DOI: 10.18290/pepsi-2025-0016

Tomasz Kijek*
Agnieszka Komor
Agnieszka Smreczyńska-Gąbka
Mariusz Sagan
Maria Paździor

Smart City Policy as a Driver of Innovation-Driven Economy of Polish Cities

ABSTRACT

The primary aim of this study is to assess the impact of implementing the smart city concept on the development of innovation-driven economy in Polish regional capital cities. To achieve this research objective, a synthetic index – the Innovation-Driven Economy Index (IDEI) – was developed, comprising five indicators. The findings indicate that in 2023, the highest IDEI values were recorded in Lublin, Warsaw, and Rzeszów, whereas the lowest values were observed in Gorzów Wielkopolski, Zielona Góra, and Bydgoszcz. To measure the extent of the sample cities' commitment to implementing the smart city concept,

* Correspondence regarding this paper should be sent to Tomasz Kijek (ORCID: 0000-0002-0134-4943), Institute of Finance and Economics, Maria Curie-Skłodowska University in Lublin, e-mail: tomasz.kijek@mail.umcs.pl; or Agnieszka Komor (ORCID: 0000-0002-7532-3141), Department of Management and Marketing, Faculty of Agrobioengineering, University of Life Sciences in Lublin, e-mail: agnieszka.komor@up.edu.pl; or Agnieszka Smreczyńska-Gąbka (ORCID: 0000-0002-8945-1603), Doctoral School of Social Sciences, Maria Curie-Skłodowska University in Lublin, e-mail: asmreczynska@gmail.com; or Mariusz Sagan (ORCID: 0000-0003-3454-691X), Collegium of Business Administration, SGH Warsaw School of Economics, e-mail: mariusz.sagan@sgh.waw.pl; or Maria Paździor (ORCID: 0000-0003-1651-0359), Institute of Economics and Finance, John Paul II Catholic University of Lublin, e-mail: maria.pazdzior@kul.pl.

the propensity to obtain the ISO 37120 certification was used as a proxy. The results reveal that only four cities currently hold or have previously held this certification. Furthermore, the study demonstrates that the level of smart city development (measured by possession of ISO 37120 certification) and the quality of human capital (measured by the number of higher education graduates per 100.000 inhabitants) have a positive impact on the level of innovation-driven economic development.

KEYWORDS: smart city; innovation-driven economy; regional capital cities in Poland; human capital

INTRODUCTION

The contemporary urban economy is increasingly based on innovation, which constitutes a key driver of socio-economic development. Innovation – understood as the capacity to create and implement new technological, organizational, or social solutions – has become one of the main determinants of territorial competitiveness, particularly in the context of the knowledge-based economy (OECD, 2005).

The issue of innovation-driven economy, both in sectoral and spatial terms, is at the core of contemporary development and spatial policy agendas (Adamowicz & Zwolińska-Ligaj, 2021). Local and regional governments play a particularly important role in this context. In response to successive European Union financial frameworks, these authorities increasingly incorporate actions that foster innovation-friendly conditions into their strategic planning documents. Urban development strategies are progressively focused on investments in innovation infrastructure, the support of local innovation ecosystems, and collaboration with higher education institutions and the private sector (Matusiak, 2011; European Commission, 2023).

An innovative city is defined not only by its infrastructure but also by the quality of relationships and trust between the public

sector, academia, and business. An innovative urban economy requires the creation of an environment conducive to attracting and retaining talent, including a culture of openness, diversity, and high-quality public space. The development of an innovative urban economy can be supported through the implementation of smart city policies based on the integration of advanced technologies aimed at improving residents' quality of life, enhancing resource management, and promoting the sustainable development of the city.

