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Article

Networking of Research Institutes in Poland as a Method of Strengthening Open Innovation—Genesis and Initial Effects in the Area of Commercialization

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Abstract: The main objective of the research was to identify the synergistic effects in the area of commercialization of the networking of research institutes in Poland following a radical reform of the functioning of the national innovation system. This goal was pursued using the example of the Łukasiewicz Research Network, which brings together some of Poland's existing research institutes under the four pillars of the modern economy: (1) smart and clean mobility, (2) digital transformation, (3) health, and (4) sustainable economy and energy. Thus, the article attempts to answer the following research questions: What were the circumstances behind the networking of Polish research institutes, how did this networking take place, and what results in the area of commercialization have been achieved so far? The research conducted in this article showed that the institutes affiliated with the "digital transformation" group achieved the following successes in the first integration phase: (1) an increase in the share of revenue from the commercialization of research results as a basis for assessing the effectiveness of the use of scientific and research potential for strengthening innovation (in five of the six institutes researched) and (2) an increase in sales revenue (in three of the six institutes).

Keywords: networking of research institutes; strengthening open innovation; effects of networking research institutions; innovativeness in Poland

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1. Introduction

Open innovation in business theory and practice is treated as a driving force of modern enterprises and economies. Its advantage over traditional innovations is due to the economies of scale of acquired knowledge and synergistic effects obtained through parallel cooperation of many organizations [1]. Thus, the transfer of new achievements, research results, and technologies takes place on a larger scale, and its pace is significantly accelerated. The beneficiaries of open innovation then become not only individual companies but also local and regional communities and entire economies [2].

Access to and development of open innovation is important not only from an economic and competitive point of view. It also makes it possible to significantly improve the quality of life, which, in the conditions of a growing population and depletion of natural resources, is crucial for the well-being of future generations. Indeed, open innovation promotes sustainable development, including the creation of pro-environmental and prosocial solutions [3–6].

The open innovation generated by the unrestricted exchange of knowledge and experience also provides valuable support in the fight against economic crises, as recent observations related to the COVID-19 pandemic confirm [7–11]. Indeed, countering epidemic threats of such magnitude would not be possible without close international cooperation between science and business.

Given the multiplicity and diversity of micro- and macrobenefits associated with the development of open innovation, theorists and practitioners are constantly looking for ways to improve the transfer and diffusion of knowledge and technology. In this context,

both the efficiency and effectiveness of the individual actors responsible for creating open innovation and the quality of the relationships linking these actors are important. For these reasons, this article analyzed the motives, course, and synergistic effects of the networking of research institutes as organizations supporting knowledge and technology transfer in the economy.

Research conducted in the area of business–science ties for open innovation is most often conducted in relation to universities and the entities they set up, such as spin-offs or technology or business incubators [12]. Research institutes receive far less attention. Meanwhile, due to the purely research-based nature of their activities, they are organizations that can and should play an important role in strengthening open innovation. This is because the essence of their activities and mission is to conduct scientific research, disseminate the results of research and development work, and create new knowledge and technologies transferred to the socioeconomic environment.

The considerations and analysis in the article apply to the Polish economy. This geographical context of the article primarily justifies the need to expand the territorial scope of research on open innovation. According to the bibliometric analyses by Baierle et al. [13], these studies have so far referred mainly to China, the United States, and Spain. Far less attention has been paid to less-developed economies, for which access to and development of open innovation can become an opportunity for more dynamic technological progress and narrowing the competitive gap.

An additional rationale for the research undertaken in the article is the relatively low innovativeness of the Polish economy, which requires urgent action to improve it. In the 2021 European Innovation Scoreboard [14], Poland was ranked only 23rd among 27 European countries. It was followed only by Latvia, Bulgaria, and Romania, economies classified as emerging. Therefore, it is important to take a look at the functioning of the innovation support system in countries with far less resource potential and experience in knowledge and technology transfer [15].

In Poland, for many years, attempts have been made to efficiently transfer knowledge between science and the socioeconomic environment. However, they are not fully effective. The research conducted by the Supreme Audit Office showed that research institutes do not use their potential [16,17]. Few of them establish cooperation with business and conduct implementation activities, despite the fact that this is their primary goal [18]. Although the number of patents is growing, only 20% of them are used in practice. Whereas in developed economies, the number of implemented patents reaches 50%. Moreover, the financial audit showed that research institutes are not looking for external sources of funding and are increasingly dependent on funding from the public budget. This causes stagnation in knowledge transfer and limits innovation. It also raises the question of the legitimacy of the existence of publicly funded institutions that poorly support Polish innovation [19].

In the context of the presented circumstances, the assessment of changes in the functioning of research institutes is desirable and justified by practical and theoretical premises. Therefore, the main objective of the research was to identify the synergistic effects of the networking of research institutes in Poland following a radical reform of the functioning of the national innovation system. This reform targeted increasing the scope of dissemination and commercialization of scientific research results and making research institutes independent (independent of public funding). This goal was pursued using the example of the Łukasiewicz Research Network, which brings together some of Poland's existing research institutes under the four pillars of the modern economy: (1) smart and clean mobility, (2) digital transformation, (3) health, and (4) sustainable economy and energy. Thus, the article attempts to answer the following research questions: What were the circumstances behind the networking of Polish research institutes, how did this networking take place, and what results in the area of commercialization have been achieved so far?

To achieve such a goal, the research presented, in turn, the characteristics of innovation in the Polish economy, rationale and genesis of the networking of research institutes in Poland, and results of this process to date.

The results of the research tentatively confirm the effectiveness of the concentration and specialization measures carried out in the analyzed group, and indicate the positive synergistic effects of networking. Nevertheless, they also imply the need for comparative analyses with regard to both institutes operating outside the network and those operating in other geographic areas and industries. They should also be monitored on an ongoing basis over the long term, considering the sources of risk associated with their near and far environment.

The research carried out supplements the concept of open innovation with conclusions regarding

- The role of research institutes in creating innovation;
- Possible paths for the development of research institutes in the national innovation system;
- Filling of the research gap in the field of financial effectiveness of reforming and networking of institutes in Poland;
- Analysis of the impact of networking of research institutes on the intensity of their relations with the business environment;
- Assessment of the legitimacy of creating research networks to strengthen knowledge transfer and innovation;
- Directions for the development of open innovation in emerging and developing economies.

2. Literature Studies

2.1. The Essence and Determinants of Open Innovation in the Economy

The concept of open innovation emerged in response to the need to unleash additional creativity and entrepreneurship, and its development was and is linked to the fourth industrial revolution. In open innovation, new knowledge and technologies become widely available, and the intensive flow of knowledge from many external sources accelerates the process of creating innovation in an organization [20–23]. This is supported by the research of Chae et al. who noted that companies enjoying the benefits of open innovation are able to produce an above-average number of new, unique products and/or processes [24].

Previous research also showed that the development of open innovation is positively influenced by the lack of licensing requirements, which makes knowledge and technology widely available, and anyone can use it in their own creativity and entrepreneurship. A stimulant of open innovation is also the high mobility of capital. This is because innovation requires significant capital investment, which is not always available to a single company or institution. Quick and efficient access to cumulative sources of funding, therefore, facilitates and accelerates the emergence and implementation of open innovation [25].

Also important in the diffusion of innovations is the internationalization of industry and the economy, which is a source of knowledge and technology inputs at the national level, in addition to being a transfer channel for the results of local research, patents, or technologies [26–28]. Similarly, the development of open innovation is influenced by the sharing economy, in which ideas, knowledge, and goods and services are shared by many entities, which drives economies of scale and synergies.

