“Assessing the impact of universities on smart city development: Global experience and the Ukrainian context”

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ASSESSING THE IMPACT OF UNIVERSITIES ON SMART CITY DEVELOPMENT: GLOBAL EXPERIENCE AND THE UKRAINIAN CONTEXT

Abstract

The purpose of this article is to evaluate the current state of collaboration between universities and businesses, identify obstacles, and propose solutions based on international experience, regional characteristics, and the challenges of Ukraine's post-war economic reconstruction. The article examines the role of universities in smart development, using international experience and the results of an original sociological study conducted in Ukraine in 2025 as a reference point. The empirical basis includes two surveys: one of local authorities with 111 respondents and one of businesses with 300 respondents. The research methodology uses descriptive statistics and binary logistic regression to determine the factors that influence cooperation between higher education institutions (HEIs), local authorities, and businesses regarding smart and sustainable development. The results demonstrate the structurally weak integration of universities into local smart development ecosystems. The study's originality lies in identifying the main obstacles to developing cooperation between universities, businesses, and local authorities: bureaucratic barriers, inflexibility, and outdated management systems in local authorities and higher education institutions; and a lack of initiative and incentives for cooperation among all stakeholders. The article confirms the insufficient awareness of Ukrainian universities' role as drivers of socioeconomic development and their potential to become powerful agents of change if their innovation and entrepreneurial capacity is strengthened. The practical significance of the results is to identify areas for improving interaction and overcoming obstacles. The key to doing so is strengthening through digitalization, which will transform the participants and their internal structure, as well as all communication and interaction between them.

Keywords universities, smart city, smart development, sustainable development, knowledge ecosystem

JEL Classification D85, I23, I25, Q01

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INTRODUCTION

The current global context shapes determinants of country development, such as comprehensive digitalization and the penetration of artificial intelligence technologies into all areas of social activity. It also shapes the need to pay more attention to environmental issues and ensure sustainable development. These aspects are particularly important for cities, which are centers of human activity. These processes have led to the emergence of smart cities and the concept of smart development in general. Smart cities combine advanced digital technologies with high environmental and social living standards. Today, the smart economy is considered a new development paradigm based on digital technologies, innovation, and knowledge. It encompasses the digitization of production processes, the development of smart institutions, and the effective utilization of human capital.

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At the same time, implementing a smart city development vector is not an easy task, as it requires not only significant additional resources but also the involvement of many stakeholders (local authorities, businesses, the public, and educational and scientific institutions). Global experience shows that successful cities are those that manage to engage all stakeholders, build effective communication, and find effective financing mechanisms. In such an ecosystem, educational and scientific institutions have a special role to play, as they can assume important functions in preparing projects, conducting research, and cooperating with the public to achieve important urban development goals. That is why the experience of those smart cities that have examples of successful cooperation between universities, local authorities, and businesses in building a smart city is of particular interest.

Modern Ukrainian cities are in an extremely difficult situation as a result of open military aggression: they face destruction, business relocation, and loss of personnel. Addressing these challenges should not mean postponing the building of modern innovation systems for the future. It is strategically important for our country to create conditions for development on a fundamentally new basis – sustainability, smartness, and resilience.

1. LITERATURE REVIEW

The issues of the smart city phenomenon and, accordingly, the smart economy and smart development became the subject of active scientific research at the beginning of the millennium. The essential features of smart cities are studied in the works of Giffinger et al. (2007), Greenfield (2013), Kumar and Bharat (2012), Pozdniakova (2017), and others. Lombardi et al. (2012) analyze the success factors of smart cities through the interrelations between smart city components connecting the cornerstones of the triple helix. Nam and Pardo (2011) outline the three main dimensions (technology, people, and institutions) of a smart city.

An important area of scientific research is the study of digital transformation and the capabilities of the latest technologies in implementing the smart city concept. The Organization for Economic Cooperation and Development emphasizes that digital transformation is a key factor in the competitiveness of states in the twenty-first century (OECD, 2021). The study of the role of the technological component in the success of smart cities is emphasized by Pozdniakova (2017) and Vasiliu-Feltes (2023). Karri et al. (2024) characterize the five most important technologies for smart and/or safe cities. Kim et al. (2024) examine the next generation, sixth generation (6G) communication systems that will play a crucial role in improving the efficiency of urban operations and services. Kvitka et al. (2021) studied the impact of artificial intelligence on the development of a digital community. Okonta and Vukovic (2024) analyzed the impact of ICT on sustainable urban development and improving the quality of life of citizens.