Smart cities utilize various technologies (e.g., ICT, AI, IoT, wireless sensor networks – WSN) to generate multiple benefits for residents, entrepreneurs, and visitors, such as improved public service delivery, more efficient transport, energy and water systems, and enhanced public safety (Arora et al., 2023; Ahad et al., 2020). According to the European Parliament (2014), a smart city addresses public challenges through ICT-based solutions supported by multilateral partnerships at the municipal level. Caragliu et al. (2011) emphasize that investments in human and social capital, traditional infrastructure (e.g., transport), and governance based on shared resource management are also of key importance for smart city development. Lombardi et al. (2012) highlight the role of citizens' education, which enables the use of innovative communication channels, including interactions with local authorities. Another definition, which underscores the importance of leadership and management practices for the sustainable development of a city, states the following:

> Smart City is one that dramatically increases the pace at which it improves its social, economic and environmental (sustainability) outcomes, responding to challenges such as climate change, rapid population growth, and political and economic instability by fundamentally improving how it engages society, how it applies collaborative leadership methods, how it works across disciplines and city systems,

> and how it uses data information and modern technologies in order to transform services and quality of life for those in and involved with the city (residents, businesses, visitors), now and for the foreseeable future, without unfair disadvantage of others or degradation of the natural environment (ISO/TMB, 2015).

The literature emphasizes that human capital is one of the key drivers of innovation-based economic development, although the scope and nature of this influence depend on regional and economic conditions (España-Barraza, 2025). The historical level of human capital is a crucial factor in explaining current differences in innovativeness and economic development (Diebolt & Hippe, 2018). Regions with historically higher levels of human capital tend to exhibit greater innovativeness and economic growth today. D'Este et al. (2014) demonstrate that human capital significantly reduces innovation barriers, particularly those related to knowledge deficits and market uncertainty. As a result, firms with strong competencies are better equipped to overcome these challenges, facilitating their engagement in innovative activities. This suggests that a higher supply of skilled labour accelerates knowledge transfer and supports the adoption of new technologies, thereby enhancing the innovativeness of economies across various spatial scales. Srihita et al. (2025) argue that human capital is a critical driver of innovation within organizations. Consequently, investments in education and human capital development, as well as strategies for attracting and retaining talent, are essential for fostering the growth of innovation-driven urban economies. It is worth noting that there is a gap in the literature regarding empirical studies on the impact of human capital on economic innovativeness. This is largely due to methodological challenges and the multidimensional nature of both concepts (Skrodzka, 2025).

The aim of this study is to assess the impact of smart city implementation on the development level of innovation-driven economies in Polish regional capital cities, taking into account human capital as a control factor.

SMART CITY POLICY AND INNOVATION

The concept of smart city policy is closely linked to effective urban management, which requires the stimulation of innovation, cooperation among various stakeholders, and the use of advanced technologies to support intelligent and sustainable development (Wiśniewska & Janasz, 2018). The smart city concept has been adopted in numerous cities through strategic decisions and development objectives articulated in strategic planning documents and development policies. According to Giffinger et al. (2007), a smart city integrates urban activities focused on the following domains: smart mobility, smart environment, smart people, smart living, and smart governance.

An important dimension of the smart city is smart people, which refers to human and social capital and influences the development of education, openness to innovation, occupational mobility, and citizen participation in public life. Giffinger et al. (2007) define smart people as a commitment to lifelong learning, creativity, social and ethnic pluralism, flexibility, cosmopolitanism, and engagement in civic activities. G. Becker (1992), in his theory of human capital, R. Putnam (1994), in the concept of social capital, and R. Florida (2005), in the theory of the creative class, argue that educated, creative, and active citizens contribute to the development of an innovation-driven economy, the improvement of public service quality, and increased institutional efficiency. Research conducted by these scholars reveals a consistent pattern: cities that invest in improving access to education, expanding educational offerings, enhancing digital competencies, and promoting

social inclusion tend to achieve higher levels of competitiveness compared to those that do not undertake such efforts.

One of the pillars of the smart city paradigm is smart governance, which is increasingly recognized as a transformative approach to addressing complex urban challenges such as rapid urbanization, climate change, social inequalities, and resource constraints. According to Buchanan et al. (2014) and within the framework of public choice theory (Tullock, 2018), the condition of institutions and the structure of governance are crucial factors influencing economic efficiency and quality of life. To implement smart governance – characterized by reduced transaction costs and increased social trust – key instruments include open data, e-administration, public consultations, and co-governance mechanisms (Sarker et al., 2018). The United Nations estimates that the global urbanization rate will rise from 56% in 2021 to 68% by 2050, resulting in an increase of 2.2 billion people living in urban areas (UN, 2022). This projection highlights the importance of scientific research aimed at better directing urban management efforts. Urban authorities should recognize that a smart city relies primarily on the exchange of information flowing between its many separate subsystems, forming an ecosystem structured around sustainable frameworks for public service delivery (Mutiara et al., 2018).