The determinants of open innovation indicated above are in the nature of certain static resource or regulatory conditions. Furthermore, systemic network determinants are also important [29,30]. This is because the diffusion of innovation requires the existence of transfer channels and entities that are carriers of knowledge and technology. The density of this network and the intensity and quality of the interrelationships between the entities forming it will determine the scope and pace of development of open innovation [31–37]. Networking makes it possible to improve innovation capabilities, as confirmed by Almeida's [38] research in the small- and medium-sized enterprise sector, despite the accompanying problems of knowledge integration and resource scarcity.

Network linkages for open innovation can take place in various dimensions in the following configurations:

1. Enterprise-to-enterprise, in the form of strategic alliances, joint ventures, or competitive partnerships [39–41];
2. Enterprise–science [42];
3. Enterprise and government [43];
4. Enterprise–local and regional community;
5. Enterprise–environmental organizations [44,45].

In addition, the above-mentioned links can form any interconnections, which lengthens the chain of cooperation and thickens the network in the thought of the idea of the fivefold helix, in which it is assumed that all economic stakeholders interact in the configuration business–science–government–society–environmentalists [46–51]. Such a relationship is not easy, but it allows optimal results to be achieved and guarantees the exchange of highly diverse knowledge and experience, fostering new ideas and creative solutions.

The following discussion focuses on the enterprise–science configuration. At the same time, this configuration is limited to research institutes, as entities less frequently analyzed in the context of open innovation, despite the fact that they are mainly established to strengthen it, as opposed to universities, which also perform an educational function.

2.2. The Role of Scientific and Research Institutions in Developing and Strengthening Open Innovation

As already mentioned, cooperation for open innovation in the enterprise–science configuration can take place through universities and research institutes. At the same time, an important aspect of cooperation between science and the socioeconomic environment is its coordination by the state generally responsible for the science and education sector of the economy. This is because past research showed that government action within the national innovation system makes knowledge and technology transfer more effective and strengthens open innovation [52–55].

Universities, due to the dichotomous nature of their activities mentioned in the introduction, often take steps to strengthen the diffusion of knowledge and technology by establishing intermediary entities between academia and business [56–59]. Technology incubators are an example of such an entity. A study by Rakthai et al. found that the activities of incubators at universities positively affect the innovative capacity and entrepreneurial performance of enterprises that benefited from their activities [60]. Incubators allow companies to systematically acquire knowledge and skills and transfer them further to the business community [61,62].

The participation of university academics in collaborative research projects with industry also contributes to the transfer and diffusion of knowledge and technology, as clearly confirmed by a study conducted in the Portuguese defense industry by Simões et al. [63]. They showed that cooperation in the configuration company–university–government not only is useful in the context of strengthening open innovation but also can have a beneficial effect on the structure and operation of the entire industry by balancing the influence of the various stakeholders on its functioning.

Alvarez-Meaza et al. [64] also emphasized that in creating open innovation on the line between science–business and other stakeholders, an important function is played by . . . them from universities is that they perform only a research function in the economy, and their main task is to conduct research on new knowledge and technologies. As a rule, their activities are financed by public funds and subsidized by the private sector as a result of the commercialization of R&D results.

A study by Ko et al. showed that the strength and extent of technology transfer in state research institutes (which are subjectively complementary to the science sector in the economy) is largely dependent on their main strategic goals that are synthetically reflected in their mission [65]. Thus, in institutes with a very general mission operating within basic science and focused on the development of publications and patent applications, technology transfer is most strongly dependent on the number of employees. In institutes with an infrastructure development focus, the extent and strength of technology transfer is most

strongly influenced by the number of patents held and the number of employees working in the technology licensing office. The latter determinant also positively affects technology transfer and commercialization revenues in Korean industrialization-oriented institutes. The results of this research indicate the great importance of specialized human resources in the process of technology diffusion and commercialization of research results. It also appears that the specialization of institutes reflected in the adopted mission is conducive to strengthening innovation directly reflected in the scope and scale of technology transfer.

The above conclusion is also supported by the findings of Zhang and Wang, who looked for a stimulant of network innovation. The results of their analysis show that technological proximity has the greatest impact on the diffusion of innovation in the network, allowing better communication and understanding of partners and allowing closer matching of needs, competencies, and skills. Organizational and temporal proximities are also important determinants of open innovation but are far less important compared with technological proximity [66].

Networking of research institutions increases the density and frequency of the links between cooperating organizations. This, in turn, enables knowledge and technology transfer on a bigger scale, which fosters creativity and entrepreneurship that are inevitable in the process of innovation creation. However, Pan et al. paid attention to the proper choice of the thematic structure of the network, so that the exchanged knowledge and experiences are not substitutable and therefore conducive to new, unfamiliar solutions [67]. The positive impact of networks on innovation potential and the effects in the form of more technological innovation were also emphasized by Liu. Moreover, his research showed that the learning process is faster and more effective in network structures [68]. In turn, Beck et al. concluded that there is a faster and wider dissemination of research results in a network, which serves the development of open innovation, as knowledge becomes widely available and can contribute to subsequent innovation activities [69].

Being part of a research network can also reduce the risk involved in innovation, which is a significant benefit of cooperation. As we know, innovation as a new venture is associated with a higher level of risk than ordinary investment [70–77]. Distribution of risks and their potential effects among partners operating in a network reduces risk aversion and allows individuals to reduce the scale of losses when risks are materialized. This is a significant determinant for both open innovations and the innovation of economy.

2.3. Innovativeness in the Research of Polish Researchers

In Poland research on innovativeness is mainly focused on enterprises and economy. In this context, the determinants of innovation, including the influence of human resources on the ability to create innovative products and services, are studied in particular [78–81]. In recent years, much attention has been paid to ecological innovations as a prerequisite for the Polish energy transition [82–85].

Research by Polish researchers, to date, shows that large manufacturing enterprises are the most innovative in Poland [86]. Small and medium enterprises are characterized by an average innovation potential and low ability to create innovation. It is also worth noting that in light of the research by Kraśnicka, those companies do not recognize major barriers to implementing innovation. This proves that they are not motivated or interested in implementing them [87].

Interesting and rare research on this subject was carried out inter alia by Okoń-Horodyńska et al. The authors identified the influence of sex on the process of innovation creation. The results obtained show that women find the ability to take decisions to be the most important determinant of innovativeness. In turn, what men appreciate most is the ability to learn and build on existing knowledge. Both groups give the same significance to the need to focus on tasks [88].

The literature and research also pay a lot of attention to the innovativeness of the Polish economy mainly due to its already mentioned low level. Therefore, the research by Gajda showed that only 18% of Polish manufacturing enterprises and 12% of service

providers take up innovative activities. Small and medium enterprises are hardly interested in innovation at all. Additionally, the structure of Polish economy is dominated by a traditional sector manufacturing low-processed products. In the above context, the author pointed out the need to increase the involvement of researchers in practical research activities and to bring the science and business sectors closer together [89].

However, it must be mentioned that the effects of increasing R&D investments are not satisfactory. The research by Kansy showed that they do not translate into better ratings for the innovativeness of the Polish economy against the European Union. The reason for this is the low level of utilization of research in practice and undemanding labor market not conducive to the development of advanced professional skills [90].

Similar conclusions were drawn by Kowalik. Among the reasons for the low innovativeness of the Polish economy, he identified

- Underdeveloped commercialization of research results;
- Low interest of research institutions in cooperation with business;
- Lack of information about new technologies [91].

The above circumstances indicate poor effectiveness of scientific and research institutions in Poland and an urgent need to effectively reform them.

Ciborowski and Grabowiecki pointed to the need for institutional changes in the Polish scientific and research system. According to the authors, it is inefficient and unsuited to a market economy, which is one of the main reasons for low innovativeness of Polish economy [92].

