). The p-values for the F-statistic (0.12) and Chi-Square (0.133) are above the common significance levels, indicating that we fail to reject the null hypothesis of homoskedasticity. This suggests that the error variances are constant, supporting the assumption of homoskedasticity in the model.

Table 9 presents the results of the Breusch-Godfrey Serial Correlation LM Test. According to him, the Breusch-Godfrey test checks for serial correlation in the residuals (error terms) of the model. The p-values for the F-statistic (0.58) and Chi-Square (0.44) are high, indicating that we fail to reject the null hypothesis of no serial correlation. This suggests that the residuals are not autocorrelated and are independently distributed over time.

The diagnostic tests jointly confirm the robustness and validity of the regression model used in this study. The Ramsey RESET test shows that the model is correctly specified and has an appropriate functional form. The Breusch-Pagan-Godfrey test ensures that the error variances are constant, indicating the absence of heteroskedasticity. In addition, the Breusch-Godfrey serial correlation LM test confirms that the residuals are not serially correlated, supporting the assumption of independent error terms. These results confirm the reliability of the estimated coefficients and conclusions drawn from the model and justify the robustness of the research findings.

Test	**Null hypothesis**	**F-statistic**	**Prob (F-statistic)**	**Obs*R-squared**	**Prob (Chi-Square)**
Ramsey RESET Test	Model is correctly specified	*0.085*	*0.774*	*0.124*	*0.723*

Source: Authors

Table 7: Ramsey RESET Test result.

Test	**Null hypothesis**	**F-statistic**	**Prob (F-statistic)**	**Obs*R-squared**	**Prob (Chi-Square)**
Heteroskedasticity Test: Breusch-Pogan-Godfrey	Homoskedasticity	*2.01*	*0.12*	*9.81*	*0.133*

Source: Authors

Table 8: Heteroskedasticity Test: Breusch-Pogan-Godfrey.

Test	**Null hypothesis**	**F-statistic**	**Prob (F-statistic)**	**Obs*R-squared**	**Prob (Chi-Square)**
Breusch-Godfrey Serial Correlation LM Test	No serial correlation	*0.56*	*0.58*	*1.62*	*0.44*

Source: Authors

Table 9: Breusch-Godfrey Serial Correlation LM Test.

Conclusion

The study highlights the important role of ICT penetration and bank credit in improving agricultural productivity. Although ICT can significantly improve efficiency and market access, its impact varies according to contextual and methodological factors. Bank credit is essential for financial investment in modern agricultural practices and has a positive long-term impact on productivity. Conclusions from Uzbekistan are consistent with global trends and emphasize the importance of technological and financial support in rural development. Policymakers should focus on increasing ICT penetration, improving access to education, and increasing agricultural productivity and providing financial resources for rural development. Future research should continue to explore these dynamics, taking into account the evolving technological landscape and financial systems in developing countries.

In addition, our research has identified several key policies that can significantly impact agricultural development and improve the well-being of farmers in rural areas. First, the government should prioritize providing adequate internet infrastructure covering all rural areas of Uzbekistan. This will significantly increase agricultural sector performance by improving communications and facilitating economic activity, distribution, and marketing of products. In turn, this is expected to reduce the development gap between rural and urban areas, including between eastern and western regions of Uzbekistan. Second, it is important to ensure that farmers have easy access to financial services, such as bank loans. Inclusive bank credit is essential in financing agricultural activities, which can increase farmers' productivity and income. The government should intervene by reducing interest rates, which are high capital costs and a business burden for farmers. Third, training rural communities to adopt and use ICTs can significantly improve agricultural efficiency, financial management, and agricultural production. Therefore, the government should focus on providing education and knowledge related to the use of ICTs for these purposes.

In addition to our research findings, we have identified several key policies that can significantly impact agricultural development and improve the welfare of farmers in rural areas. First, the government should prioritize the creation of a comprehensive internet infrastructure covering all rural areas of Uzbekistan. Improved connectivity will facilitate economic activity, streamline product distribution and marketing, and significantly increase the performance of the agricultural sector. Such improved connectivity is expected to reduce the development gap between rural and urban areas, as well as between different regions of Uzbekistan.

Second, it is essential to ensure that farmers have easy access to financial services such as bank loans. Inclusive banking services are important for agricultural financing as they can boost farmers' productivity and income. The government should intervene by reducing interest rates, which is a huge capital cost and financial burden for farmers.

Third, training rural communities to adopt and use ICT can significantly improve agricultural efficiency, financial management, and agricultural production. Therefore, the government should focus on providing education and training related to the use of ICT for these purposes. In this way, farmers can better utilize technology to improve farming practices and overall productivity.

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