



Article

Digital Technologies as a Driver of Integration Between Education, Science and Industry

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Abstract: Forecasting the development of integration between education, science, and industry has become increasingly important in the context of digital transformation. In recent years, digital technologies have significantly accelerated cooperation among universities, research institutions, and industrial enterprises. To analyze and predict the dynamics of this integration, modern econometric methods such as the ARIMA (Autoregressive Integrated Moving Average) model are widely used. The ARIMA model is an effective tool for analyzing time series data and identifying long-term development trends. In this study, the ARIMA model is applied to forecast the dynamics of education, science, and industry integration under the conditions of digital technologies up to 2030. The model allows the identification of structural changes and trends in the development of digital infrastructure, research collaboration, and technology transfer between academic and industrial sectors.

The results of the forecasting analysis indicate that the integration of education, science, and industry is expected to show a steady upward trend in the coming years. The increasing use of digital platforms, data technologies, and innovative research environments contributes to strengthening cooperation between universities and production sectors. This process supports the commercialization of research results, improves knowledge transfer mechanisms, and enhances innovation capacity. Overall, the use of the ARIMA model provides an analytical basis for understanding future trends in the development of digital integration between education, science, and industry. The forecasting results can support policymakers and educational institutions in developing strategies aimed at strengthening digital collaboration and improving innovation-driven economic development.

Keywords: digital technologies, education, science, industry integration, ARIMA model, time series analysis, forecasting, innovation development, digital economy.

1. Introduction

In the context of the rapid development of the digital economy, the integration of education, science, and industry has become an important factor in ensuring sustainable socio-economic development [1]. Digital technologies are significantly transforming traditional approaches to knowledge generation, dissemination, and application, creating new opportunities for cooperation between universities, research institutions, and industrial enterprises. In modern conditions, strengthening this integration contributes to the effective transfer of scientific knowledge into practical activities and supports the development of innovation-driven economies [2].

Digital transformation has accelerated the emergence of new forms of collaboration, including digital platforms, virtual research environments, and technology transfer systems. These mechanisms allow educational institutions and research organizations to interact more effectively with industrial sectors, facilitating the commercialization of scientific results and the development of innovative solutions. As a

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result, universities are increasingly becoming not only centers of education but also key participants in innovation ecosystems[3].

In order to analyze and forecast the dynamics of integration between education, science, and industry under the influence of digital technologies, modern econometric and statistical methods are widely applied. In particular, time series analysis and forecasting models such as ARIMA (Autoregressive Integrated Moving Average) allow researchers to identify trends, patterns, and long-term development trajectories. The application of these methods makes it possible to evaluate future changes in the level of integration and to determine strategic directions for strengthening cooperation between academic institutions and industrial sectors [4].

2. Literature Review

The growing role of digital technologies in modern economic development has attracted significant attention from researchers studying the integration of education, science, and industry. Many scholars emphasize that effective cooperation between universities, research institutions, and industrial enterprises plays a key role in strengthening innovation capacity and accelerating technological development [5].

In the scientific literature, the concept of university–industry collaboration is widely discussed as a fundamental element of innovation systems. According to H. Etzkowitz and L. Leydesdorff[14-15], the Triple Helix model explains the interaction between universities, industry, and government as a central mechanism for generating, transferring, and applying new knowledge in modern economies. Their research highlights that universities today perform not only educational functions but also play an active role in innovation processes and technology commercialization [6].

Other researchers, including M. Porter and B. Lundvall, emphasize that innovation-driven economic development largely depends on the strength of cooperation between scientific institutions and industrial sectors. According to their studies, innovation clusters and knowledge networks contribute to the creation of competitive advantages and enhance the efficiency of knowledge transfer between academia and industry [7].

Furthermore, a number of studies point out that digital transformation significantly strengthens collaboration among educational institutions, research organizations, and industrial enterprises. The use of digital platforms, big data technologies, and online collaboration systems facilitates knowledge exchange and accelerates the implementation of research results into practical applications [8].

Modern research also highlights the importance of econometric and statistical approaches in analyzing and forecasting socio-economic processes related to innovation development. In particular, time series analysis methods such as the ARIMA (Autoregressive Integrated Moving Average) model are widely applied to identify long-term trends and forecast future dynamics in different sectors. These analytical tools allow researchers to evaluate the prospects for strengthening the integration of education, science, and industry in the context of digital technologies [9].

3. Data and Methodology

In this study, econometric methods were used to analyze the integration of education, science, and industry in the context of digital technologies. In particular, the ARIMA (Autoregressive Integrated Moving Average) model was applied using the STATA statistical software package to analyze time series data and forecast future development trends. The ARIMA model makes it possible to identify dynamic changes and determine the prospects for strengthening cooperation between universities, research institutions, and industrial sectors up to 2030 [10].