Despite the above weaknesses, the literature gives little attention to the relationship between the science sector and business. Moreover, significant part of these publications was created before 2015 [93–95]. One of the more recent and comprehensive works in this area is the monograph by Gryzik, which is entirely devoted to the role of research institutes in the modern economy. The author highlighted the need to prepare mechanisms to promote knowledge and technology transfer in order to increase the scope of commercialization or research results. Without measures in this area, the institutes will not effectively support innovation in the Polish economy [96].

In the light of the above conclusions, there is a repeatedly stressed need to monitor the activities of research institutes in Poland in the context of not only patents or publications (in which the number is increasing but are used in practice to a very little extent) but also cooperation with business. The tangible result of such cooperation is revenue, especially commercialization revenue, to which the considerations presented later in this article are devoted.

3. Materials and Methods

3.1. Problems, Objectives, and Research Steps

As shown in the literature review, the need to analyze the effectiveness of functioning of networked research institutes in the context of research results commercialization stems from

- Small number of publications describing the effects of research institutes networks;
- Focus by researchers on the innovativeness of enterprises and economy;
- The need to reduce the innovation gap between developing and developed economies;
- Unsatisfactory level of cooperation between Polish science and business;
- The need to improve the effectiveness of Polish publicly funded scientific and research system.

As the most serious obstacle to the development of innovation in Poland is the lack of tangible effects of cooperation with business, the paper mainly focused on the financial dimension of this cooperation, which is reflected in the total and commercialization revenues. The number of contracts, publications, and patents was not studied and analyzed because previous research clearly showed that they are evidentiary in nature and do not contribute to improving the innovativeness of the Polish economy.

Moreover, the main aim of networking research institutes is to make them financially independent and to relieve the public budget and improve public efficiency. Thus, the main focus of the paper was the financial dimension of the analyzed data. Such a context is addressed far less frequently in the literature on the subject, and, as such, the research findings fill a research gap that exists in this area.

In the course of the research, the following question was asked: What were the circumstances behind the networking of Polish research institutes, how did this networking take place, and what results in the area of commercialization have been achieved so far? The main objective of the research was to identify the synergistic effects of the networking of research institutes in Poland following a radical reform of the functioning of the national innovation system.

To achieve such a goal, the first stage of the research presented the circumstances and rationale for the establishment of the Łukasiewicz Research Network, with particular emphasis on the recent assessment of the innovativeness of the Polish economy.

In the second research stage, one of the groups of research institutes forming the Łukasiewicz Research Network was selected for analysis. In the end, the research sample included six units engaged in digital transformation. In assessing the effects of their networking, their financial results obtained in 2019 (before integration) and 2020 (just after integration) were used.

3.2. Information Sources and Research Methods

In the process of evaluating the synergistic effects of the networking of research institutes in Poland, a multiple case study involving six research institutes operating within the established network in one subject group was used. This method allows for a detailed look at a given unit and a more in-depth causal analysis than statistical quantitative studies. However, its disadvantage is the lack of representativeness of the sample and the possibility of generalizing the results to the population.

The assessment used data included in the European Innovation Scoreboard [14] on assessing the innovativeness of the Polish economy, source materials describing the functioning of the Łukasiewicz Research Network, and financial statements of the analyzed research institutes made available by the Polish Ministry of Finance [97]. The studied research institutes publish their financial data in annual financial statements. The data on revenue come from the profit-and-loss account. Data on the assets are represented in the balance sheet. All the above sources are publicly available and can be used to conduct a financial analysis to assess the effectiveness of cooperation of the studied institutes with the social and economic environment.

When evaluating the effects of cross-linking, we used the following:

- Change in the volume of total revenues reflecting the scale of improvement or deterioration in the ability to attract economic partners and the level of effectiveness in providing sources to cover the institute's costs;
- Change in the share of commercialization revenues in total revenues documenting the real interest of the business environment in the institute's research offerings and illustrating its level of financial independence;
- Change in the net income showing the impact of integration on the absolute result of operations;
- Return on net assets (ROA), calculated as the ratio of the financial result to the institute's assets, illustrating the efficiency of the use of material resources held by the surveyed units.

The aforementioned changes were calculated for the period 2019–2020. The 2019 results still reflected the individual strategies of the surveyed institutes. The 2020 results were already fully worked out in the Łukasiewicz Research Network. The comparison allowed a preliminary estimate of the benefits of networking in the immediate post-integration phase.

4. Results

4.1. Causes and Circumstances of Networking of Research Institutes in Poland

As already mentioned in the introduction, in the latest European innovation ranking, Poland was ranked among moderate innovators at the end of the published European Innovation Scoreboard 2021 [14]. In the assessment of innovativeness proposed by the European Union, four assessment groups are considered with the following indicators:

1. Framework conditions (human resources: new doctorate graduates (STEM) (% share) and population with tertiary education (% share); attractive research systems: international scientific copublications per million population, top 10% most cited publications (% share), foreign doctorate students (% share); digitalization: broadband penetration (% share), individuals who have above basic overall digital skills (% share));
2. Investments (finance and support: R&D expenditures public sector (% of GDP), venture capital expenditures (% of GDP), direct government funding and government tax support for business R&D; firm investments: R&D expenditures business sector (% of GDP), non-R&D innovation expenditures (% of turnover), innovation expenditure per person employed; use of information technologies: enterprises providing training to develop or upgrade ICT skills of their personnel (% share), employed ICT specialists (% of total employment));
3. Innovation activities (innovators: SMEs with product innovations (% share), SMEs with business process innovations (% share); linkages: innovative SMEs collaborating with others (% share), public–private copublications per million population, job-to-job mobility of human resources in science and technology (% share); intellectual assets: PCT patent applications per billion GDP (in PPS), trademark applications per billion GDP (in PPS), design applications per billion GDP (in PPS));
4. Impacts (employment impacts: employment in knowledge-intensive activities (% share), employment in innovative enterprises (% share); sales impacts: medium- and high-tech product exports (% share), knowledge-intensive services exports (% share), sales of new or improved products ("product innovations") (% of turnover); environmental sustainability: resource productivity (measured as domestic material consumption (DMC) in relation to GDP), air emissions by fine particulate matter (PM2.5) in industry development of environment-related technologies).

The overall score for Polish innovation was 58.5, whereas the EU average was 65.9. The results obtained in each evaluation category are shown in Figure 1.

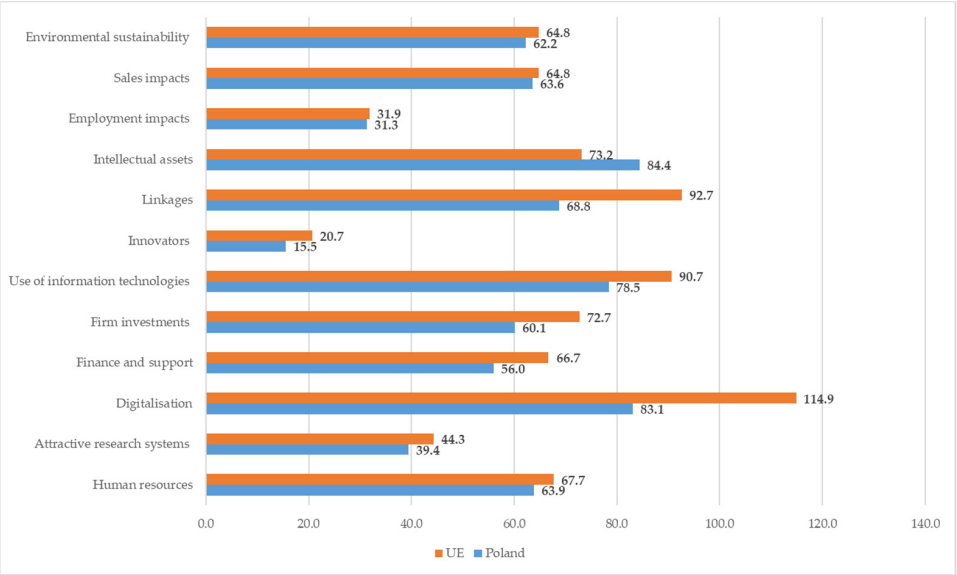

Figure 1. Poland's ranking as compared with EU's average using particular innovativeness assessment criteria in European Innovation Scoreboard, 2021.

