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ANALYSIS OF SUPPORT FOR THE DEVELOPMENT OF INNOVATION IN HYDROGEN TECHNOLOGY SECTOR ENTERPRISES IN THE REGIONS BASED ON EMPIRICAL RESEARCH - DECISION PROJECT

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ABSTRACT

Purpose: *Energy and hydrogen technologies are considered to be technologies of the future, forward-looking and highly innovative, and therefore fit perfectly into the concept of smart specialisations implemented in the regions. The article analyses the current decisions regarding measures taken in regions for innovation development, with a particular focus on the importance of building innovation potential (RIS3 strategies).*

Need for the study: *The market for hydrogen technologies is increasingly supported by regions interested in innovation, and these technologies are or are now becoming priorities for EU energy policy. Therefore, it seems interesting to identify and evaluate decisions regarding their public support in innovation policy at the regional level.*

Methodology: *The study used logistic regression, which is a statistical method of analysis used to model the probability of a binary event. The purpose of using this type of regression was to identify and assess the significance of the determinants of the performance of the companies studied.*

Findings: *The approach to supporting the development of innovation in hydrogen technology companies has recently undergone a transformation. The results of the analyses help to identify challenges in the perspective of future pro-innovation decisions, updating approaches, and improvements in influencing the technological potential of companies.*

Practical implications: *The conclusions developed allow new decisions to be taken or existing ones to be revised toward public support, which in turn should foster modern solutions to stimulate innovation in regional economies.*

Keywords: Smart specializations, innovation, energy, hydrogen technology, public support, regional development, public sector governance

Jel codes: 031; O32; L21; R11

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1. INTRODUCTION

To maximise its innovation potential, Europe is investing in innovative areas through a number of support mechanisms. In Poland, various solutions are taken into account in the context of innovation development, including the so-called smart specialisation (*Smart Specialisation Strategy*). The identification of smart specialisation at the regional level through the identification of technologies and innovative solutions increasingly relates to energy policy priorities. However, in Poland, unlike other European countries, there is a visible gap with regard to hydrogen technologies. The deployment of FCH technologies should be supported by regions interested in innovation, as these technologies are or are now becoming priorities in EU energy policies. Furthermore, FCH technologies are innovative and thus fit perfectly into the concept of smart specialisation proposed by Prof. Dominique Foray (Foray et al., 2012) , and which currently seems to be the basis for major European initiatives to support innovation.

The current structure of public support in the regions concentrates most of the efforts on the system of financing enterprises within operational programmes. The system of financial support alone for the purchase of new technologies by enterprises is becoming insufficient in the context of the need to build a whole ecosystem of links between enterprises, public administration, and business environment institutions. Public action should create a favourable environment for innovation, stimulate research and development, and foster rapid technological challenges. In light of the above, it is interesting to analyse the key benefits and needs of business innovation development, using the example of hydrogen technology companies, to identify the decision-making challenges that are most relevant in the near future.

The paper will identify and analyse the forms and effects, as well as the subject and scope of the public support functioning system to influence the development of innovation in hydrogen technology companies. The purpose of the article is to formulate conclusions and provide information on current decisions about actions taken in regions for the development of innovation, with particular emphasis on the importance of building the innovation potential (RIS3 strategies).). The changes taking place in the environment of contemporary enterprises, related to the constant competitive struggle, force a change in the way of looking at the current standards of public management and generate new challenges in this area. Changes in support systems require the application of the principles of smart governance - one that can adapt public policy to the rapidly evolving hydrogen market. Smart governance in a policy context, often understood as smart governance, refers to the use of technology and innovation to improve the efficiency, transparency and effectiveness of decision-making by public bodies. The use of regional smart specialization strategies, illustrates the need for smart governance to support innovation at the regional level. In the context of the defined research objective that indicates the evaluation of the importance of public decisions and actions in the development of innovativeness of enterprises that implement hydrogen technologies within the framework of the so-called smart specialisations, it should be stated that companies that implement new technologies perceive the need for continuous verification and updating of the functioning support mechanisms.

In identifying the research gap, it was assumed that the deployment of hydrogen technologies is certainly one of the promising activities to be supported by regions interested in innovation, as these technologies are beginning to play a dominant role in the energy policies of many countries. Hydrogen-based technological solutions have many potential applications in the industrial, transport, construction and, in particular, energy sectors, which have very ambitious goals and operate in a dynamically changing environment. Energy and environmental safety issues are constantly being redefined here.