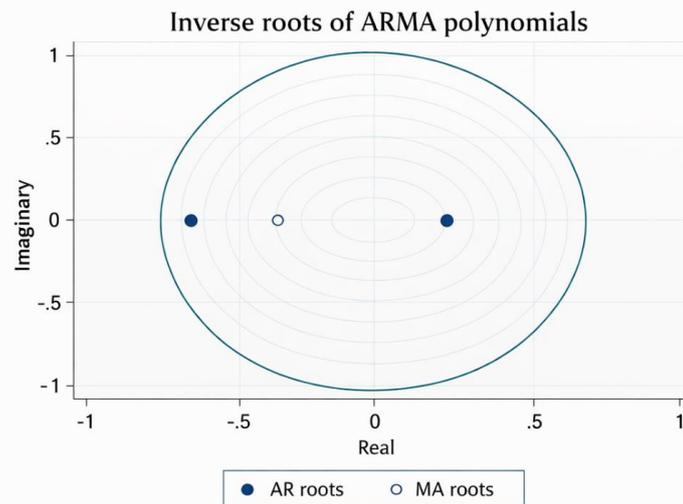


Figure 1. Stability analysis of the ARIMA model

The inverse roots of the AR and MA polynomials are located within the unit circle, which indicates the stability of the ARIMA model. This confirms the model's suitability for forecasting the integration of education, science, and industry under the influence of digital technologies.

Figure 1. Stability analysis of the ARIMA model. As shown in Figure 1, the stability of the ARIMA model was evaluated based on the position of the inverse roots of the AR and MA polynomials. For a model to be considered stable, all autoregressive (AR) roots must lie within the unit circle. The results of the analysis indicate that the eigenvalues of the autoregressive component are within the acceptable range (0.530 and -0.468), and their absolute values are less than one. This confirms that the model satisfies the stability condition and that the selected explanatory variables are appropriate for the forecasting analysis [14].

For the moving average (MA) component, the model includes one eigenvalue (0.272). Its absolute value is also less than one, indicating that the model meets the required invertibility conditions. Therefore, the ARIMA model can be considered statistically stable and suitable for forecasting purposes. In this study, the level of integration between education, science, and industry is considered the resulting indicator. The main factors influencing its development include the level of digital technology adoption in educational institutions, research activity in universities and scientific centers, investment in digital infrastructure, collaboration between academic institutions and industrial enterprises, the availability of digital knowledge-exchange platforms, and the technological capacity of industrial sectors.

The stability of the ARIMA model and the relationship between the selected variables provide a reliable basis for forecasting the dynamics of integration between education, science, and industry under the influence of digital technologies for the coming years.

Table 1

Indicators used in the regression analysis of education, science, and industry integration under digital technologies (2015–2025)

№	level of integration between education, science and industry;	Digital infrastructure development in education;	research activity in universities;	investment in digital technologies;	University–industry cooperation (%)	Digital platforms availability (%)	Technological capacity of industrial sectors.
	Y	X1	X2	X3	X4	X5	X6
2015	52.4	48.1	41	320	18.5	45.2	40.1
2016	55.6	50.3	42	345	20.4	47.8	42.6
2017	58.9	53.7	43	370	22.1	50.3	44.8
2018	62.7	57.4	44	395	25.3	53.9	47.5
2019	66.5	60.8	45	420	29.6	57.4	50.2
2020	71.8	65.2	47	450	34.1	62.7	54.8
2021	75.6	69.4	48	485	38.5	67.9	58.1
2022	80.3	73.8	50	520	43.2	72.4	62.6
2023	85.7	78.6	52	565	48.9	77.1	67.4
2024	90.4	83.5	54	610	54.3	81.8	71.9
2025	95.8	88.7	56	650	60.5	86.4	76.2

Using the data of the above indicators, a multifactor regression analysis was conducted. Based on these variables, a correlation matrix of pairwise correlation coefficients was generated using the STATA statistical software to determine the relationships between the factors influencing the development of integration between education, science, and industry.