Smart mobility represents another key dimension of the smart city concept. In recent years, a major challenge in urban areas has been the provision of integrated and efficient urban transport, as well as the development of sustainable mobility systems. From the perspective of urban economics, the goal is to optimize urban space, improve accessibility, and reduce the external costs of transport, such as pollution and congestion. Cities are employing a variety of tools, including e-mobility, investments in shared transport systems and cycling infrastructure, intelligent transport systems (ITS), and low-emission public transport. In the European Union, the Strategic Transport Research and Innovation Agenda (STRIA) of the European Commission has outlined

future priorities for research and innovation in transport, aimed at reducing CO_2 emissions in the European transport sector. These priorities include: Connected and Automated Transport (CAT), Smart Mobility and Services (SMO), Transport Electrification (ELT), Low-emission Alternative Energy (ALT), Transport Infrastructure (INF), Network and Traffic Management Systems (NTM), and Vehicle Design and Manufacturing (VDM) (Vătămănescu et al., 2024).

The development of smart cities is supported by *smart environment* technologies, which involve environmental monitoring and data-driven decision-making by city managers, utilizing tools such as big data and the Internet of Things (IoT). The optimization of resources, management of natural resources, and urban ecosystems through these technologies includes efficient energy, water, and waste management, as well as the reduction of CO_2 emissions (Ramírez-Márquez et al., 2024). According to George and George (2023), Society 5.0 represents a significant advancement that goes beyond the industrial orientations of Industry 4.0 and Industry 5.0. A key focus is the harmonization of cutting-edge technologies (automation, digitalization) with fundamental human needs related to environmental and resource management (Shaddiq & Irpan, 2023). A crucial element of Society 5.0 is resource optimization and alignment with the United Nations' Sustainable Development Goals (SDGs) (Leng et al., 2022).

Smart living pertains to the improvement of residents' quality of life, which is a fundamental objective of all local development strategies and the smart economy. This approach integrates technologies that enhance the efficiency and accessibility of services, including e-health, smart buildings, and social participation platforms (Stara et al., 2023). Ambient Assisted Living (AAL) systems hold significant potential to address urban healthcare challenges and engage citizens in their own health care through information and communication technologies (ICT) (Belbachir et al., 2010). AAL systems consist of an ecosystem of medical

sensors, computers, wireless networks, and software applications for healthcare monitoring (Vrančić et al., 2024). Giffinger's model, which encompasses the functional domains of smart city solutions, includes social, equity, inclusion, housing, and participation projects (Rudewicz, 2019). This model, developed by the Vienna University of Technology in cooperation with European partners, is one of the most recognized tools for classifying smart cities. Within Giffinger's framework, smart living is not only a factor influencing quality of life but also a significant driver of urban economic development. From the perspective of urban economics, it impacts investment, mobility, productivity, and the efficiency of urban resource management (Marchlewska-Patyk, 2023).

At the current stage of urban development within the smart city concept, artificial intelligence (AI) is an integral component. Zhu (2020) compares AI with other scientific fields such as space technology, genetic engineering, nanoscience, and energy technology. AI introduces numerous new possibilities for smart city development that should be incorporated into smart city policies. These include predictive infrastructure management, such as energy grids or water supply networks (Wrana, 2025), personalization of urban services, for example in education management (Hybka et al., 2024), spatial development simulations (Anwar & Sakti, 2024), as well as anomaly detection and support for crime prevention (Niedopytalski, 2000).