Poland scored the highest in the following categories:

1. Intellectual assets (patent applications, trademark applications, and design applications);
2. Digitalization (broadband penetration and people with above basic overall digital skills);
3. Use of information technologies (enterprises providing ICT training and employed ICT specialists).

However, it should be added that only in the case of the first criterion mentioned above did Poland manage to surpass the EU average. It is also worth referring to the information already given in the literature review that, despite the increasing number of patents, they are not being implemented and used in practice. Moreover, they are rarely of international nature. In all other categories, Poland's rating was lower than the average for EU countries, and in the case of digitalization, mentioned above as the second, Poland's distance from the EU average was the largest, amounting to more than 38% (Figure 2).

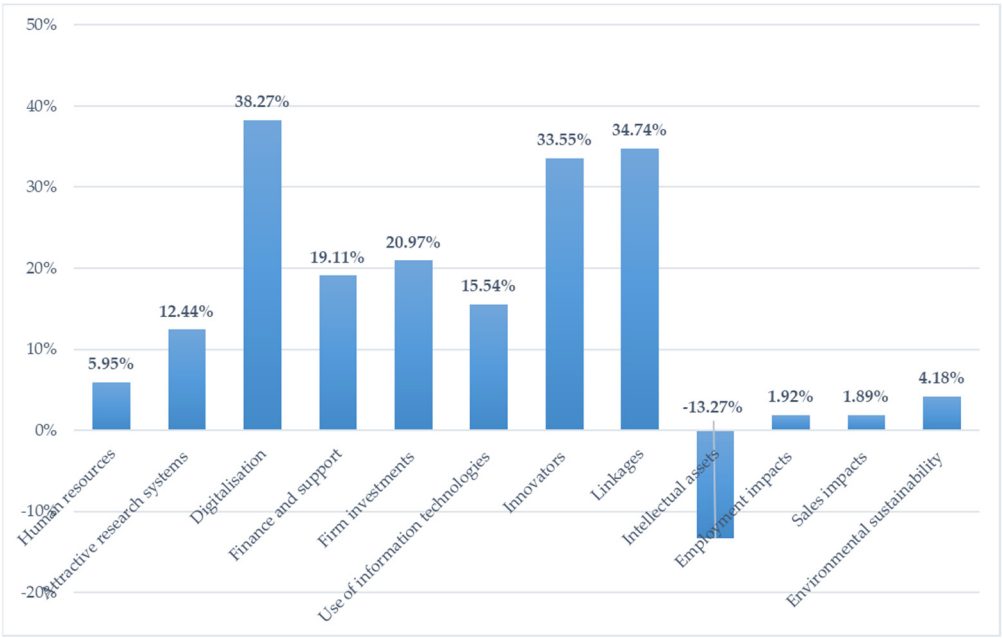

Figure 2. Poland's gap to EU's average using particular innovativeness assessment criteria in European Innovation Scoreboard, 2021.

In addition to the aforementioned digitalization, Poland also has a lot of catching up to do in the innovators category relating to product and process innovations created in the SME sector, as well as in linkages covering the cooperation between innovative SMEs and the business environment, public–private publishing, and labor mobility.

As highlighted in the introduction, the scientific and research sector, which is made up of universities and other research units, is responsible for knowledge and technology transfer in the economy. Given the far lower number of publications devoted to other institutions in this sector, the remainder of this article undertakes a study of research institutes in Poland, including the authorities' efforts to reform them aimed at strengthening innovation in Poland.

The activities of research institutes in Poland are regulated by the Act of 30 April 2010 on research institutes [98]. According to the provisions contained therein, a research institute is a state organizational unit, legally, organizationally, economically, and financially separate, which conducts scientific research and development work aimed at their implementation and application in practice. The basic activities of the institute include

(1) Conducting scientific R&D;
(2) Adapting the R&D results to the needs of practice;

(3) Implementing the R&D results.

According to the above, the idea behind the existence of research institutes is to conduct research and transfer knowledge and technology to the socioeconomic environment, so they should be entities working to strengthen innovation, including that of an open nature.

Currently, in Poland, research institutes can function in the following groups:

1. Units subordinate to ministries (the type of ministry depends on the profile of the institute);
2. Units operating within the Polish Academy of Sciences (the so-called institutes of the Polish Academy of Sciences);
3. Units operating as part of the Łukasiewicz Research Network, which was established in April 2019.

This article focused its considerations on the last of the above-mentioned groups. The main objective of the Łukasiewicz Research Network is to conduct research work that is crucial to the country and to commercialize its results. Furthermore, the goal of the network is to support the economic policy of the country, particularly by making forecasts of trends and effects of technological changes that can have a strong impact on society and its development, as well as analyses of the current state of technology for the purposes of public policies [99]. We should also add that the creation of the Łukasiewicz Research Network is a response to the need to support public administration with highly specialized expertise, especially in areas related to modern technologies.

Beside their core activities, institutes can also produce unique research apparatus and unique materials; conduct metrology, standardization, and certification activities; develop prototypes of new technological solutions; conduct courses and personnel training for the economy; and, if necessary, conduct other activities related to their nature. An important aspect of the functioning of the institutes is their activity for the benefit of society, so among the tasks of the institutes is also the popularization of science and knowledge of new technologies [100].

Accordingly, the Łukasiewicz Research Network is designed to integrate the innovation potential inherent in individual institutes and thereby strengthen the Polish economy. The economies of scale (synergies) resulting from such integration include

- Joint use of knowledge and resources;
- Increased power to influence the environment and attract business partners;
- Joint marketing campaign with increased scale and unified media coverage;
- Exchange and transfer of knowledge and experience within the network;
- Joint dissemination of technology and popularization of science;
- Enhanced resilience against operational risks and external threats.

In the context of the desired effects of integration defined in this way, the networking of research institutes in Poland should also contribute to the development of open innovation by taking advantage of the internal exchange of knowledge and technology in the network and the popularization and dissemination of its achievements in the socioeconomic environment.

Currently, the network includes 26 research institutes located in 12 different cities in Poland offering solutions in the areas of automation, chemistry, biomedicine, ICT, materials, and advanced manufacturing. The Łukasiewicz Research Network is the third largest group of research institutes in Europe after Germany's Fraunhofer Sieve and France's CARNOT network.

These institutes have been divided into four thematic groups applicable to the following key areas of development of the Polish economy:

1. Smart and clean mobility (technologies related to the design, manufacture, production, characterization, and use of logistics infrastructure and vehicles);
2. Digital transformation (technologies for automation and robotics, artificial intelligence and data science, as well as in the area of smart cities and sensor networks);

3. Health (technologies for diagnostics and therapeutics, the manufacture of medicinal products and medical apparatus and technology);
4. Sustainable economy and energy (technologies for raw material extraction, waste and wastewater treatment, eco-design of processes and products in the pulp and paper and packaging industries, and production of composite and biodegradable materials) [101,102].

The research included institutes in the group representing digital transformation. This group is most strongly associated with innovation, including mainly IT and ICT technologies. The characteristics of the researched entities are shown in Table 1.

Table 1. Characteristics of researched institutes in digital transformation group.