Overall, the reviewed literature confirms that universities act as system-forming actors in smart city transformation by generating knowledge, fostering innovation, building governance capacities, and supporting sustainable development strategies in response to global and local challenges. In the context of ensuring smart development, universities are an important institution as key actors in knowledge production, the formation of innovative infrastructure, and human development. Universities are increasingly becoming "economic agents" that generate digital competencies and promote innovation. The expanding role and increasing influence of universities in ensuring the economic development of society has long been recognized in scientific research. In addition to the classical functions of education and research, modern universities are becoming subjects of entrepreneurship and innovation (Clark, 2008; Slaughter & Leslie, 1997; Schulte, 2004). The importance of forming an effective interaction between universities and other actors of the external environment is emphasized (Forliano et al., 2020; Romanovski, 2012; Florida et al., 2010). The Triple Helix (Etzkowitz & Leydesdorff, 2000) and Quadruple Helix (Carayannis & Campbell, 2019) models are essential in the formation of an innovative economy, which defines the interaction of universities, business, government, and society as a driving force for development.

The historically important role of universities as subjects of education and science in the modern social context is significantly expanding, and their contribution to the creation of new knowledge, promotion of technological progress, and promotion of economic development as agents of change in local and regional communities is now highly valued (Vidican, 2009). Hatakenaka (2007) emphasizes that the fundamental societal roles of universities are raising awareness, producing knowledge, developing skills, and creating value, which are key elements in achieving a sustainable future. Expanding the role of universities beyond the traditional functions of teaching and research has long been recognized and explored as the "third mission" of universities (Garcia & Tuesta, 2025).

The third mission is the active collaboration of universities with industry and society to facilitate knowledge transfer, strengthen entrepreneurship, foster innovation, and promote sustainable development of countries, going beyond their primary academic functions (Garcia & Tuesta, 2025; Compagnucci & Spigarelli, 2020; Popescu & Mandru, 2020; Rosli & Rossi, 2016; Trencher et al., 2014). Key components of this mission include the mobilization of both scientific knowledge, skills, and experience (knowledge transfer) and technical innovations and tools (technology transfer) from universities to society and industry (Garcia & Tuesta, 2025; Rybnicek & Königsgruber, 2019).

Contemporary research on university–city cooperation within the framework of smart urban development emphasizes the role of higher education institutions as key agents of innovation, entrepreneurship, and institutional capacity building. The British Council report "Smart Places: How Universities are Shaping a New Wave of Smart Cities" presents case studies from Nottingham, Darmstadt, Dublin, Lille, Milan, and Zaragoza, demonstrating how universities contribute to digital innovation, inclusive urban policies, and the formation of collaborative ecosystems linking academia, business, and municipalities (British Council, 2020). The report highlights the transformation of universities from traditional educational institutions into platforms for co-creation and urban policy innovation. Peng and Xu (2024) explore the influence of universities on urban innovation systems, particularly in Asian contexts. The authors conceptualize universities as knowledge generators, catalysts of startup ecosystems, and drivers of technology transfer, generating long-term effects on urban economic growth. Special attention is paid to the integration of universities into city development strategies and mechanisms supporting innovation-driven entrepreneurship. Voitko and Yurchyshyn (2025) examine the specific role of technical universities in promoting sustainable smart city development through smart specialization policies and applied research in energy efficiency, digital infrastructure, and sustainable governance. The authors argue that technical universities function as institutional cores of regional innovation ecosystems, strengthening the technological and analytical foundations of smart urban transformation.

In the Ukrainian context, university–municipality partnerships have gained particular relevance in the process of post-war reconstruction and "green" recovery. The collaboration between ISTU and the Unicities network focuses on integrating sustainability principles into Ukraine's reconstruction efforts despite wartime challenges (ISTU, 2025). This initiative underscores the growing role of universities as analytical and advisory centers supporting local governments. A significant contribution is also made by the Erasmus+ UNICITIES project, a European–Ukrainian initiative aimed at unlocking the transformative potential of universities for climate-neutral and sustainable cities (Erasmus+ National Office in Ukraine, 2025). The project combines European best practices with the needs of Ukrainian communities, emphasizing capacity building, interdisciplinary cooperation, and governance modernization. Additionally, the educational dimension of strengthening urban governance is reflected in the City Management Program, a double-degree initiative implemented by the Kyiv School of Public Administration, Alfred Nobel University, and Coventry University (KSPA, 2025). The program is designed to prepare professionals in urban management and smart development, thereby forming the human capital base necessary for institutional modernization of Ukrainian cities.

The European Commission, through its Smart Specialization strategy, emphasizes the need to integrate science, education, and business in region-

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al innovation ecosystems (EC, 2017). There are studies on the role of higher education in smart specialization (Martinaitis et al., 2020). They play a crucial role in contributing to the assessment of their region's knowledge assets, capabilities, and competencies, providing fundamental data for strategic planning (The Role). Universities actively cooperate with regional authorities not only to formulate but also to implement S3, creating a favorable environment for cooperation (The Role). In the context of the smart economy, it is especially important to transform universities into "entrepreneurial" organizations that actively interact with business and government, commercialize knowledge, and create startups (Perkmann et al., 2013). Benneworth and Sanderson (2009), Reichert (2019), and Tijssen et al. (2021) show that universities are becoming drivers of regional development, forming innovation clusters and technology transfer centers. Goddard and Vallance (2013) draw attention to the concept of "civic university", where universities actively integrate into urban innovation ecosystems, developing the local economy and culture. Thus, the role of universities goes far beyond the educational function and involves strategic participation in building the smart economy at various levels.