The literature review confirms the positive impact of smart cities on innovation. It has been demonstrated that smart city development policies significantly enhance the efficiency of urban innovation (Shu et al., 2024; Wang & Deng, 2022). Lim et al. (2024) argue that second-wave smart cities, which emphasize comprehensive urban management, are characterized not only by higher economic growth and improved perceptions of democracy but also by increased levels of innovation. The mechanism through which smart cities influence innovation is multifaceted. Smart cities stimulate technological innovation growth through the

allocation of technological resources, agglomeration effects, and encouragement of entrepreneurial activities. Research shows that substantial activity in implementing smart city policies positively affects patenting intensity (Caragliu & Del Bo, 2019) as well as the increase in research and development expenditures (Ma et al., 2024), thereby driving the development of an innovation-driven economy. Moreover, smart cities generate positive externalities and contribute to increasing innovation, competitiveness, and entrepreneurship within urban areas, which accelerates economic growth (Visvizi et al., 2023). The availability of high-quality ICT infrastructure, along with ICT-supported tools and applications in smart cities, provides entrepreneurs with access to data and services and real-time connectivity between entrepreneurs and other stakeholders. This facilitates information exchange and the implementation of new business ideas and innovations (Radu & Voda, 2022). In this context, the role of municipal authorities and public policy is crucial in developing ICT-based solutions in smart cities, which bring significant benefits to residents, entrepreneurs, and tourists (Komor, 2024).

MEASUREMENT OF SMART CITY IN THE CONTEXT OF ISO 37120 STANDARD

Various indicators exist for assessing the development of smart cities. From the perspective of implementing smart city policies, the ISO 37120 standard holds significant importance, as it serves both as a certification of the adoption of the smart development concept and as a benchmark for evaluating the level of sustainable development implementation (Legutko-Kobus, 2021; Midor & Płaza, 2020). The ISO 37120:2014 standard, titled "Sustainable development of communities – Indicators for city services and quality of life," was developed in 2014 in Canada by the World Council on City Data (WCCD, 2025). It was the first international

standard for cities published by the International Organization for Standardization (ISO). Currently, the 2018 version, ISO 37120:2018 "Sustainable cities and communities – Indicators for city services and quality of life," is in force (ISO 37120, 2018). This standard encompasses a set of indicators classified into 19 categories, including economy, education, energy, environment and climate change, finance, governance, health, housing, population and social conditions, recreation, safety, solid waste, sport and culture, telecommunication, transportation, urban/local agriculture and food security, urban planning, wastewater, and water. Some indicators are classified as core, while others are considered supporting. The level of certification (aspirant, bronze, silver, gold, or platinum) depends on the number of indicators reported by a given city, with a city aspiring to be recognized as "smart" required to measure at least the core indicators. The ISO 37120 standard specifies data sources and defines the measurement methods for individual indicators without setting minimum threshold values. Consequently, the evaluation concerns the adequacy and reliability of the data used, as well as the correctness of the indicator calculations, rather than the values of the indicators themselves.

In Poland, the standard PN-ISO 37120:2015-03 "Sustainable social development – Indicators for city services and quality of life" was published by the Polish Committee for Standardization (2025). Cities have the option to choose between an international or a national certification pathway. In the case of international certification, the process is overseen by the World Council on City Data (WCCD), whereas the national certification is conducted by Polish certifying bodies such as the Polish Register of Shipping or the Polish Committee for Standardization. Obtaining certification from the WCCD entails the inclusion of the city's name in the Global Cities Registry database. Although this involves higher costs, it offers significant reputational benefits and enables benchmarking against other urban centers across Europe and worldwide. The certification must be renewed annually, which

is a requirement to maintain the validity of the certificate and the city's inclusion in the international registry.

The standardized indicators of the ISO 37120 standard provide access to reliable, accurate, and up-to-date data, which enhances the efficiency of urban management and consequently contributes to improving residents' quality of life. Data serve as the foundation for sustainable urban development (Bokolo, 2023) as well as for the advancement of smart cities by streamlining decision-making processes and ensuring better and smarter services for inhabitants (Sarker, 2022). Research shows that ISO 37120 constitutes a practical method for measuring city performance (Hajduk, 2016), particularly in assessing the efficiency of smart cities (Kowalczyk & Rącka, 2024). The measurement and analysis of the standard's indicators enable the monitoring of urban development across various dimensions (economic, social, and environmental), identification of strengths and weaknesses, and adaptation of public policy measures accordingly, which should yield benefits over a longer time horizon. Studies confirm that the ISO 37120 indicators serve as an effective tool for evaluating urban public policies, and benchmarking against other cities globally can support the implementation of innovations in public governance (Stefani et al., 2024).