Hydrogen technologies, and hydrogen itself, are also essential to meet the EU's commitment to achieve carbon neutrality by 2050, while aiming for zero emissions. Investments in hydrogen will contribute to sustainable economic growth and job creation. Hence, it is often stressed that a breakthrough in the development of hydrogen technologies is needed, based on new investments, a favourable regulatory framework, new lead markets, sustained research and innovation in breakthrough technologies (Hydrogen Strategy..., 2020). Although, increasingly in practice, hydrogen technologies are creating new conditions for companies operating in traditional regional arrangements, forcing change and operating within networks, there is a lack of analysis in the literature linking and describing these phenomena. On the one hand, it can be seen that hydrogen technologies create innovation potential and are becoming the main focus of smart specialisation strategies in the regions, but on the other hand,

they are new enough to be well established as the subject of separate studies on stimulating their development as specialised industries in innovation-supporting regions.

The regional enterprise support system was evaluated based on the results of a quantitative survey conducted on a sample of 150 enterprises in the energy sector related to the development and deployment of hydrogen technologies. The study used logistic regression, which is a statistical method of analysis used to model the probability of a binary event. A key reason for selecting and using this type of regression was its feasibility and usefulness in identifying and assessing the significance of the results obtained from the companies surveyed.

2. LITERATURE REVIEW

Smart growth and sustainability are directly correlated and the concept of innovation is a factor integrating them (Dziedzic et al., 2015, 2016). According to Dziedzic et al. the support provided by public actors is particularly important as they can combine their efforts within national and regional innovation systems to develop technology and support research. Cooperation between the world of science and the world of business supports the commercialisation of knowledge and technology (Dziedzic et al., 2015). However, it becomes crucial to verify whether the implemented support meets the needs of entrepreneurs (Kogut-Jaworska & Ociepa-Kicińska, 2020). The focus on innovation and technology per se is to identify how the transition to sustainable economic development relates to changes in the economy and society in general, and public policy in particular.

Public policy issues are now treated as a significant socio-economic challenge. Public policy is mission-oriented and argues that major challenges such as sustainable growth, climate change, energy transition will require the adoption of new ways of cooperation (especially between public and private actors) (Gifford & McKelvey, 2019). Besides, innovation and new technologies only contribute to sustainability goals if they become more accessible in the larger socio-technical system (Gifford & McKelvey, 2019; Köhler et al., 2019). Current knowledge of how to achieve such goals is inadequate, so it is necessary to invest in the development of new technologies and new scientific knowledge (Gifford & McKelvey, 2019). The result of this combination can be a Regional Innovation Strategy (RIS3), prioritising the achievement of competitive advantage by developing and combining strengths in research and innovation with business needs. The concept of smart specialisation is central to defining the path of innovative growth in the regions. Although the principles and implementation of regional smart specialisation strategies (RIS3) are widely discussed in the literature, the effectiveness of these policies depends on the willingness and ability of the beneficiaries to use them (Gemma & Bulderberga, 2017). As Grillitsch and Asheim argue, in order to address any emerging opportunities, businesses should be impacted in a coherent way, while avoiding any duplication or fragmentation of efforts (Asheim et al., 2016; Grillitsch & Asheim, 2018b, 2018a). On the other hand, Gianelle and Guzo point out that regional decision-makers may lack the capacity and resources necessary to manage efficiently the innovation support system set by smart specialisation strategies (Gianelle et al., 2020).

RIS3 aims at economic development through regional priorities that correspond to efficiency, research and innovation in the knowledge economy. According to (Bevilacqua et al., 2019; Kangas & Aarrevaara, 2020) the main point is to allocate resources to research and innovation to strengthen priority areas of regional funding, governance and regulation, creating a regional policy mix (Kangas & Aarrevaara, 2020). This corresponds to what is probably the largest attempt yet at a structured, transnational innovation strategy, which, according to Grillitsch and Asheim, stimulates economic growth through economic diversification and the development of a new pathway, e.g. diversifying the economy into technologically more advanced activities that make progress towards more complex knowledge compared to its current level in the region (Grillitsch & Asheim, 2018b).

Smart specialisation can be seen as a key solution to avoid the dispersion of research funds and focus research, human and financial resources on those sectors that have innovative potential, are highly productive, strategic from a socio-economic perspective, environmentally friendly and attractive to investors (Rusu, 2013). Public impact is justified and advisable especially when the complex interactions that take place between the different organisations and institutions involved in innovation do not work smoothly (Coenen et al., 2017). EU strategy documents and other claims in the literature (Gifford & McKelvey, 2019; Köhler et al., 2019; Schot & Steinmueller, 2018; Uyarra et al., 2020) have an

important impact on the current discussion on smart and sustainable development, especially based on smart specialisation strategies.