Universities are increasingly aligning their institutional strategies with broader regional development strategies. Their commitment to innovation is manifested through reforms in learning, teaching, and research approaches that actively foster collaboration and aim for significant societal and economic impact (Reichert, 2019). HEIs play a critical role in Smart Specialization Strategies (S3) by helping regions identify and develop competitive advantages.

Thus, the literature review shows that modern universities are becoming important actors in the smart city ecosystem and the smart economy in general. Ukrainian universities have accumulated significant educational and scientific potential, and they are actively involved in the processes of digitalization and local development. A good example is the activity of regional IT clusters, such as Lviv, Kharkiv, and Dnipro, where universities cooperate with businesses to develop innovative projects. On the other hand, it should be noted that the digitalization of the educational process of domestic universities is uneven, and their integration into innovation ecosystems is limited. The development of effective mechanisms for cooperation between universities and businesses is an urgent problem for all countries, and it is of paramount importance for modern Ukraine. In general, there is a lack of mechanisms for effective cooperation between universities and business and government in the context of urban development.

The purpose of the article is to assess the current state of cooperation between universities and business and government, identify obstacles, and formulate proposals for its development, taking into account international experience, regional specifics, and challenges of post-war economic reconstruction in Ukraine.

2. METHOD

The empirical basis of the article is the results of two sociological surveys conducted on the basis of a combined study with quantitative and qualitative components. The authors developed questionnaires to determine the role of local governments and businesses in the formation of the smart economy ecosystem. The survey "The Role of Local Self-Government in the Economic Recovery of Ukraine: Regional Potentials and Smart Development" involved 111 representatives of local governments of Ukrainian cities throughout Ukraine (excluding the temporarily occupied territories) (Kalenyuk & Tsymbal, 2025a). Business respondents are represented by 58% micro enterprises, 16% small, 15% medium, and 10% large enterprises. The second survey covered business representatives representing a wide range of economic activities and included representatives of small, medium, and large businesses. Respondents from local governments represented cities of various sizes, in particular, 14.5% from cities with a population of less than 10 thousand, 23.5% from 10 to 50 thousand people, 2.7% from 50-200 thousand, 29% from 200-500 thousand people, 3% from 500-700 thousand people, 9% from 700-900 thousand people, 14.4% from cities with a population of more than 1 million inhabitants (Kalenyuk & Tsymbal, 2025b). Both surveys covered a number of issues related to the current cooperation of business and local governments with higher education institutions (HEIs) in the context of building a re-

gional knowledge ecosystem, smart economy, and post-war reconstruction.

For further quantitative analysis, regression models with the binary dependent variable "availability of cooperation with HEIs" were used separately for the samples of business and local governments. The results obtained allowed us to clearly identify the factors that stimulate and discourage cooperation and quantify their impact on the likelihood of partnership, and can be used to customize city and regional cooperation programs (selecting incentives and removing key barriers) and develop standard roadmaps for partnerships between HEIs, businesses, and local governments. Obtaining basic statistical characteristics for each variable allowed us to identify general trends based on the data set and formulate conclusions about the current state of cooperation between universities and businesses and local governments, existing obstacles, and future prospects.

For an in-depth analysis of the factors of cooperation with higher education institutions, we used a binary logistic regression, in which the event Y=1 means the presence (or declared readiness for) cooperation, $Y = 0$ – no cooperation. This specification directly operates with probabilities, guaranteeing predictions within [0; 1], adequately reflects the nonlinear nature of the relationship between predictors and the event, and is more resistant to heteroscedasticity typical of dichotomous dependent variables (Hosmer et al., 2013).

Logistic regression models the probability of an event occurring (in our case, the existence of a partnership between a higher education institution and local government): $p(X) = \Pr(Y = 1|X)$.

Basic logistic regression equation:

$$\log\left(\frac{p(X)}{1-p(X)}\right) = \beta_0 + \beta_1 X_1 + \ldots + \beta_p X_p, \quad (1)$$

where Y – binary dependent variable, $X_j (j = 1, \ldots, p)$ – vector of explanatory variables (predictors), $p(X) = \Pr(Y = 1|X)$– conditional probability of an event occurring given the given values of the predictors, β_0 – free parameter of the model, β_j (j = 1, …, p) – coefficients of the predictors, p – number of explanatory variables in the model.