DATA AND METHODS

The research sample consists of 18 Polish regional capital cities, as the smart city policies are mainly implemented in the largest Polish cities and their metropolitan areas (Masik et al., 2018). We apply data derived from the Local Data Bank provided by Statistics Poland. Considering the data availability, the research period covers the year 2023.

In our study, the innovation-driven economy index (IDEI) is used as the dependent variable. The indicators for assessing

innovation-driven economy at the city level include: share of newly registered creative sector entities in the number of total newly registered entities, patents granted by the Patent Office of the Republic of Poland /100 thousand inhabitants, new registered enterprises in high-tech and medium high tech industry sectors/100 thousand inhabitants, new registered enterprises in high-tech services sectors/100 thousand inhabitants, new registered enterprises in knowledge-based services sectors/100 thousand inhabitants. The dummy variable indicating smart city certification status (Polish ISO 37120 certification) serves as the main explanatory variable (SCC). It is coded as 1 for cities that currently hold or have previously held the certification, and 0 otherwise. Consistent with the findings of empirical studies, including those by Cui et al. (2025), we control for human resource potential for innovation activities in cities by including higher education graduates/100 thousand inhabitants (HR) as a control variable.

To construct the innovation-driven economy index, we apply the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Hwang & Yoon, 1981), which belongs to the group of multi-criteria decision analysis methods. The TOPSIS allows for finding the best alternative by considering its proximity from the positive ideal solution (PIS) and from the negative ideal solution (NIS). The TOPSIS method involves the following steps: constructing a normalised decision matrix, constructing a weighted normalised decision matrix, determining positive ideal and negative ideal solutions from a set of alternatives, calculating the separation measures for respective alternatives, and calculating the relative closeness of alternatives to the ideal solution. The range of the relative closeness factor is between 0 and 1, i.e., the higher the factor / index, the better the rank.

Since our dependent variable takes values between 0 and 1, we use a fractional response model, which incorporates a probit model for the conditional mean (Papke & Wooldridge, 1996). The probit fractional regression model can be expressed as:

$$E(IDEI_i \mid SCC_i, HC_i) = \Phi(\beta_0 + \beta_1 SCC_i + \beta_2 HR_i)$$

where: $IDEI_i \in [0,1]$ – the innovation-driven economy index, SCC_i – binary variable equal to 1 if the city holds ISO 37120 certification or has previously held the certification, and 0 otherwise, HC_i – the number of higher education graduates/100 thousand inhabitants.

RESULTS AND DISCUSSION

Table 1 shows the descriptive statistics. As can be seen, there is high cross-sectional variation in the analysed variables.

Table 1. Descriptive statistics in 2023.

Variable	Mean	Std. dev.	Min.	Max.
IDEI	0.326	0.170	0.064	0.645
SCC	0.222	0.428	0	1
HR	508.359	203.117	100.895	824.008

Note. Own elaboration.

In Poland, a total of five cities have held or currently hold the ISO 37120 certification, four of which belong to the group of studied voivodeship (provincial) cities – see Table 2. In addition to the voivodeship cities, the city of Gdynia has also held this certification.

Figure 1 presents the ranking of Polish voivodeship cities based on the value of the Innovation-Driven Economy Index (IDEI) in 2023. The leader in the ranking was Lublin. This was primarily due to the highest level of technological entrepreneurship in the industry among the sample cities (measured by the number of newly registered enterprises in high-tech and medium-high-tech industry sectors per 100,000 inhabitants) as well as a strong

Table 2. Polish regional capital cities with ISO 37120 certification.