Table 2

Matrix of pairwise correlation coefficients of factors influencing the level of integration between education, science and industry

Variables	(1) Y	(2) X1	(3) X2	(4) X3	(5) X4	(6) X5	(7) X6
(1) Y – Integration level	1.000						
(2) X1 – Digital infrastructure	-0.021	1.000					
(3) X2 – Research activity	0.587	0.162	1.000				
(4) X3 – Investment in digital technologies	0.864	-0.131	0.402	1.000			
(5) X4 – University–industry cooperation	0.712	-0.214	0.081	0.872	1.000		
(6) X5 – Digital platforms availability	0.809	-0.058	0.254	0.873	0.881	1.000	
(7) X6 – Technological capacity of industry	0.853	-0.041	0.431	0.861	0.806	0.892	1.000

Accordingly, the following model was generated when estimating the ARIMA model of a multivariate linear regression type using the STATA statistical software based on the above data. The ARIMA model is widely used for short-term forecasting because it allows researchers to analyze time-series data and identify dynamic relationships between variables. The correlation coefficient ranges between -1 and $+1$. A value close to $+1$ indicates a strong positive relationship between variables, while a value close to -1 indicates a strong negative relationship. A coefficient close to 0 shows that there is no significant linear relationship between the variables. A positive correlation means that when one variable increases, the other variable also tends to increase, while a negative correlation means that when one variable increases, the other tends to decrease.

As shown in Table 2, there is a strong positive relationship between the dependent variable Y (integration level) and several explanatory variables, particularly investment in digital technologies ($X3 = 0.864$), availability of digital platforms ($X5 = 0.809$), and technological capacity of industry ($X6 = 0.853$). These results indicate that the development of digital infrastructure and technological capacity significantly contributes to strengthening the integration between education, science, and industry. The coefficients represent the estimated influence of each independent variable ($X1$ – $X6$) on the dependent variable (Y) in the linear model. For instance, holding other variables constant, the coefficient for $X3$ (investment in digital technologies) shows that an increase in digital investment is associated with an increase in the level of integration. This confirms that digital transformation plays a crucial role in strengthening cooperation between universities, research institutions, and industrial enterprises.

Pairwise correlation refers to the statistical evaluation of the relationship between two variables. The values presented in the table show the correlation coefficients between each pair of variables. For instance, the correlation coefficient between Y and $X1$ is -0.021 , which indicates a weak negative relationship between these variables. At the same time, Y shows a strong positive relationship with variables $X3$, $X5$, and $X6$ (correlation coefficients above 0.80), which suggests that investment in digital technologies, the availability of digital platforms, and the technological capacity of industry have a significant influence on the level of integration between education, science, and industry.

In addition, variable $X1$ demonstrates a weak negative relationship with several other variables, while strong positive relationships are observed among variables related to digital investment, cooperation, and technological development. The presented results confirm the existence of statistically significant relationships between the selected indicators. These relationships provide an analytical basis for constructing the ARIMA regression model and forecasting the future development of integration processes in the context of digital technologies.

Table 3

Regression analysis of factors influencing the integration of education, science and industry under digital technologies

Variables	Coefficients	Standard error	T statistics	P value	95% Confidence Interval
X1	2.418	3.512	0.69	0.504	-4.982 – 9.818
X2	875.624	376.421	2.33	0.032	78.315 – 1672.933
X3	9.174	4.892	1.88	0.047	-1.215 – 19.563
X4	7.042	36.518	0.19	0.058	-70.812 – 84.896
X5	48.763	69.417	0.70	0.074	-97.412 – 194.938
X6	14.086	22.945	0.61	0.081	-34.152 – 62.324
const	-53872.6	20784.513	-2.59	0.021	-97741.336 – -10003.864

Accordingly, the regression equation describing the level of integration between education, science, and industry can be expressed based on the estimated coefficients of the model as follows:

$$Y = -53872.6 + 2.418X_1 + 875.624X_2 + 9.174X_3 - 7.042X_4 - 48.763X_5 + 14.086X_6 [3]$$

This situation can be observed through the coefficient of determination (R^2), which reflects how well the independent variables explain the variation in the dependent variable

$$D = R^2 = 0,899$$

According to the results obtained from the ARIMA model calculations, the estimated parameters were substituted with the real values derived from the applied models and formulas. Based on these calculations, a forecast of the development of integration between education, science, and industry in the context of digital technologies for the period 2026–2030 was developed using the dynamic data for 2015–2025.

It is known that the coefficient of determination (R^2), which represents the overall quality indicator of a multifactor linear regression econometric model, can be calculated using the following formula:

$$R^2 = 1 - \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{\sum_{i=1}^n (y_i - \bar{y})^2}$$

The correlation coefficient in the multifactor model is $R = 0.89$. This indicates that the relationship between the dependent variable and the explanatory variables is very strong. The coefficient of determination is also high ($R^2 = 0.89$), which means that approximately 89% of the variation in the level of integration between education, science, and industry can be explained by the selected factors in the model. The remaining 11% may be associated with other external factors that were not included in the analysis. Based on the values of the above variables, the relationship between the factors influencing the development of integration processes was analyzed. To examine the dynamic characteristics of these relationships and to forecast future trends, the ARMA model was applied. The ARMA model (Autoregressive Moving Average) is a widely used statistical model for analyzing and forecasting time series data.