The sign of the coefficient βj in the logistic regression reflects the direction of association of the variable X_j with the event $Y = 1$: a positive coefficient β_j corresponds to an increase, and a negative coefficient β_j corresponds to a decrease in the conditional probability of cooperation, holding other variables constant. The value of βj is measured in log odds and is not directly intuitive to interpret, so average marginal effects (AME) are also used to present the results. The AME is the average change in the probability of event $Y = 1$ for a change in the corresponding explanatory variable: for continuous and ordinal variables, for an increase of one unit (or a move up one category); for dichotomous variables, for a move from the base category to the alternative category. AME values are given in percentage points: a positive value means an increase in the probability of an event; a negative value means a decrease.

3. RESULTS

The evolution of universities from isolated academic centers to active, integrated participants in innovation ecosystems represents a profound paradigm shift. It goes beyond the traditional, more siloed roles of knowledge creation and research. Universities are increasingly moving beyond their primary academic functions to actively collaborate with industry and society. This means a fundamental shift from a predominantly one-way knowledge transfer (from university to society) to a dynamic model of social development in which universities are deeply embedded in regional innovation networks and are active agents in their formation. This requires universities to undertake systematic institutional transformations, develop new organizational structures, interface services, and innovation-oriented collaborative cultures to effectively facilitate this integration.

To determine the involvement of higher education and research institutions in the development of the smart economy in Ukraine, and to assess their cooperation with business and local authorities in addressing urban development issues, sociological studies were conducted. The first concerned business representatives, and the second concerned local governments in their assessment of cooperation with higher education institutions.

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To build the model, we used the results of a survey of 111 representatives of local governments. The dependent variable is the indicator of cooperation with universities, formed by the question "Do you cooperate with higher education institutions in the implementation of urban development goals?" The primary options ("yes", 'no', "in the future") are aggregated into a binary scale: 1 – the presence or formed readiness for cooperation ("yes" / "in the future"), 0 – no cooperation ("no"). This aggregation increases the stability and accuracy of the estimates of the logistic regression parameters. As explanatory variables, we selected indicators that characterize the potential and practices of interaction with HEIs and can determine cooperation: the size of the settlement, institutional preconditions (availability of a smart city development strategy; involvement in smart initiatives at the regional/state level), operational development practices (digitalization initiatives, green development, social programs, e-government), as well as barriers to interaction with HEIs. Taking into account the categorical nature of the predictors, preliminary coding was carried out: ordinal variables are presented in increasing integer levels, nominal variables - using unitary coding with the selection of the basic category; rare answers in the barriers block are grouped into thematically homogeneous groups.

After recoding the variables, we estimate the binary logistic model in specification (1), which describes the probability of cooperation between local governments and universities. The results are presented in Table 1: the column β shows the estimates of the coefficients of the logistic model, the column p(β) shows the levels of statistical significance of the corresponding coefficients, the column AME shows the average marginal effects, i.e. the average change in the probability of event $Y = 1$ in percentage points, and the column p(AME) shows the statistical significance of the corresponding AMEs.

Next, we will decipher the names of the model's predictors: pop_size is the size of the community in terms of population (ordinal scale); smart_join is the city's involvement in smart initiatives of a higher (regional/state) level; digital_init, green_init, social_init are the presence of digitalization, green development, and social programs, respectively; the barriers block was formed by thematically aggregating the answers: bar:rigidity covers bureaucratic obstacles, inflexibility/outdated management systems in HEIs and/or local authorities; bar:stimuli reflects the lack of incentives from HEIs and/or local authorities; finance – financial constraints (taxes) is used as a basic (reference) category, so it is not shown in the table (see Table 1).

The signs of the β coefficients and the corresponding AMEs are consistent, but for further analysis, we will focus on the marginal effects as they are more informative in an applied sense. The analysis of the AME values shows that the predictor *pop_size* has a positive and statistically significant effect: larger communities have, ceteris paribus, an average of 19.8 (p(AME) < 0.001) percentage points higher probability of cooperation with HEIs compared to smaller communities. The *smart_join* predictor is also a stimulating factor: the city's involvement in higher-level smart initiatives increases the likelihood of partnership by 8.2 percentage points on average (p(AME) = 0.041). The coefficients of the predictors *digital_init*, *green_init*, and *social_init* are not statistically significant even at the level of 0.1, which may indicate the in-

Table 1. Determinants of cooperation between LGEs and HEIs: logistic regression coefficients and average marginal effects

Source: Calculated by the authors based on Kalenyuk and Tsymbal (2025a, 2025b).

Predictor	β	p(β)	AME	p(AME)
pop_size	1.807	0.000	0.198	0.000
smart_join	0.751	0.054	0.082	0.041
digital_init	1.653	0.228	0.181	0.215
green_init	–2.516	0.169	–0.275	0.158
social_init	3.773	0.128	0.412	0.117
bar:rigidity	–1.559	0.067	–0.171	0.055
bar:stimuli	–2.279	0.028	–0.249	0.019

Source: Kalenyuk and Tsymbal (2025a, 2025b).