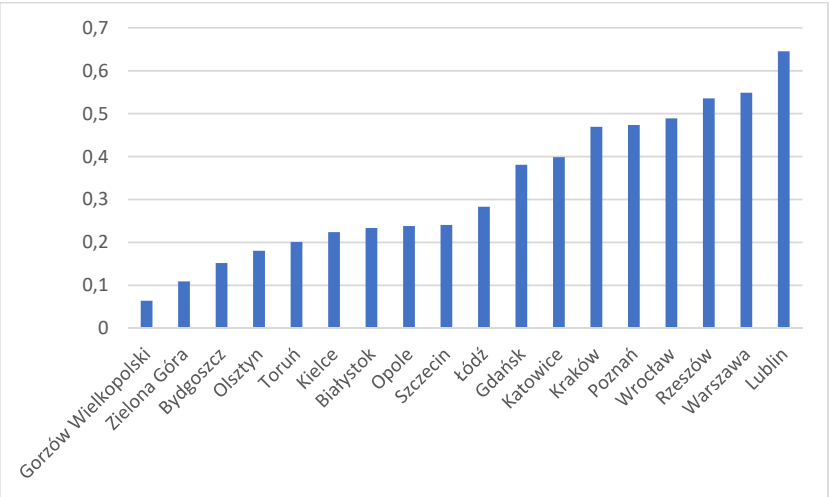
Regional capital cities	Validity period	Certifying institution	Certificate level
Gdańsk	2017-2026	Polish Register of Shipping (PRS)	The city presented data for 87 indicators, which corresponds to a gold level certificate
Kielce	2018-2019	WCCD	Platinum
Lublin	2019-2022	Polish Committee for Standardization	The city presented data for 96 indicators, which corresponds to a platinum level certificate
Warszawa	2019-2020	WCCD	Platinum

Note. Own elaboration based on City of Gdansk, 2025; City of Kielce, 2025; City of Lublin, 2025; City of Warsaw, 2025; Moneta, 2024.

propensity for patenting (patents granted by the Patent Office of the Republic of Poland per 100,000 inhabitants). Moreover, Lublin stood out for its relatively high share of newly registered entities in the creative sector among all newly registered entities. Warsaw ranked second among the voivodeship cities. The capital's high position in the ranking was mainly driven by the highest level of service entrepreneurship in high-tech sectors, other knowledge-based sectors, and the creative sector among the examined cities. Additionally, Warsaw also exhibited a relatively high level of technological entrepreneurship in industry. Rzeszów took the third place in the ranking, characterized by a relatively high propensity for patenting as well as a strong level of technological entrepreneurship in both industry and the creative sector. At the bottom of the ranking were, respectively, Gorzów Wielkopolski, Zielona Góra, and Bydgoszcz. Gorzów Wielkopolski had the lowest indicators among the studied spatial units in service entrepreneurship in high-tech sectors, other knowledge-based sectors, and the creative sector, as well as the lowest propensity for patenting. Zielona Góra and Bydgoszcz demonstrated relatively low levels across all measured indicators, except for the level of

technological entrepreneurship in industry for Bydgoszcz and the level of service entrepreneurship in other knowledge-based sectors for Zielona Góra.

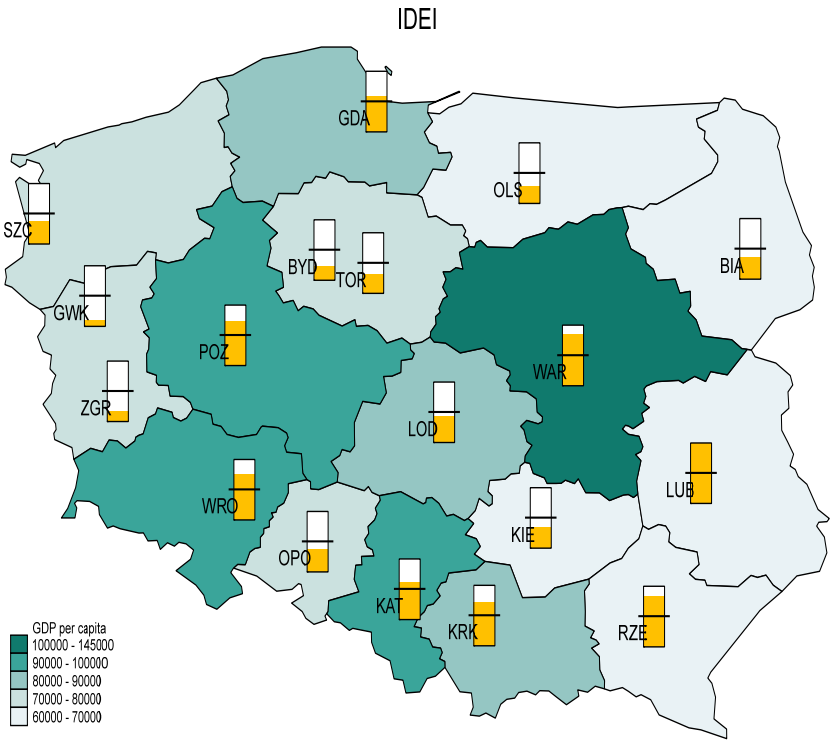
Figure 1. The innovation-driven economy index (IDEI) in Polish regional capital cities in 2023.