Name	Business Description
Institute of Microelectronics and Photonics	R&D in nanoelectronics; optoelectronics; materials engineering; photonics (including nanophotonics); microwave electronics; power electronics; and printed, transparent, and flexible electronics.
Institute of Innovative Technologies EMAG	Information systems: security for monitoring and assessing natural hazards and technological processes; dispatching for managing large organizations; information; decision support, analysis and processing of large data sets; power supply and control of electrical equipment with particular emphasis on its energy efficiency and safety; measurement in the field of mineral quality; energy management.
Institute of Medical Technology and Equipment ITAM	Medical technology used in diagnosis and therapy of cardiovascular diseases; intensive patient monitoring; medical resuscitation; medical rehabilitation; biomedical engineering; telemedicine; application of computer techniques in medicine; operational safety of medical apparatus; testing, attestation, and certification of medical apparatus.
Institute of Exploration Technology	Innovative solutions in the areas of machinery construction and operation, technical safety and environmental protection, as well as the development of model solutions for programs of continuing education and personnel improvement for an innovative economy and the transfer of advanced technologies to industrial applications.
Tele and Radio Research Institute	ICT systems, electronics, electronic assembly, and solutions for Industry 4.0.
Industrial Research Institute for Automation and Measurements PIAP	Technologies in robotics, automation, measurement techniques, and 3D printing, including space technologies; automation and robotization of production lines and factories; 3D printing solutions for industry.

Compilation basis: [103].

From the characteristics presented in Table 1, it is clear that the research institutes in the digital transformation group are united by their use of information and ICT technologies. However, they are used for very different purposes, and their recipients are very diverse economic sectors, from traditional ones such as natural resource exploration to more modern ones such as medicine, energy, and Industry 4.0.

4.2. Effects of Networking of Research Institutes in Poland in the Area of Commercialization

As already mentioned, the effects of networking of the surveyed institutes were evaluated in detail in terms of the sales revenue achieved, the share of revenue from commercialization, and holistically in terms of the financial result achieved and the profitability of the assets used.

The results of the first research perspective are shown in Figures 3 and 4.

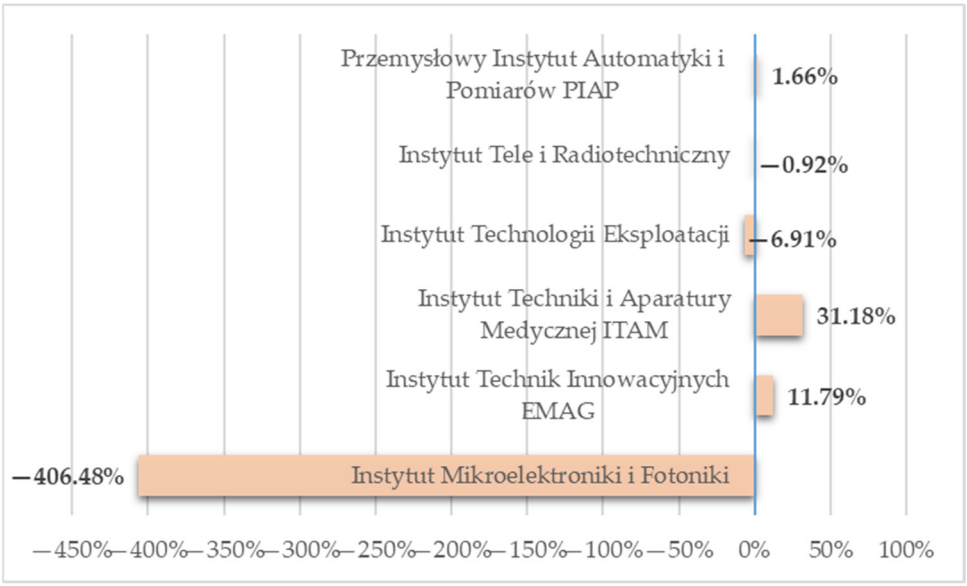

Figure 3. Change in sales revenue at researched institutes over the period 2019–2020 [in %]. Source: [97].

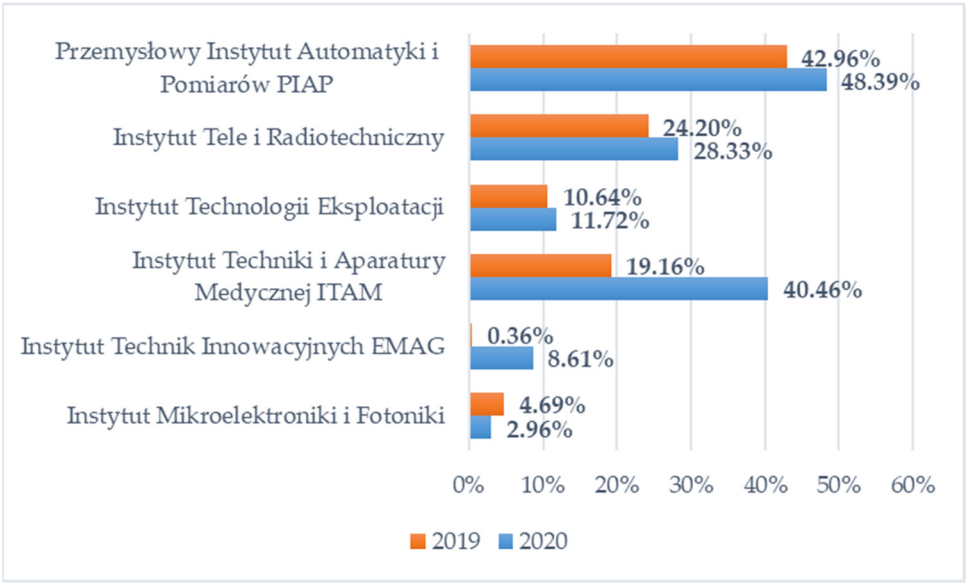

Figure 4. Share of commercialization revenue in total revenue of researched institutes between 2019 and 2020 [in %]. Source: [97].

As shown in Figure 3, three of the six institutes researched saw their sales revenues increase overall in 2019–2020, which should be positively viewed, as 2020 is the year the COVID-19 pandemic begins, an extremely difficult year for the institutes themselves and their principals. Despite the very unfavorable economic climate, half of the institutes managed to improve the efficiency of their operational activities compared with 2019. However, the scale of the growth achieved greatly varied, ranging from 1.66% to over 31%. The leaders of the list were undoubtedly the Institute of Medical Technology and Equipment ITAM and the Institute of Innovative Technologies EMAG, i.e., units located in rapidly growing sectors of the economy, such as medicine, IT, and energy. In the case of the ITAM, the COVID-19 pandemic and the associated increase in the demand for medical devices and telemedicine services certainly became the stimulants of the observed, very favorable changes in revenues.

The Institute of Microelectronics and Photonics fared worst in assessing changes in sales revenue, with a more than fourfold reduction in revenue from core activities. Revenues also declined at the Institute of Exploration Technology (by more than 6%) and the Tele and Radio Research Institute (less than 1%). These are the more traditional units directly related to manufacturing companies, which, in turn, were very adversely affected by the pandemic and the subsequent lockdowns and reduced associated market demand.

Interestingly, both the EMAG and ITAM significantly increased the share of commercialization revenues in total revenues (Figure 4) after joining the Łukasiewicz Research Network. At the ITAM, the change was 21.30%, and at the EMAG, it was 8.15%. In the next three researched units, the share of revenue from commercialization of research results also increased, which gives a positive view of the effects of their networking. The increase in this share in the Industrial Research Institute for Automation and Measurements PIAP, Tele and Radio Research Institute, and Institute of Exploration Technology was admittedly only 1–2%, but we must emphasize that these units were already characterized by significant financial independence in 2019, manifested in the high value of revenues generated from cooperation with the socioeconomic environment. The record holder in this regard in both analyzed periods was the Industrial Research Institute for Automation and Measurements PIAP, where the share of revenues from commercialization ranged from 42% to over 48%.

The Institute of Microelectronics and Photonics had the lowest share of commercialization revenue in total revenue. This unit—as the only one among the respondents—also recorded a decrease in the mentioned share of total revenue, which may have also contributed to the decrease in the total revenue identified in the first part of this analysis.