Recently, it has been noted that the link between business support policies and hydrogen technologies is increasing. This is the view of Ortiz Cebolla, Rafael & Navas, Carlos, among others. (2018), arguing that economies are moving away from hydrocarbon-based energy and that hydrogen is an effective alternative for them, of interest to policy-makers creating innovation support policies. In addition, the use of hydrogen technologies in modern economies, mainly energy or transport, aims to halt the progressive greenhouse effect and is part of many policy documents (among others, it forms one of the pillars of the implementation of the European Green Deal, which aims for Europe to achieve climate neutrality by 2050).

In summary, it should be assumed that contemporary approaches to stimulating innovation potential are based on the 'logic of regional innovation systems' (Weidenfeld, 2018) and focus on the interrelationships and complementarities between industries and sectors. Innovation systems in regions should consist of a knowledge generation and dissemination subsystem, which includes R&D organisations, educational institutions and technology transfer agencies, and a knowledge application and utilisation subsystem, which includes firms and clusters located in the region. Here, there is an intensive flow of knowledge, resources and human capital, which is important and underpins systemic innovation.

3. METHODOLOGY

The identification and evaluation of public support decisions for innovation policy at regional level, with a particular focus on EU innovation policy and hydrogen technologies was the subject of a study conducted in the second half of 2023. The intention of the overall research project was to collect and present data on the effectiveness of the management of innovation based on energy sources and hydrogen technologies in the implementation of regional innovation strategies (RIS3). In particular, the research assumption was to identify progress in the implementation of smart specialisation strategies and, consequently, to define guidelines and recommendations to increase the effectiveness of management, including decision-making of applied public support mechanisms.

As a first step, documents in force in the regions concerning support for innovation, including in particular the RIS3 strategies, were analysed. This research intention was analysed by means of a qualitative structural content analysis. The information contained in the strategies was compared with the guidelines of the national and European documents that were in force in the period 2020-2025. Based on the conclusions drawn, a quantitative study was designed and a survey questionnaire was prepared. The survey used the CATI (Computer-Assisted Telephone Interview) and CAWI (Computer-Assisted Web Interview) survey techniques. The questionnaire developed consisted of a total of 12 closed-ended and semi-open-ended questions, with single or multiple choice. For the clarity of the survey, the questions were grouped into sections of metrics and pertinent questions.

The database was created for the survey and consisted of 200 records, and during the survey process it was extended by 50 records in order to reach the desired number of respondents, i.e. n=150 business entities representing the energy sector (according to PKD) operating in industries related to hydrogen technologies. The research sample was selected from data contained in the Kompass International and Business Navigator databases (the indicated databases contained data on enterprises from all over Poland). Entities meeting the criteria for conducting the study were selected from the databases, and due to the definition of the group of respondents in terms of business activity, the sample was selected on the basis of the identification of the leading PKD code (selected sections: Section D - production and supply of electricity, gas, steam, hot water and air to air conditioning systems; Section C - industrial processing, G - wholesale and retail trade, repair of motor vehicles, including motorbikes; M - professional, scientific and technical activities).

Consequently, the survey generated a sample of 150 enterprises with knowledge of the concept of smart specialisations. The enterprises participating in the study represented all voivodeships in Poland. The largest number of respondents came from Pomorskie Province n = 26 (17.33%) and Mazowieckie Province n = 21 (14.00%). The smallest number of respondents conducted their business activities in the Opolskie Province n = 3 (2.00%) and Podlaskie Province n = 2 (1.33%). The characteristics of the

companies in relation to their sector of activity were as follows: the group of companies operating in the renewable energy sector (RES) was n = 69 (46.00%), to which n = 54 (36.00%) companies came from the heating, industry and transport sector and n = 27 (18.00%) companies operated in the combined heat and power (CHP) sector. In addition, the surveyed sample consisted mainly of companies operating on the market for several years, with a geographical concentration in the Pomeranian and Mazovian Voivodeships. The dominant group were companies operating in the RES sector, which may indicate an increased interest in the green economy and the development of innovation in this field in the near future. The survey covered companies with different market seniority, which made it possible to observe the dynamics and development trends also in the context of the companies' time on the market.

The results of the study were constructed using logistic regression, which is a statistical method of analysis used to model the probability of binary events. The use of this type of regression allowed the identification and assessment of the significance of the determinants of the surveyed companies' performance. The analysis was carried out at a predetermined level of alpha (α) = 0.05, which determined a 5% risk of Type I error. The normality distribution of the numerical variables was assessed using the Shapiro-Wilk test. A backward stepwise algorithm based on the Bayes Information Criterion (BIC) was used to select the independent variables for the logistic regression model. This algorithm at a later stage allowed the modelling process to start with a full model, including all potential independent variables, and then iteratively eliminated those variables whose removal led to the greatest improvement in the BIC value. Variables whose coefficients were not statistically significant at the α=0.05 confidence level were candidates for removal. Analyses were performed using the statistical language R (version 4.3.1; R Core Team, 2023) on Windows 10 Pro 64 bit (compilation 19045).