Note. Own elaboration.

The highest value of human capital (HC) was found in Rzeszów. Lublin ranked second and was also the leader among Polish voivodeship cities in terms of the Innovation-Driven Economy Index (IDEI). Following them in HC values were Katowice, Poznań, and Kraków, which also ranked relatively high in the IDEI city rankings. The lowest HC values were recorded in Gorzów Wielkopolski, followed by Zielona Góra, Szczecin, and Bydgoszcz. These cities—except for Szczecin—also exhibited the lowest levels of the Innovation-Driven Economy Index. The spatial distribution of IDEI is presented in Figure 2.

Figure 2. The spatial distribution of the innovation-driven economy index*.



* The yellow color indicates the level of the IDEI index in regional capital cities in Poland.
Note. Own elaboration.

The probit fractional regression results, presented in Table 3, indicate that cities holding ISO 37120 certification tend to have a more developed innovation-driven economy. The literature provides evidence supporting the positive impact of a city possessing the ISO 37120 certification on the development of an innovative economy (Haras & Zimmer, 2015). De Santana et al. (2018) emphasize that the goal of the ISO 37120 standard is to accredit a city as a smart city by implementing public policy measures aimed at, among others, facilitating innovation and economic growth, building an

innovative economy, achieving sustainable development goals in a more innovative manner, and identifying the demand for intelligent infrastructure. The standard serves as a foundation for smart management (i.e., knowledge- and data-driven management) as well as a reliable and multidimensional basis for monitoring and improving the quality of life and urban services (Malinowska & Kurkowska, 2018; Przybyłowski et al., 2022).

Table 3. The probit fractional regression estimation.

Variable	Coef.	Std. err.	z	P>|z|
SCC	0.333	0.191	1.75	0.081
HC	0.002	0.0002	8.03	0.000
const.	-1.547	0.140	-11.01	0.000
Wald chi2(2) = 113.67 Prob > chi2 = 0.000				

Note. Own elaboration.

The results also show that cities with higher human capital tend to have a more developed innovation-driven economy. Studies conducted in various countries have demonstrated that human capital significantly and positively influences the innovativeness of these countries' economies (Skrodzka, 2025; Gao et al., 2014). Furthermore, research conducted in China indicates that an increase in the number of students positively affects the growth in patent applications (Kang et al., 2022; Yue, 2023), thereby stimulating the development of innovation-based economy.

To translate our findings into effective urban policy, several examples of public policy instruments can be identified whose implementation may accelerate the development of innovation-driven economies at the city level. Municipal authorities should adopt a problem-oriented policy mix, that is, a set of complementary and integrated policy instruments encompassing regulatory instruments based on legal measures, economic and financial instruments that support or constrain specific types of activities, as well as soft instruments of a voluntary nature

(e.g., recommendations, voluntary agreements and contractual relations, and public–private partnerships) (Borrás & Edquist, 2013).

Among regulatory instruments, legal provisions that stimulate innovation development and strategic documents – such as smart specialization strategies – play a significant role (Casado, 2014). An important challenge is to ensure financial support for cities in implementing solutions that contribute to the development of an innovation-driven economy, such as Open Data initiatives. This support may include various instruments, such as governmental and EU funds, including grants, repayable instruments, or tax incentives for firms implementing innovative solutions. Tarkkala et al. (2020) emphasize the importance of public–private partnerships (PPPs), through which cities can collaborate with private companies, software developers, and research institutes to develop new products and services based on open data. PPPs are crucial for leveraging the knowledge and resources of the private sector to stimulate innovation in public services and infrastructure. Moreover, they facilitate the sharing of risks and benefits between public and private actors, fostering a collaborative environment conducive to innovation.