The above observations allow us to conclude that the increase in the share of commercialization revenues in total revenues had a positive effect on the growth of total revenues, thus strengthening the financial independence of the institutes researched.

The results obtained in the second research perspective relating to changes in net income and return on assets are shown in Figures 5 and 6, respectively.

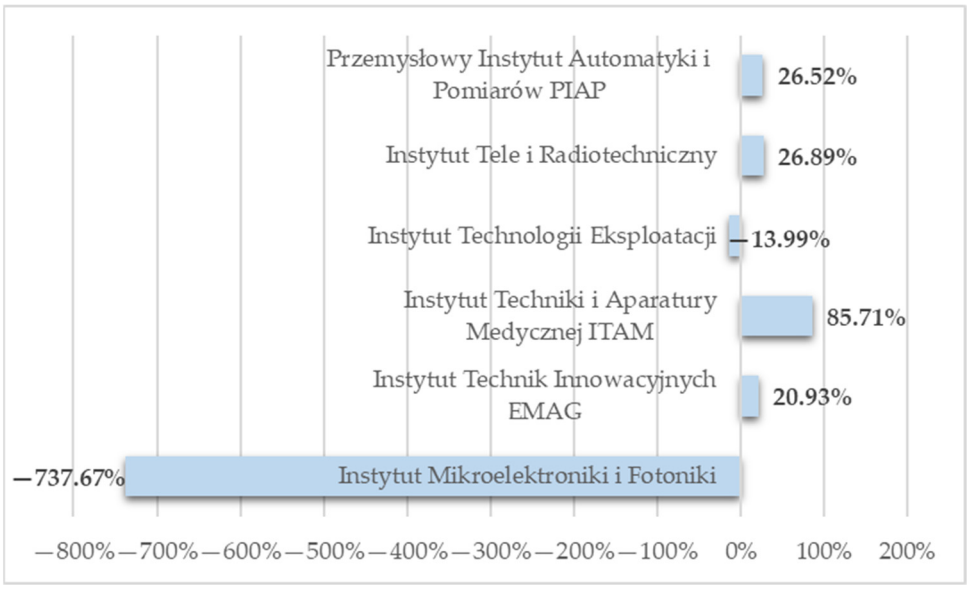

Figure 5. Change in net profit at researched institutes over the period 2019–2020 [in %]. Source: [97].

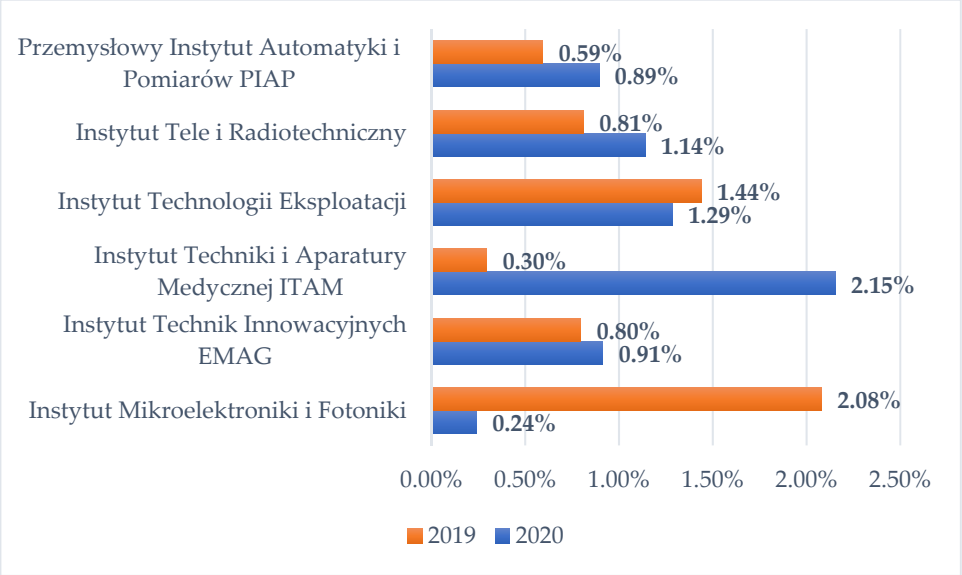

Figure 6. Return on assets (ROA) of researched institutes in 2019–2020 [in %]. Source: [97].

According to the results obtained (Figure 5), the increase in sales revenue and the dynamically increasing share of commercialization revenue in total revenue positively influenced the improvement of the financial result at the ITAM, EMAG, as well as PIAP. These institutes significantly improved their financial result compared with 2020. Despite the decrease in sales revenue, the net financial result also managed to improve at the Tele and Radio Research Institute. The most difficult situation occurred at the Institute of Microelectronics and Photonics and Institute of Exploration Technology, where production stoppages prevented the maximization of revenues and contacts with the industrial environment. Nevertheless, in the former institute, the deterioration of the financial result should be considered significant, more than seven times. Importantly, however, all of the institutes researched earned a net profit during the period under review, and therefore effectively operated, despite the economic crisis.

This is reflected in the positive profitability shown in Figure 6. In this comparison, the ITAM again led the way with a return on assets of more than 2%. A result above 1% was also achieved by the Tele and Radio Institute. The PIAP and EMAG could also boast ROA results better than in 2019. Return on assets most sharply declined at the Institute of Microelectronics and Photonics and Institute of Exploration Technology, which is in line with the results of previous analyses of changes in income and financial result of these units, and is due to their strong exposure to the economic consequences of the COVID-19 pandemic. However, it is worth adding once again that all the researched units effectively functioned and did not make losses, which means that they managed to both resist the crisis and at least partially realize the synergistic effects of operating in the Łukasiewicz Research Network. The findings obtained allow us to conclude that the networking of research institutes has safeguarded them—at least in part—from the risks associated with the economic crisis, confirming the beneficial impact of cooperation on risk reduction.

5. Discussion

Innovation and its openness require the inflow and transfer of knowledge from multiple sources [20–23]. In this context, the networking of scientific and research units promotes the multiplication of intellectual resources held and exchanged, and can therefore be a stimulant of innovation. The number of contacts between units and their business partners also creates favorable conditions for the popularization of scientific and research achievements, which, in turn, is a prerequisite for strengthening open innovation [24].

In network structures, it is also easier to access more capital resources and business contacts, which is one of the key determinants of open innovation [25]. The results of the research conducted in the article confirm this observation, as most of the researched units managed to increase commercialization revenues, and in half of them the level of total revenues increased. Nevertheless, it is worth adding that this process is more intensive in the case of institutes representing the most modern sectors of the economy.

Operating in a group also allows increasing international recognition [26–28], which in the case of the Łukasiewicz Research Network—the third largest in Europe—is important for the internationalization of knowledge and technology necessary in the process of improving innovation, so important for the Polish economy.

The research conducted also proved that operating in a network has allowed research institutes to reduce the risks associated with the economic crisis caused by the COVID-19 pandemic. The majority of the entities studied have, in fact, maintained profitability and even improved their previous financial performance. This confirms the positive influence of cooperation in a network on the reduction of risks associated with innovative activities [70].

It is also worth mentioning that the institutes under research—unlike universities—do not need to establish special additional intermediary entities for knowledge and technology transfer such as incubators or technology parks [60–62]. Their contacts with the socioeconomic environment are direct [104]. In addition, they are not engaged in educational activities, which allows them to focus their efforts on the commercialization of research results. This is an additional advantage in conducting innovation activities.