4 RESULTS

The assessment of public support within the framework of stimulating the development of innovation of hydrogen technology enterprises is a multi-threaded issue and can be the subject of broad decision-making analyses. The conducted research focused on key decision-making aspects, i.e. the effects, object, scope and forms of public support within the framework of the implemented innovation policy and implemented innovation stimulation strategies (RIS3).

The expected benefits from the implementation of smart specialisations may relate to the innovative development of enterprises, increasing their competitiveness in markets or, in a broader context, fostering the development of sectors and industries. Among the benefits related to the development of the innovativeness of enterprises are increases in production, income or employment. In turn, the impact on the competitiveness of enterprises is associated with the flow of technological thought from areas of smart specialisation to others, the innovative activation of entities and their employees directly related to the smart specialisation of the region. The mobilisation of innovative attitudes of suppliers, collaborators and competitors of companies in smart specialisation areas may also favour the development, of markets. Public support provided to stimulate the development of innovation in the regions may also contribute to influencing the demand for smart specialisation products. The characteristics of the distributions of the variable on past support for innovation development of the surveyed firms in the regions are presented in Table 1.

Table 1. Evaluation of public support to date in stimulating innovation development in the region

Characteristics	**N**	**Total sample** n (%)
Contributes to the development of company innovation	150	40,00 (26,67%)
Increases the competitiveness of the company on the international market	150	23,00 (15,33%)
Promotes the development of the energy sector in the region	150	16,00 (10,67%)
Promotes the development of the renewable energy sector in the region	150	16,00 (10,67%)

Characteristics	N	Total sample n (%)
Promotes the development of the hydrogen market and technology in the region	150	29,00 (19,33%)

Source: own elaboration.

The survey shows that public support is perceived by respondents as a factor contributing to the development of business innovation. It should be noted that 26.7% of the surveyed enterprises consider it as an important element of the system stimulating the development of innovativeness. On the other hand, the indicator, however, shows that the majority of surveyed enterprises do not perceive a direct impact of the support on their propensity to create or implement innovation. The suggestion here is that decisions need to be made to intensify pro-innovation activities or to better adapt existing forms of public support to the needs and market conditions of enterprises.

An evaluation of public support to date in stimulating the development of innovation in the regions, reveals that support to increase the competitiveness of enterprises on international markets is only perceived by 15.33% of the surveyed entities. This may mean that pro-innovation activities offered by the public sector at the regional level may not be globally relevant enough or are insufficiently promoted to companies with international aspirations. The importance of development projects that increase competitiveness in international markets may also stem from the need to create a sustainable co-operation-friendly ecosystem. It should therefore be important to take measures to support the cooperation of entrepreneurs, business environment institutions and research and development units, going beyond regional borders.

The analysis shows that support conducive to the development of the energy sector and the renewable energy sector in the region is assessed by respondents at a similar level. 10.67% of the responses indicate an even perception of the impact of support on both areas, which may indicate a balanced approach to the different energy fields. Nevertheless, it should be noted that the results have low percentages. The results may suggest that public support provided at regional level is not sufficiently felt by energy companies, or that these companies expect a more specific and targeted impact on markets, including specific technologies. An indicator illustrating support favouring the development of the hydrogen market and technologies may confirm this. 19.33% of respondents see the need for such measures, which is relatively the highest score. This indicates the potential emphasis of pro-innovation policies on this market segment, which may result from global trends and priorities in the field of green energy.

The distribution of variables characterising the potential and technological readiness of companies in the hydrogen economy value chain to develop innovation provides interesting results, as shown in Table 2.

Table 2. Assessment of the potential and technological readiness of companies in the hydrogen economy value chain

Characteristics	N	Total sample n (%)
Part of the hydrogen economy value chain	150	
Distribution		40,00 (26,67%)
Storage		17,00 (11,33%)
Production		76,00 (50,67%)
Application		17,00 (11,33%)
Form of activity in the context of technological readiness	150	
Supplier of hydrogen technology		91,00 (60,67%)

Recipient of hydrogen technology	59,00 (39,33%)

Source: own elaboration.

The results obtained from the analyses in Table 2 indicate that there is potential for a dynamic development of the hydrogen production sector. The obtained results are a signal for policy makers and companies to focus on the development of other elements of the value chain. Simultaneous support for innovation and technological competence in hydrogen storage and application may prove crucial for the sustainable development of the hydrogen economy. Building synergies between suppliers and consumers of hydrogen technologies through initiatives that support knowledge and technology transfer can significantly contribute to accelerating technology readiness along the value chain.