Another group of public policy instruments involves stimulating demand for innovation through targeted public procurement (Mao & Zhong, 2024; Georghiou et al., 2014; Edler & Georghiou, 2007). This demand-driven approach encourages firms to invest in research and development in order to meet the specific needs of public entities. Empirical evidence shows that demand-side policies involving public procurement of innovation have a significant and positive impact on product and process innovation in firms through research and development activities (Sein & Prokop, 2023). Equally important is the collaboration-based approach within cities. Strengthening cooperation and integrating multiple stakeholders – including academia, industry, government, and civil society – through open innovation frameworks can stimulate joint innovation activities. This approach is particularly

relevant in smart city initiatives, where diverse actors collaborate to design and implement digital services and other innovative solutions (Marchesani & Ceci, 2025).

Research by Yerden et al. (2021) indicates that instruments stimulating the development of smart cities include, among others, the establishment of an organizational unit responsible for smart city development, the availability of municipal funding, the adoption of a collaborative approach, and the level of digital skills among municipal employees and residents. Building technological and analytical competencies among local government employees through training programs and strategic human resource development helps bridge skill gaps and enhances the capacity of municipal offices to manage data, conduct analyses, and implement smart city projects. This is crucial in the context of supporting innovation-driven economies in urban areas. According to Cardoso and Gomes (2025), the development of digital competencies among public administration officials should include, among others, data analysis, cybersecurity, and artificial intelligence (AI). These competencies are essential for improving efficiency, transparency, and service delivery within public administration.

Instruments that inform residents about solutions contributing to innovation-driven urban economic development are also of significant importance. Mele (2023) emphasizes that informing citizens about open data tools and platforms can enable their participation in community planning and development. Disseminating such information allows citizens to monitor, oversee, and evaluate the implementation of public policies, thereby promoting transparency in governance and fostering civic engagement (Castro Neto et al., 2017). For instance, innovation contests or hackathons utilizing open data can help identify and address urban challenges by engaging residents in the co-creation of solutions (Hartmann et al., 2018). Open data–based tools encourage residents to interact with city authorities and provide real-time

feedback, thereby supporting the creation of an open innovation ecosystem (Gagliardi et al., 2017). As demonstrated in this study, another important instrument involves the adoption of standards and monitoring systems for assessing progress in implementing smart and sustainable cities, such as the ISO 37120 certification, which has a positive impact on the level of innovation-driven economic development.

CONCLUSIONS

The research findings indicate that in 2023, the innovation-driven economy index (IDEI) reached its highest values during the analyzed period in Lublin, Warsaw, and Rzeszów, while the lowest values were recorded in Gorzów Wielkopolski, Zielona Góra, and Bydgoszcz. Lublin's high ranking was primarily due to the highest level of technological entrepreneurship in industry and propensity to patent among the analyzed spatial units. Warsaw stood out with the highest level of service entrepreneurship in sectors related to smart cities, whereas Rzeszów was characterized by a relatively high propensity to patent as well as relatively high levels of technological entrepreneurship in industry and the creative sector. Additionally, the study demonstrated that the level of smart city development, confirmed by possession of the ISO 37120 certification, positively influences the development level of the innovation-driven economy. A similar relationship was observed with respect to human capital, measured by the number of higher education graduates per 100,000 inhabitants.

The results have practical applications and can serve as support for public policy in shaping instruments that foster the innovativeness of urban economies. In this context, continuous investment in human capital, as well as the implementation of smart city solutions, is of great importance.

When interpreting the obtained results, it is important to consider the conceptual and methodological limitations of the conducted research. Firstly, measuring the implementation of the smart city concept based solely on the possession of the ISO 37120 certification by a city is a simplified approach. Secondly, the study is static in nature and does not account for the dynamics of the analyzed phenomena. Thirdly, the research model of the innovation development of Polish voivodeship cities' economies includes only one control variable. To address these limitations, future empirical research should be based on panel data, utilise more precise indicators describing smart cities, and incorporate a broader range of factors determining urban economy innovativeness. Furthermore, future research directions may include analyses conducted at the level of other countries, including those in Central and Eastern Europe, which would allow the positioning of the results for Polish cities within a broader regional context.

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