Focus on commercialization is an important dimension of the effectiveness of the studied network because, as shown by previous research, this is the weakest area of innovativeness of the Polish economy [89–91]. In the recent years, institutes have increased the number of patents and publications, but this is not reflected in new ideas and implementations. In the case of commercialization, we deal with real interest of business in solutions offered by research institutes because enterprises pay for specific knowledge or technology and therefore want to put it into practice. The results obtained from the assessment of the extent of commercialization in the network under study allow for a cautious, yet positive prognosis for the future cooperation of the network between science and the socioeconomic environment.

In light of the circumstances described above, the decision to establish the Łukasiewicz Research Network in Poland is fully justified and motivated not only by the practical considerations described but also by previous considerations and scientific research [29,30].

However, in the process of integration—which is important for the further development of the studied network—problems may arise related to the integration of knowledge and compatibility of the resources held [42]. For the studied group of units, this finding may be relevant because despite the common name of the group and their combined use of IT and ICT, they offer services and products to very different audiences, which may hinder the desired effects of networking. Meanwhile, studies by Ko et al. [65] and Zhang and Wang [66] unequivocally showed that the most significant determinant of innovation in a network of research institutes is technological proximity, which allows for better communication and understanding of partners and enables closer matching of needs, competencies, and skills.

The different degree of development of institutes associated with traditional and modern industries may also be a problem. This is already evident at the current stage of integration and manifests itself in different rates of revenue growth and resilience to economic crises. Meanwhile, as emphasized in the literature [31–37], the intensity and scale of contacts of networked units determine the rate of improvement of innovation and the degree of their openness.

In the context of the establishment and operation of the Łukasiewicz Research Network, it is also worth emphasizing the extension of the chain of relations, which is no longer mainly limited to institute–business contact [42] but has been strengthened with an additional link, which is the state, and directly acting for the development of the Polish

economy [43]. Given previous research results, such an extension of cooperation is beneficial and desirable for the development of open innovation and takes place in accordance with the triple economic helix within the national innovation system [52–55].

In the future, it would certainly be worthwhile to expand it to include other links, i.e., society and environmental organizations in accordance with the concept of the fivefold helix [46–51]. According to research, such cooperation not only allows strengthening innovation but also contributes to balancing the influence of the various stakeholders on the development of the given industries in the economy [63].

As part of the development recommendations for the Network of Łukasiewicz Institutes and improvement of the above-mentioned cooperation with stakeholders, it would be worth pointing out the need to intensify activities related to the dissemination of knowledge, including, in particular, through modern communication channels available on the Internet. According to Sánchez-Teba et al., this is an attractive new medium for the diffusion of knowledge and technology [105].

6. Conclusions

The research conducted in this article showed that the institutes affiliated with the "digital transformation" group achieved the following successes in the first integration phase:

- An increase in the share of revenue from the commercialization of research results as a basis for assessing the effectiveness of the use of scientific and research potential for strengthening innovation (in five of the six institutes researched);
- An increase in sales revenue (in three of the six institutes);

Therefore, our conclusion may be that the networking of the institutes under research has had the desired effect of increasing their financial and research independence and reducing their exposure to external risks.

Observations on the performance of the group as a whole, in turn, allow us to formulate the following conclusions:

- Networking effects are more pronounced in units operating in modern economic sectors such as medicine or energy than in sectors perceived as traditional (e.g., resource extraction, heavy industry);
- Networking effects are determined by external factors of a conjunctural nature with the direction of their impact being either positive (e.g., ITAM—medical development in a pandemic) or negative (e.g., institutes related to industrial production in a pandemic);
- Taking into account the increase or the lack of changes in revenues, it can be indirectly concluded that the network allowed to minimize the risk related to the economic crisis caused by COVID-19.

The networking of Polish research institutes and the establishment of the Łukasiewicz Research Network were intended to strengthen the innovativeness of the Polish economy by taking advantage of economies of scale. Its establishment may also contribute to the development of open innovation both in the exchange of knowledge, technology, and experience within the network itself and their popularization in the socioeconomic environment. Undoubtedly, the establishment of a large research center with many in-house units increases the visibility of Polish science and research at home and abroad, thus increasing the power of research institutes to influence the scientific and business community.

However, it is worth adding that the fulfillment of the above expectations set for the newly established network requires the creation and monitoring of specific conditions. The vision of an ideal research network should involve the key circumstances resulting from the current research on networking of research institutions and the need to eliminate Poland's innovation weakness. Among these, first and foremost, we need to mention the intensification of the network's relations with the business environment, finding a reflection in the commercialization and practical use of patents and results of scientific publications. The achievement of such an objective should also positively influence the financial and organizational independence of the research institutes and relieve the public sector and

improve its efficiency. Without meeting the above conditions, it will not be possible to make the transfer of knowledge and the results of scientific research effective, which will make it impossible to improve the innovativeness of the Polish economy.

An ideal, meaning dense and complementary, research network can also support the open innovativeness through popularization of research results, successful implementations, and cooperation between science and business. It is also worth noting that joint science and industry ventures are a starting point for further research, publications, and more advanced inventions. Triggering a multiple feedback mechanism in a network is easier and can happen on a larger scale, which accelerates further ideas and actions and spreads knowledge and encourages learning.

It should be also added that a significant task for the newly created Polish research network is reaching the sector of small and medium enterprises, which—as found in previous research—show very little interest in innovations. The strength of the network's impact and its internal diversity can be an important factor in encouraging SMEs to collaborate and motivating innovative activities.

The research did not analyze the ability of the institutes to develop patents. Nevertheless, due to the shortcomings of the Polish innovation system highlighted in the introduction, the newly created network should also pay attention to this aspect not only in the context of increasing their number but also, above all, in the context of their practical use and internationalization.

The network of institutes should gain more and more recognition in Polish business and in the international scientific community in the coming years. This is a necessary condition for its effectiveness and positive impact on Polish innovation.

Considering the low interest in innovations and the low motivation of enterprises to undertake them, it would also be worth carrying out educational activities increasing awareness of the importance of innovation for civilization, social, and, above all, economic development.

The results obtained are an original research contribution on the effects of networking of research units in the immediate post-integration phase in developing economies facing low or average innovation. In the case of the Polish economy, these results are promising for the further development of the Łukasiewicz Research Network and allow for a positive assessment of its potential to strengthen innovation, including intranetwork knowledge transfer and its dissemination in the socioeconomic environment.

The main research limitation in this case is the multiple case study and the short period of monitoring of the results of networking, which does not allow generalizing the research results. Furthermore, the analyzed integration effects are affected by a wide variety of factors (e.g., the COVID-19 pandemic), which makes it difficult to separate post-integration effects from those caused by external determinants. Nonetheless, the results obtained make it possible to partially fill the research gap related to the evaluation of post-integration results of the networking of scientific and research units.

Further research should target a comparative analysis of the effects of networking conducted in terms of time (for successive periods) and entity (in relation to other groups of units at home and abroad).