Among the respondents, the largest proportion of companies (50.67%) point to production as the main element of the value chain for which they see an increased need to mobilise public support. Indeed, technological development in this area, seems to be advancing more each year, suggesting that hydrogen production could be a key area for investment in innovation. Distribution is the second largest segment, with 26.67% of respondents specifically indicating innovation potential in this area. It can be concluded that, in the context of the need to efficiently deliver hydrogen to consumers, influencing the development of innovation can be very successful here. The elements of the value chain in the hydrogen economy that were much less noted by respondents were hydrogen storage and use. The representativeness of the responses here is much lower at 11.33% each, which may indicate that they are perhaps supported under other disciplines than hydrogen technologies or require additional investment in research and development.

When analysing the forms of enterprise activity in the context of their future technological readiness, it should be pointed out that the majority of enterprises surveyed (60.67%) identified hydrogen technology suppliers as the main group of public support. This may indicate maturity and technological readiness in this area, as well as companies' perception of business opportunities in developing products and solutions based on new technologies. On the other hand, 39.33% of respondents point to recipients of hydrogen technologies as key beneficiaries of public support. This shows that there is also a significant number of actors ready to implement new solutions, which may favour the rapid adoption and development of the hydrogen technology market.

Creation of a strong institutional system of innovation support may refer to structures set within regional innovation systems (including development strategies of voivodships together with regional innovation strategies) or structures created at the national level (within selected fields of innovative activity). The integration of the management system for the development of innovation, apart from financing pro-innovation projects, should serve the development of new cooperation and strengthen the already existing network connections, and not only be a response to the needs of public administration. A system functioning in this way should create conditions for the development of specialisation and ensure its proper infrastructure, access to information for entrepreneurs on technological or economic opportunities and threats, standards and norms of activity, as well as sources of financing, etc. The task of public decision-makers should therefore be to create individualised support tailored to the needs of a specific area of specialisation within the resulting innovation ecosystem.

The results of the study point to the need to review and adapt impact strategies for innovation development at national and regional level. Public policy makers should focus on increasing the effectiveness of programmes by better adapting to the specific needs of businesses including those in the area of hydrogen technologies. An integrated approach should be key to ensure coherence between actions at different levels of government and to create a strong ecosystem to support innovation and competence development in the hydrogen sector.

Table 3. Importance of public support for smart specialisations to the company's business (on a scale of 1 to 5, where 1 means "not at all important" and 5 means "very important")

Characteristics	N	Overall sample[1]
Support at national level - within the framework of National Intelligent Specialisations (NIS) - supporting more often the construction of the "supply side" of hydrogen technologies, e.g. within complex hydrogen economy value chains for company operations	150	3,00 (2,00, 3,75)
Support at Regional level - within the framework of Regional Intelligent Specialisations (RIS) - supporting the building of the "demand side" for hydrogen technologies (e.g. subsidies for the purchase of hydrogen vehicles)	150	3,00 (2,00, 3,00)
Sum of scores for the above questions	150	6,00 (4,00, 7,00)

[1] *Mdn* (*Q1*, *Q3*)

Source: own elaboration.

Analysing the data obtained, it is important to point out that support at the national level, under the NIS, shows a median significance rating of 3.00 with a quartile range from 2.00 to 3.75. This indicator shows a moderate rating of the importance of national support, which may suggest that companies perceive some benefits from NIS initiatives, but this level is not rated as critical to the companies' operations. It is likely that companies expect more specific or direct assistance that would have a greater impact on their business. On the other hand, support at the regional level, under RIS, also received a median score of 3.00, but with a narrower quarterly spread from 2.00 to 3.00. This is a signal that, although regional support is perceived as equally important as national support, expectations of it are more homogeneous among respondents. The sum of the scores for both types of support is 6.00, which, with an average score of 3.00 for each type of support, indicates a symmetrical perception of the importance of both levels of public influence on innovation development.

The surveyed entrepreneurs did not indicate significant shortcomings in the context of full integration of the innovation development management system. Apart from activities in the area of financial support, where respondents indicated full integration of the system, there is a need for improvement in other areas. Respondents perceive the need for integration of regional innovation ecosystems that bring together enterprises, research and development units and business support organisations. Respondents had a similar response to the issue of cooperation with local authorities. This may be due to reasons related to the short time of establishment and immaturity of some structures, as well as quite dynamic changes, evaluation or updates within the designated smart specialisations.