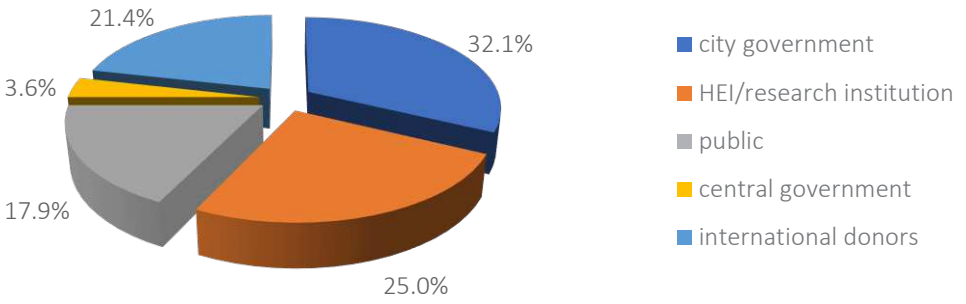

Figure 1. Results of the survey of local governments on the initiators of joint sustainable or smart development projects

direct or context-dependent nature of the impact of these variables. The barriers block uses three categories, with finance being the basic (reference) category. Compared to this basic category, the other two groups of barriers have a distinctly negative impact on cooperation: *bar:rigidity* (bureaucratic obstacles, inflexibility and outdated management systems in HEIs and/or local authorities) is associated with a decrease in the probability of partnership by 17.1 percentage points on average ($p(AME)$ = 0.055), and *bar:stimuli* (lack of incentives from HEIs and/or local authorities) – by about 24.9 percentage points ($p(AME)$ = 0.019). Thus, financial constraints are associated with a less pronounced decrease in the likelihood of cooperation, while institutional inflexibility and outdated management systems, as well as a lack of incentives, significantly reduce the likelihood of cooperation with universities.

According to the survey, there are partnership practices between local governments and higher education institutions in Ukraine. They include both formal involvement in strategic planning and practical infrastructure projects. More than 44% of respondents representing local governments noted the existence of cooperation with higher education institutions, and 30.6% noted the possibility of such cooperation in the future. These findings suggest that although nearly half of municipalities have established interaction with universities, a significant share either lacks structured cooperation or has not institutionalized partnerships. The relatively high proportion of responses indicating potential future cooperation reflects unrealized capacity within local knowledge ecosystems. Overall, the data confirm that collaboration between local authorities and HEIs in the sphere of smart and urban development remains fragmented and requires systemic strengthening (Kalenyuk & Tsymbal, 2025a, 2025b).

The survey of local governments on joint projects with higher education or research institutions in the field of sustainable or smart development showed that only 17.1% reported having such collaborations, while the majority – 55.9% – indicated they do not currently engage in them, and 27.0% gave other responses such as being in the planning stage, having informal cooperation, or uncertainty about whether their activities qualify; overall, the results highlight limited existing interaction but significant potential for expanding partnerships between municipalities and the academic or research sector (Kalenyuk & Tsymbal, 2025a, 2025b).

According to the study, 32.1% of respondents noted that such projects were initiated by the city authorities, 25% – by higher education institutions, 21.4% – by international donors, 17.1% – by the public, and only 3.6% identified the central government as the project initiator (see Figure 1).

The block of barriers is organized into three categories, with finance being the basic (reference) category. Compared to this basic category, the other two groups of barriers have a distinctly negative impact on cooperation: *bar:rigidity* (bureaucratic obstacles, inflexibility and outdated management systems in HEIs and/or local authorities) is associated with a decrease in the probability of partnership by 17.1 percentage points on average ($p(AME)$ = 0.055), and *bar:stimuli* (lack of incentives from

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HEIs and/or local authorities) – by about 24.9 percentage points ($p(AME)$ = 0.019). Thus, financial constraints are associated with a less pronounced decrease in the likelihood of cooperation, while institutional inflexibility and outdated management systems, as well as a lack of incentives, significantly reduce the likelihood of cooperation with universities.

The reasons for the weak cooperation between the government and higher education institutions are seen differently by the survey respondents. Along with external factors, such as the war, systemic problems at the level of initiative and mutual interest are also mentioned. At the same time, opinions were expressed that there are no obstacles, which indicates a gap in the perception of deep barriers between representatives of different sectors.

It should be noted that the war, as a key external factor, has had a significant impact on staffing, institutional capacity, and resources. This makes it difficult to implement joint projects. Internal obstacles to expanding cooperation between authorities and HEIs in the context of regional smart development include the mismatch of educational programs with the current needs of the community, which reduces the potential for cooperation; low initiative of HEIs themselves; political demonstration of initiatives; and lack of related areas, which limits the possibilities of cross-sectoral partnerships.

The results indicate the importance of community scale and institutional integration into higher-level smart grids as factors that increase the likelihood of cooperation between local governments and HEIs, while lack of incentives, institutional inflexibility, and outdated management systems significantly reduce the likelihood of such cooperation.

The metrics for assessing the accuracy of the logistic regression model (overall accuracy, precision, completeness, F1-measure) are presented in Table 2 for both states of the dependent variable.