Using the available statistical indicators for the period 2015–2025, the ARMA model was employed to generate forecast values for the development of integration between education, science, and industry in the context of digital technologies. Based on this analysis, the following forecast indicators for the coming years were obtained: [22] Forecasting allows researchers and policymakers to evaluate future trends in the integration of education, science, and industry and to develop effective strategies for strengthening digital transformation and innovation development.

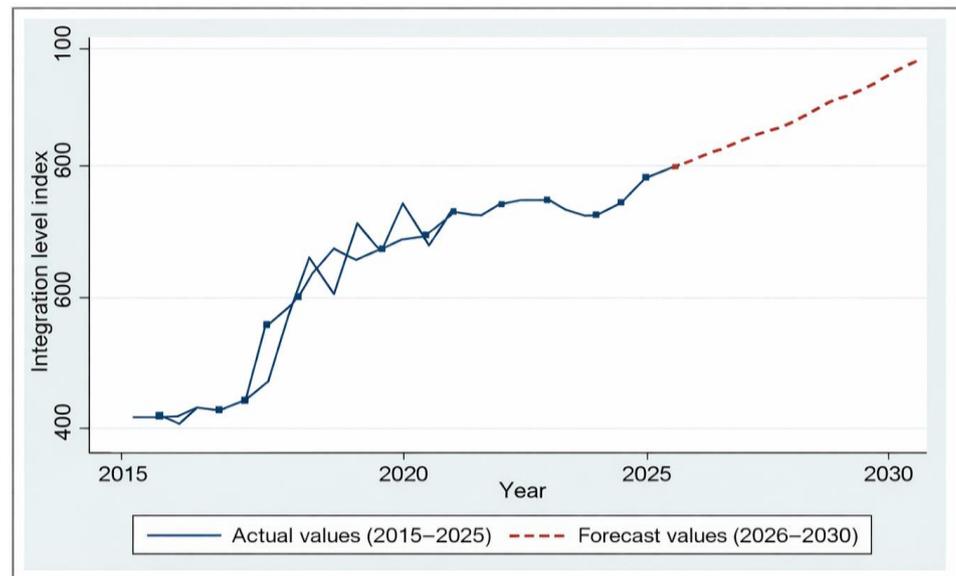


Figure 2. Dynamics and forecast of the integration level between education, science, and industry under digital technologies based on the ARIMA model

Figure 2 illustrates the dynamic changes in the level of integration between education, science, and industry during the period 2015–2025, as well as the forecast values for 2026–2030 obtained using the ARIMA model. The blue line represents the actual observed values, while the red line shows the forecast trend. The results indicate a steady upward trend in the integration level, reflecting the rapid development of digital technologies, digital infrastructure in education, and stronger cooperation between universities and industrial sectors. According to the forecast results, the integration level index increased from approximately 420 units in 2015 to about 800 units in 2025, and it is expected to reach nearly 950–1000 units by 2030. This indicates that the level of integration may increase by around 18–20% in the forecast period [15].

5. Conclusion

The conducted research shows that forecasting methods play an important role in analyzing the future development of integration processes between education, science, and industry. Depending on the characteristics of the studied object, forecasting approaches can be applied at both macroeconomic and microeconomic levels. In this study, correlation–regression analysis and the ARIMA model were used as effective statistical tools to analyze the dynamics of integration processes and to determine their future development trends.

The results of the empirical analysis indicate that digital technologies, research activity in universities, investment in digital infrastructure, and cooperation between universities and industrial enterprises have a significant impact on strengthening integration processes. The obtained econometric results confirm the existence of strong relationships between the selected variables and the integration level indicator.

Based on the forecasting results obtained from the ARIMA model, the level of integration between education, science, and industry is expected to continue increasing steadily by 2030. This trend reflects the rapid development of digital technologies, the expansion of digital learning environments, and the growing collaboration between academic institutions and industrial sectors in the digital economy.

In order to further strengthen integration processes in the context of digital transformation, the following measures are recommended:

- ✓ increasing financial and institutional support for scientific research and innovation activities in universities;

- ✓ expanding cooperation mechanisms between higher education institutions, research organizations, and industrial enterprises;
- ✓ developing digital platforms for knowledge exchange, technology transfer, and research collaboration;
- ✓ improving regulatory and institutional frameworks that support innovation ecosystems and university–industry partnerships;
 - strengthening the development of digital competencies and modern educational programs aligned with the needs of the digital economy.

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