As the survey shows, grants, financial instruments and expert and advisory services are perceived as moderately effective (mean of 3.00), with some businesses rating them as more effective (upper quartile at 4.00). In contrast, vouchers for specialised services appear to be perceived as less effective (lower quartile at 1.00), suggesting that some businesses may be experiencing difficulties in using these support instruments effectively in their business. The assessment of the effectiveness of the forms of support offered under smart specialisations is presented in Table 4.

There is a widespread perception that the grant system is more popular among entrepreneurs than the repayable support system provided in the form of loans or guarantees. It is often pointed out that repayable instruments are less attractive than non-repayable financing in the form of grants, due to the time and manner of capital involvement. This is mainly important in the case of large investments requiring several years of planning, where the risk of success increases and, consequently, the prospect of achieving the set objectives is more difficult to realise. The use of repayable instruments requires entrepreneurs to make rational decisions based on sound economic accounts, to carry out well-considered actions and to use the funds put at their disposal within the framework of public support in a balanced and effective way. The advantage of grant instruments, as opposed to repayable instruments,

is their relative cheapness (no interest costs) and flexibility (possibility to refinance the capital remaining in the company). These instruments are a convenient form of support for investment in modern technologies, conducting research in a broad sense of development, which in turn has an impact on increasing income, improving competitiveness and increasing the value of enterprises.

Table 4. Evaluation of the effectiveness of the forms of support offered under smart specialisations from the point of view of meeting the needs of the enterprise (on a scale of 1 to 5, where 1 means "very ineffective" and 5 means "very effective")

Characteristics	**N**	**Overall sample[1]**
Grants	150	3,00 (2,00, 3,00)
Financial instruments (e.g. soft loans and credits)	150	3,00 (2,00, 4,00)
Expert and consultancy services	150	3,00 (2,00, 4,00)
Vouchers for specialised services (e.g. to be selected from the Development Services Database)	150	3,00 (1,00, 3,00)
Cooperation and collaboration (e.g. within cluster initiatives, hydrogen valleys and other institutional)	150	3,00 (2,00, 4,00)
Sum of scores for the above questions	150	15,00 (13,00, 16,00)

[1] *Mdn* (*Q1*, *Q3*)

Source: own elaboration.

Cooperation, collaboration, co-generation of demand for smart specialisation products within cluster initiatives and hydrogen valleys involves strengthening the development potential of entities forming a given cooperation network, including strengthening human resources, financing R&D infrastructure, financing activities supporting the professionalisation of research services, creating a system of research vouchers. The commissioning and implementation of R&D projects is often linked to the use of grant incentive systems consisting in the funding of programmes, research works or the purchase of research infrastructure. In addition, a popular activity is the organisation of meetings of representatives of the world of science and enterprises focusing on the specific sector of the economy identified as a smart specialisation (smart labs, technology workshops, good practices, exchange of views and working standards), which leads to a reduction in transaction costs of activities within the framework of the established cooperation networks. According to the survey, the vast majority of surveyed companies feel the benefits of this type of support system. The importance of business environment institutions in the context of building a public support system and developing smart specialisations is illustrated in Figure 1.

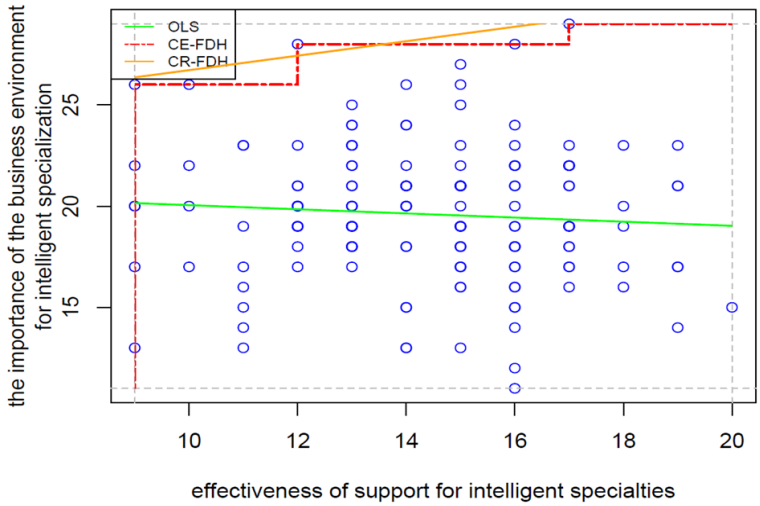

Figure 1. Importance of business environment institutions in the context of building a public support system and developing smart specialisations
Source: own elaboration

Developing the idea of smart specialisations, as well as supporting pro-innovation activities among businesses, should be a priority activity of public authorities at the regional level. Both decision-makers and administrative structures at the regional level should consider supporting and promoting cooperation networks within the framework of smart specialisations, as one of the basic challenges of the contemporary economy. As the study shows, strengthening the links between the world of science and the world of business, as well as building an innovation ecosystem and supporting initiatives of business environment institutions such as clusters or hydrogen valleys should be considered as one of the most important actions taken within the public support system for enterprises including the hydrogen technology sector