The consistency of modelled estimates of the probability of cooperation with actual responses was assessed through the overall accuracy of assigning observations to a fixed threshold of predicted probability (0.5). The value of 0.86 means that in about 86% of cases, the status of cooperation determined on the basis of the calculated probabilities coincides with the answers of the respondents. For the state of the dependent variable Y = 1, the indicators are: accuracy = 0.89, completeness = 0.94, and F1-measure = 0.91, which indicates a confident reproduction of cases of existing or declared cooperation. For the state of the dependent variable Y = 0, the accuracy = 0.78, completeness = 0.64, and F1 = 0.71 are lower, i.e., the attribution to this state is more cautious. In general, the model has a sufficient level of accuracy to quantify the impact of predictors on the presence/absence of cooperation.

Regarding cooperation between business and higher education institutions in building a smart economy, the survey results show an extremely low level of cooperation between business, science, and education on urban development goals or the implementation of sustainable and smart development projects. Obviously, businesses expect initiatives from the government, which should shape the agenda and organize platforms for engaging both the business and educational communities in projects that meet urban development goals.

To identify the determinants of business cooperation with higher education institutions, a binary logistic model of the form (1) was built, in which the probability of the event Y = 1 corresponds to the existing or declared readiness for cooperation. The empirical basis is the responses of 300 representatives of the business sector. The dependent variable is formed by the question "Do you cooperate with higher education institutions in the implementation of urban development goals?" The initial answer options ("yes", "in the future", "no")

Table 2. Determinants of cooperation between LGEs and HEIs: assessment of the accuracy of the logistic model

Source: Calculated by the authors based on Kalenyuk and Tsymbal (2025a, 2025b).

Dependent variable U	Accuracy	Completeness	F1-measure
$Y = 0$	0.78	0.64	0.71
$Y = 1$	0.89	0.94	0.91
Overall accuracy	–	–	0.86

are aggregated into a binary scale: 1 – existing cooperation or formed readiness for it ("yes" / "in the future"), 0 – no cooperation ("no"). This convolution increases the stability and interpretability of logistic regression estimates.

A set of categorical variables was used as predictors, reflecting: the level of digitalization of the company and its change in wartime; technological and innovation capacity (practices of using modern technologies, implementation of innovations, organizational prerequisites for their support); size of the enterprise; practices and forms of interaction with educational institutions; barriers to partnership, grouped into substantively homogeneous blocks (coordination and organizational constraints, lack of incentives, resource and financial risks, etc.) The variables were coded as follows: ordinal features are represented by numerical values that monotonically increase according to the level of the feature; nominal features are represented by a set of dummy indicators with a clearly defined base category for comparison; small number of answer options were previously grouped into thematically consistent categories.

A binary logistic model was built, in which only those predictors that provide the best information without overloading the specification were retained after a stepwise selection. The coefficients (β) of the model, average marginal effects (AME) and their corresponding levels of statistical significance ($p(\beta)$ and $p(AME)$) are presented in Table 3.

For correct interpretation of further results, we provide a semantic interpretation of the designations of the predictors used in Table 3: *digital_level* – self-assessed level of digitalization of the company (ordinal scale); *ai_use* – use of artificial intelligence technologies by the company in its activities (1 – yes); *firm_size* – size of the enterprise by number of employees (ordinal scale). Block init: reflects who initiated the joint projects on sustainable or smart development: init:hromadskist – the public; *init:vlada* – authorities; *init:zvo* – university/research institution; base category – *init:other* (all others/not specified). Block bar: – obstacles to cooperation: bar:none – no obstacles noted; *bar:finance* – financial/resource constraints; *bar:rigidity* – regulatory/organizational/coordination difficulties; *bar:stimuli* – lack of motivation of partners; base category *bar:other* (other unclassified obstacles).

It should be noted that, similarly to the section on cooperation between local governments and HEIs, further interpretation of the modelling results is based on average marginal effects (AME) rather than the β coefficients themselves. The most convincing effects are demonstrated by predictors that reflect the practical technological sophistication of the company and the institutional initiative of the academic partner. First, the use of artificial intelligence technologies by companies increases the likelihood of cooperation with universities: the average marginal effect for this predictor is 10.5 percentage points ($p(AME) < 0.001$), which may indicate a higher demand of technologically mature firms for knowledge and human capital of higher education institutions. Second, if the project is initiated by the university (*init:zvo*), the probability of partnership increases by an average of 20.9 percentage points ($p(AME) = 0.010$) compared to cases where the initiator is not a uni-

Table 3. Determinants of business cooperation with higher education institutions: logistic regression coefficients and average marginal effects

Source: Calculated by the authors based on Kalenyuk and Tsymbal (2025a, 2025b).

Predictor	β	p(β)	AME	p(AME)
digital_level	–0.212	0.408	–0.032	0.407
ai_use	0.789	0.000	0.105	0.000
firm_size	0.160	0.268	0.024	0.265
init:hromadskist	0.901	0.071	0.134	0.067
init:vlada	0.379	0.465	0.056	0.464
init:zvo	1.415	0.013	0.209	0.010
bar:finance	1.084	0.029	0.161	0.026
bar:none	2.777	0.000	0.412	0.000
bar:rigidity	0.743	0.163	0.110	0.160
bar:stimuli	0.611	0.195	0.091	0.192

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versity. This means that the proactivity of the academic side is a significant catalyst for establishing links with business.

The effect of public initiative (*init:hromadskist*) is positive and statistically significant (13.4 percentage points, $p(AME) = 0.067$), which is consistent with the role of the public sector as a potential moderator of interaction, although the impact of public initiative in establishing cooperation between business and HEIs is less than for the initiative of universities. In addition, situations when respondents see no obstacles (bar:none) are associated with the largest increase in the probability of cooperation, namely by 41.2 percentage points ($p(AME) < 0.001$), which is quite expected to reflect a favorable institutional context.

The comparison with the base category *bar:other* is interesting: in the presence of clearly identified financial constraints (*bar:finance*), the probability of cooperation is still higher by 16.1 percentage points ($p(AME) = 0.026$). This indicates that in the case of clearly identified financial barriers, the probability of cooperation is higher than in the case of vaguely defined or complex barriers classified as "other". In contrast, the coefficients on the predictors of *digital_level* and *firm_size* are expectedly positive, but do not reach statistical significance in this model specification. This may indicate that it is not the declared level of digitalization of the company or the size of the company that is decisive, but the presence of specific practices (such as the use of artificial intelligence technologies) and targeted institutional impulses from the HEI.

Thus, the model demonstrates that business cooperation with higher education institutions is most likely to be driven by the practical technological involvement of enterprises and the proactivity of academic institutions as initiators of joint projects, and that the likelihood of partnership increases significantly in a favorable institutional environment (no barriers to cooperation). The metrics for assessing the accuracy of the logistic regression model are shown in Table 4, namely the overall accuracy, as well as the accuracy, completeness, and F1-measure separately for each state of the dependent variable.

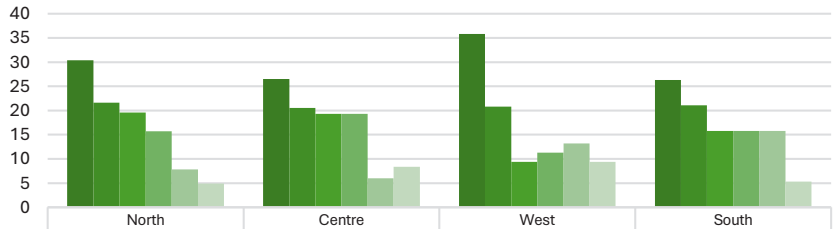
Table 4. Determinants of business cooperation with higher education institutions: assessment of the accuracy of the logistic model

Source: Calculated by the authors based on European Commission (2014, 2017).

Dependent variable U	Accuracy	Completeness	F1-measure
$Y = 0$	0.81	0.94	0.87
$Y = 1$	0.70	0.40	0.51
Overall accuracy			0.79

The consistency of the modelled probability estimates with the observed responses is determined by the overall accuracy at a fixed threshold of 0.5: a value of 0.79 means that in 79% of cases the binarized prediction of the cooperation status corresponds to the empirical data. For the state Y = 1 (presence of cooperation/in prospect), the accuracy = 0.70, completeness = 0.40, F1-measure = 0.51, which indicates that the model is more restrained in assigning observations to this state; for Y = 0 (no cooperation), the accuracy = 0.81, completeness = 0.94, F1-measure = 0.87 reflect the confident reproduction of cases of no cooperation. Such a configuration of metrics may indicate the influence of relevant but not included in the model factors (such as the intensity of interaction, time lags, or industry specifics), the inclusion of which is currently complicated by the lack of reliable statistical information and detailed indicators in available sources. Under these conditions, the results obtained are sufficient to draw generalized conclusions about the determinants of cooperation, i.e. the factors that influence the presence/absence of business interaction with universities.

Among the obstacles that businesses see to effective cooperation with higher education institutions on sustainable and smart development goals are bureaucratic obstacles, financial constraints, and lack of incentives from local authorities (see Figure 4). Bureaucratic obstacles are noted as key obstacles to cooperation by representatives of the western regions of Ukraine (35.8%), lack of incentives from local authorities is more important for business representatives from the north of the country (21.6%), lack of incentives for cooperation from HEIs was noted by representatives of the business community in the central region of the country (19.3%), inflexibility and outdated management system of higher education institutions is more noticeable for business representatives of the Western region (9.4%) (see Figure 2).