5. DISCUSSION

This study contributes to the growing field of research related to public management and innovation, and the development of hydrogen technologies. It largely focuses on the evaluation of regional innovation support showing how the concept of smart specialisation is perceived by hydrogen technology companies and what can be improved in this respect. This article analyses the decision-making mechanisms taken in the regions to support innovation through the prism of the evaluations of the companies surveyed. Using a typical research pattern and starting from identification, through diagnosis and evaluation, and concluding with research analyses, results and conclusions were obtained that are consistent with those presented in the literature.

The results obtained confirm the theses presented in the paper "Smart Specialisation: what gets lost in translation from concept to practice?" (Gianelle, Guzzo and Mieszkowski, 2020, p.1386) , indicating that regional decision-makers lack the capacity and resources necessary for efficient management within the innovation support system set by smart specialisation strategies. The results obtained highlight the need to increase the effectiveness of support, as well as the need to revise aid programmes to better meet the needs of hydrogen technology companies. Better management of smart specialisation strategies and more pertinent decisions responding to regional specificities can result from intensified cooperation between the public sector and the business sector.

Improving the quality of public policies and decisions concerning the regional innovation system and supporting the development of new fields, sectors and industries (i.e. renewing pathways and creating pathways) to stimulate regional potential is now becoming an essential requirement. The studies carried out point to the need to adapt public actions to the challenges and needs of the market, which are still undergoing new transformations. The specifics of the hydrogen technology market require disruptive technological innovation and investment to make the impact more effective. This is also

reflected in the claims made in the publication 'Environment and Planning C: Politics and Space' (Coenen *et al.*, 2017, p. 605) , among others, that public impact is only justified and needed if the complex interactions that take place between the different organisations and institutions involved in innovation do not work.

It should be pointed out that, in line with previous findings, the ability of energy companies to adapt to a turbulent environment will be important in the future. This environment will also be influenced by innovation development policies, including smart specialisations that develop the potential of regions. The competitive position on the market can be largely shaped by services or investments, which can be of comparable importance for companies as investments in technical infrastructure. As argued by (Weber and Cabras, 2017, p. 1222) , in order to improve the efficiency of public services, public organisations will face the challenge of optimising and innovating their policies and services

Conclusions from the analysis conducted on the basis of the collected empirical material allow us to conclude that, in the context of innovation capacity building, there is also a need to implement integrated management strategies in enterprises that will focus on the implementation of innovative solutions. This assertion is consistent with the opinions contained in the work "Smart specialisation strategy assessment in Baltic states" (Gemma and Bulderberga, 2017, p. 135-141) and "How outward looking is smart specialisation? Rationales, drivers and barriers' (Uyarra, Marzocchi and Sorvik, 2018, p. 2345) , presented in the aforementioned literature, who highlight the importance of developing smart specialisations in the context of various challenges. In the case of the deployment of hydrogen technologies by energy companies, these may oscillate around issues such as hydrogen energy, renewable energy sources and renewable energy technologies, renewable and mineral resources management, renewable energy engineering, renewable energy sources and waste management.

6. CONCLUSION

The analysis of support for the development of innovation in hydrogen technology companies carried out in this work allows us to define challenges in the perspective of future updates and improvements in the implementation of innovation policy in the regions. On the other hand, the conclusions resulting from the study help to make new or correct existing decisions on the directions of public support, which will consequently foster modern solutions for the dynamisation of innovation development in regional economies.

The analyses carried out lead to the conclusion that for the majority of the surveyed enterprises, the greatest benefit resulting from the implementation of the support system based on smart specialisation strategies, which constitute guidelines for innovation development policy, is the modernisation of the regional economy. Therefore, it is worth continuing activities supporting the development of innovativeness of enterprises, as the effects are visible not only from the perspective of individual beneficiaries of support, but also in the broader context of the economy in the region. However, in order to increase the effectiveness of innovation support, it is necessary to review and adapt existing programmes and impact mechanisms.

Smart governance can help better tailor support instruments to the actual needs of businesses, reducing the gap between public policy objectives and outcomes. Support programmes and mechanisms should better respond to the dynamically changing needs of enterprises and be easier to identify and use by potential recipients. Increased awareness among business managers and decision-makers regarding the use of available support tools can directly contribute to improved competitiveness, not only in local markets, but also in international arrangements. It is also important here to carry out a detailed analysis of the impact of support programmes on the energy sector to better tailor them to the unique challenges of the industry and to ensure that they are effective in driving innovation and sustainability.