	North	Centre	West	South
bureaucratic obstacles	30.4	26.5	35.8	26.3
financial constraints	21.6	20.5	20.8	21.1
lack of incentives from local authorities	19.6	19.3	9.4	15.8
lack of incentives for cooperation from HEIs	15.7	19.3	11.3	15.8
inflexibility and obsolescence of the management system in city government bodies	7.8	6	13.2	15.8
inflexibility and obsolescence of the management system in higher education institutions	4.9	8.4	9.4	5.3

Figure 2. Survey results of business representatives on the constraints and obstacles to the development of cooperation with HEIs in the context of sustainable and smart development, %, 2025

4. DISCUSSION

The important role of universities in ensuring socio-economic development is an axiom and requires no proof. At the same time, the research has revealed certain gaps: on the one hand, there is a clear understanding of the importance and necessity of cooperation between local governments and businesses and higher education institutions. On the other hand, the level of cooperation is insufficient to realize the potential of higher education institutions.

The results show that larger communities, ceteris paribus, are on average 19.8 ($p(AME) < 0.001$) percentage points more likely to cooperate with higher education institutions than smaller communities. Another stimulating factor is that the city's involvement in higher-level smart initiatives increases the likelihood of partnership by 8.2 percentage points on average ($p(AME) = 0.041$). An unexpected finding was the statistical insignificance of such predictors as *digital_init*, *green_init*, and *social_init*. This may indicate the indirect or context-dependent nature of the impact of these variables. Nevertheless, we believe that further research in this area may be interesting.

The analysis has confirmed that among the barriers to cooperation between HEIs and local self-government bodies, institutional inflexibility and outdated management systems, lack of incentives significantly reduce the likelihood of cooperation with universities, while financial constraints are associated with a less pronounced decrease in the likelihood of cooperation. Both groups of barriers have a distinct negative impact on cooperation, whereas: *bar:rigidity* (bureaucratic obstacles, inflexibility and outdated management systems in HEIs and/or local authorities) is associated with a decrease in the probability of partnership by 17.1 percentage points on average ($p(AME) = 0.055$), and bar: stimuli (absence of incentives from the HEI and/or local authorities) is associated with a decrease in the likelihood of partnership by about 24.9 percentage points ($p(AME) = 0.019$).

When analyzing business cooperation with higher education institutions, the most convincing effects are demonstrated by predictors that reflect the practical technological sophistication of the company and the institutional initiative of the academic partner. The use of artificial intelligence technologies by companies increases the likelihood of cooperation with universities: the average marginal effect for this predictor is 10.5 percentage points ($p(AME) < 0.001$). On the other hand, the likelihood of partnership increases by an average of 20.9 percentage points ($p(AME) = 0.010$) if the project is initiated by a university (*init:zvo*). The fact that the proactivity of the academic side is a significant catalyst for cooperation with business is important for further development and practical application of the results.

A university's important role in ensuring socio-economic development is an axiom that requires no proof. At the same time, the question of how universities should ensure the unity of free academic spirit and entrepreneurial and innovative activity remains a subject of debate. What mechanisms can be used to turn universities, businesses, and government into active participants in a single knowledge ecosystem?

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CONCLUSIONS, LIMITATIONS, AND DIRECTIONS FOR FUTURE RESEARCH

The purpose of the article is to assess the current state of cooperation between universities and business and government, identify obstacles, and formulate proposals for its development, taking into account international experience, regional specifics, and challenges of the post-war economic recovery of Ukraine. The assessment of cooperation between local governments and higher education institutions confirmed that the role of universities remains underutilized in Ukraine. The main conclusion of the surveys is that there is extremely weak interaction with business and local authorities. Among the main obstacles are bureaucratic barriers, inflexibility, and outdated management systems in local authorities and universities, a lack of initiative and incentives for cooperation on the part of all stakeholders: business, government, and universities.

Overcoming these obstacles is possible only through enhanced digital transformation, which will transform both the entities themselves and their internal structure, as well as all communications and interactions between them. Implementation of these recommendations will help strengthen the role of higher education institutions as key drivers of the smart economy, ensuring sustainable and inclusive development of the Ukrainian economy. First of all, universities should become powerful agents of change, based on their innovative and entrepreneurial potential. In general, universities are becoming not only educational institutions, but also innovation hubs, policy-making centres, and cluster drivers. Universities should have diversified sources of income and be able to raise significant funds through teaching, research, various services, etc. And accordingly, they should be more flexible and freer to use the funds they earn.

In addition, the formation of an effective knowledge ecosystem requires the development of the entire system of relations and interactions between universities and external actors. The subject of future research is further elaboration and development of effective mechanisms for transforming universities, business, and government into active, equal actors in a single knowledge ecosystem. Building effective cooperation in addressing pressing local development issues can be a real success factor.

SCIENTIFIC AND PRACTICAL IMPLICATIONS

The results obtained are intended to identify areas for intensifying interaction and overcoming barriers, the key to which is enhanced digitalization, which will transform both the subjects themselves and their internal structure, as well as all communications and interactions between them.

AUTHOR CONTRIBUTIONS

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