Public support for hydrogen technologies should be continued and systematically expanded, given the potential to contribute to the energy transition and to strengthen the market position of companies. By focusing on the development of the hydrogen market, regional innovation can be stimulated, job creation can be supported and decarbonisation goals can be contributed to.

With regard to the assessment of the potential to develop the innovation and technological readiness of companies involved in the hydrogen economy value chain, several conclusions can be drawn. Stepping up efforts to produce hydrogen highlights its important role in the energy sector. The analyses

also show that it is equally important to focus on other links in the chain, such as storage, distribution and end-uses. Hydrogen storage, due to the specificity of this energy carrier, requires decisions on increasing funding and seeking breakthrough technological innovations in order to become more economically efficient. It should be borne in mind that developing hydrogen applications, both in industry and in sectors such as transport or heating, can contribute significantly to decarbonisation and increased flexibility of energy systems. Hence, it is important to create investment mechanisms and tools, as well as to support research in these directions. Logistical and infrastructural challenges accompany decisions related to increasing the innovation of hydrogen distribution systems. The distribution of hydrogen, on the other hand, is an important element that needs to be addressed not only in terms of infrastructure development, but also in terms of ensuring safety and operational efficiency.

Strengthening cooperation between hydrogen technology providers and their customers, through knowledge sharing and competence development, is key to accelerating technology adoption and realising the full potential of hydrogen. This approach can also foster innovation and enable a more comprehensive use of hydrogen as an energy carrier in different sectors.

On the basis of data on the importance of support for the activities of companies in the context of smart specialisations, it is possible to conduct a detailed analysis and develop conclusions aimed at optimising the management strategy in the area of the hydrogen economy. In formulating further recommendations for the future, it should be emphasised that there is a need to decide on the modification of the current structure of public support in the implementation of smart specialisation strategies. This support concentrates most of its efforts on the system of financing enterprises within operational programmes. At the same time, the system of financial support alone for the purchase of new technologies by companies is becoming insufficient in the context of the need to build an ecosystem of links between them, public administration and business environment institutions. The system of public support under the smart specialisation strategy should create a favourable environment for innovation and stimulate research and development. At the same time, the attitude towards innovation processes and the attitude of enterprises towards development activities should be considered as determinants that significantly influence the decision-making, but also the effectiveness of institutional solutions aimed at helping to build capacity in the regions.

It should be stressed that economic operators perceive the need for support from both the national and regional levels, which indicates the need for a harmonious combination of the activities of these two levels of administration in terms of the instruments offered. Average evaluations of current support programmes may indicate the existence of unfulfilled expectations of businesses in relation to available forms of assistance. Thus, in order to increase the effectiveness of the public impact, support programmes should be analysed more thoroughly and adapted. They should be more responsive to the needs of enterprises. From this perspective, it is important to intensify the dialogue between businesses and pro-innovation policy-makers to ensure that these initiatives prove to be more relevant and meet the expectations of the economic sphere.

In addition, strengthening education and promotional activities can help companies to make better use of available resources and support programmes. This can include both information on how to access these programmes and education on the benefits of using them.

It should also be pointed out that there is moderate satisfaction with current forms of public support and, in particular, considerable variability in the perception of their effectiveness, which may indicate heterogeneity in the needs and expectations of enterprises. Further analysis is advisable here, aiming to identify and understand the reasons why some enterprises consider some tools to be very effective, while others have a different view. For example, vouchers for specialised services are considered ineffective by companies in the hydrogen technology sector, while in other sectors vouchers are perceived quite positively. The quartile values presented in the paper indicate that there may be barriers to accessing or using support, which may also require special attention in order to increase the effectiveness of the instruments offered. In order to increase efficiency, organisations managing support programmes need to conduct a thorough review and adapt their tools to the specific needs of different groups of entrepreneurs. Improving communication and advisory services regarding the available support measures will certainly help businesses to better understand and use the resources on offer.

Smart governance also involves coordinating actions across different levels of administration to create a coherent system that supports the development of hydrogen technologies. Strengthening cooperation networks can be considered a key dimension of smart governance in innovation ecosystems.

Cooperation and networking are key to innovation and growth, so initiatives to promote the emergence of clusters or hydrogen valleys should not only be continued, but also developed taking into account the specific needs and expectations of entrepreneurs. Such activities stimulate the exchange of experience, cooperation and the creation of synergies between different market players. Management strategies should be guided by the expectations and needs of the business sphere. This should involve adapting instruments to specific business contexts and needs, offering flexible financial solutions and specialised advisory assistance. This individual dimension of influence can significantly increase the effectiveness of innovation stimulation in the regions.

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