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References

1. Adu-Gyamfi, G.; Nketiah, E.; Obuobi, B.; Adjei, M. Trade Openness, Inflation and GDP Growth: Panel Data Evidence from Nine West Africa Countries. *Open J. Bus. Manag.* **2020**, *8*, 314–328. [CrossRef]
2. Eppinger, E. How Open Innovation Practices Deliver Societal Benefits. *Sustainability* **2021**, *13*, 1431. [CrossRef]
3. Eisenreich, A.; Füller, J.; Stuchtey, M. Open Circular Innovation: How Companies Can Develop Circular Innovations in Collaboration with Stakeholders. *Sustainability* **2021**, *13*, 13456. [CrossRef]
4. Pichlak, M. The Drivers of Technological Eco-Innovation—Dynamic Capabilities and Leadership. *Sustainability* **2021**, *13*, 5354. [CrossRef]
5. Ryszko, A. Proactive Environmental Strategy, Technological Eco-Innovation and Firm Performance—Case of Poland. *Sustainability* **2016**, *8*, 156. [CrossRef]
6. Janik, A.; Ryszko, A.; Szafraniec, M. Greenhouse Gases and Circular Economy Issues in Sustainability Reports from the Energy Sector in the European Union. *Energies* **2020**, *13*, 5993. [CrossRef]
7. Khan, M.S.; Rabbani, M.R.; Hawaldar, I.T.; Bashar, A. Determinants of Behavioral Intentions to Use Islamic Financial Technology: An Empirical Assessment. *Risks* **2022**, *10*, 114. [CrossRef]
8. Taufiq Hail, G.A. Educational Learning and Teaching Methods' Challenges during COVID-19 Outbreak and a Sudden Transformation towards Totally Digitizing Education. *Int. J. Educ. Sci.* **2020**, *3*, 56–57. [CrossRef]
9. Laato, S.; Islam, A.N.; Farooq, A.; Dhir, A. Unusual purchasing behavior during the early stages of the COVID-19 pandemic: The stimulus-organism-response approach. *J. Retail. Consum. Serv.* **2020**, *57*, 102224. [CrossRef]
10. Bertello, A.; Bogers, M.L.; De Bernardi, P. Open innovation in the face of the COVID-19 grand challenge: Insights from the Pan-European hackathon 'EUvsVirus'. *R&D Manag.* **2021**, *52*, 178–192.
11. Kim, H.J.; Cho, K.T. Analysis of Changes in Innovative Management of Global Insurers in the Pre- and Post-COVID-19 Eras. *Sustainability* **2022**, *14*, 9976. [CrossRef]
12. Kordel, P.; Wolniak, R. Technology Entrepreneurship and the Performance of Enterprises in the Conditions of COVID-19 Pandemic: The Fuzzy Set Analysis of Waste to Energy Enterprises in Poland. *Energies* **2021**, *14*, 3891. [CrossRef]
13. Burbridge, M.; Morrison, G.M. A Systematic Literature Review of Partnership Development at the University–Industry–Government Nexus. *Sustainability* **2021**, *13*, 13780. [CrossRef]
14. Quintane, E.; Casselman, R.M.; Reiche, B.S.; Nylund, P.A. Innovation as a knowledge-based outcome. *J. Knowl. Manag.* **2011**, *15*, 928–947.
15. European Innovation Scoreboard. Available online: https://research-and-innovation.ec.europa.eu/statistics/performance-indicators/european-innovation-scoreboard_enfile:///C:/Users/ijonk/AppData/Local/Temp/ET-AY-21-001-EN-N.pdf (accessed on 28 December 2021).
16. Kim, C.Y.; Seo, E.-H.; Booranabanyat, C.; Kim, K. Effects of Emerging-Economy Firms' Knowledge Acquisition from an Advanced International Joint Venture Partner on Their Financial Performance Based on the Open Innovation Perspective. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 67. [CrossRef]
17. Efekty Działalności Instytutów Badawczych. Najwyższa Izba Kontroli. 2015. Available online: https://www.nik.gov.pl/plik/id,10114,vp,12426.pdf (accessed on 22 August 2022).
18. Available online: https://www.nik.gov.pl/aktualnosci/nik-o-instytutach-badawczych.html (accessed on 22 August 2022).
19. Cilak, M. Instytuty badawcze jako forma działalności naukowej i gospodarczej państwa—Problematyka pozycji i formy prawnej. *Prawo Budżetowe Państwa Samorz.* **2016**, *3*, 63–76. [CrossRef]
20. Funkcjonowanie Wybranych Instytutów Badawczych Nadzorowanych Przez Ministra Zdrowia. Najwyższa Izba Kontroli. 2011. Available online: https://www.nik.gov.pl/plik/id,4233,vp,5394.pdf (accessed on 22 August 2022).
21. Park, H.S. Technology convergence, open innovation, and dynamic economy. *J. Open Innov. Technol. Mark. Complex.* **2017**, *3*, 24. [CrossRef]
22. Wikhamn, B.R.; Wikhamn, W. Structuring of the Open Innovation Field. *J. Technol. Manag. Innov.* **2013**, *8*, 173–185.
23. Chesbrough, H. *Open Innovation*; Harvard Business Press: Boston, MA, USA, 2003.
24. Yun, J.H.J.; Park, K.B.; Yang, J.H.; Jung, W.Y. The philosophy of "open innovation". *J. Sci. Technol. Policy Manag.* **2016**, *7*, 134–153. [CrossRef]
25. Chae, H.S.; Choi, Y.Y.; Huh, E.J. Venture firm's open innovation: Strategy for external knowledge search and innovation performance of domestic manufacturing industry. *Asia-Pac. J. Bus. Ventur. Entrep.* **2014**, *9*, 1–13.
26. Mergel, I.; Desouza, K.C. Implementing open innovation in the public sector: The case of Challenge.gov. *Public Adm. Rev.* **2013**, *73*, 882–890. [CrossRef]
27. Bettiol, M.; Chiarvesio, M.; Di Maria, E.; Gottardello, D. Local or global? Does internationalization drive innovation in clusters? *Eur. Plan Stud.* **2019**, *27*, 1995–2014. [CrossRef]
28. Sekliuckiene, J.; Sedziniauskiene, R.; Viburys, V. Adoption of Open Innovation in the Internationalization of Knowledge Intensive Firms. *Eng. Econ.* **2016**, *27*, 607–617. [CrossRef]
29. Leckel, A.; Veilleux, S.; Dana, L.P. Local Open Innovation: A means for public policy to increase collaboration for innovation in SMEs. *Technol. Soc.* **2020**, *153*, 119891. [CrossRef]
30. Öberg, C.; Alexander, A.T. The openness of open innovation in ecosystems—Integrating innovation and management literature on knowledge linkages. *J. Innov. Knowl.* **2019**, *4*, 211–218. [CrossRef]

31. Suh, Y.; Jeon, J. Monitoring patterns of open innovation using the patent-based brokerage analysis. *Technol. Soc.* **2019**, *146*, 595–605. [CrossRef]
32. Radziwon, A.; Bogers, M. Open innovation in SMEs: Exploring inter-organizational relationships in an ecosystem. *Technol. Soc.* **2019**, *146*, 573–587. [CrossRef]
33. O'Connor, M.; Doran, J.; McCarthy, N. Cognitive proximity and innovation performance: Are collaborators equal? *Eur. J. Innov. Manag.* **2020**, *24*, 637–654. [CrossRef]
34. Kim, E.; Lee, I.; Kim, H.; Shin, K. Factors Affecting Outbound Open Innovation Performance in Bio-Pharmaceutical Industry-Focus on Out-Licensing Deals. *Sustainability* **2021**, *13*, 4122. [CrossRef]
35. Boschma, R. Proximity and Innovation: A Critical Assessment. *Reg. Stud.* **2005**, *39*, 61–74. [CrossRef]
36. Liu, Y.; Shao, X.; Tang, M.; Lan, H. Spatio-temporal evolution of green innovation network and its multidimensional proximity analysis: Empirical evidence from China. *J. Clean. Prod.* **2021**, *283*, 124649. [CrossRef]
37. Knoben, J.; Oerlemans, L.A.G. Proximity and inter-organizational collaboration: A literature review. *Int. J. Manag. Rev.* **2006**, *8*, 71–89. [CrossRef]
38. Balland, P. Proximity and the Evolution of Collaboration Networks: Evidence from Research and Development Projects within the Global Navigation Satellite System (GNSS) Industry. *Reg. Stud.* **2012**, *46*, 741–756. [CrossRef]
39. Almeida, F. Open-Innovation Practices: Diversity in Portuguese SMEs. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 169. [CrossRef]
40. Čirjevskis, A. Exploring Critical Success Factors of Competence-Based Synergy in Strategic Alliances: The Renault–Nissan–Mitsubishi Strategic Alliance. *J. Risk Financ. Manag.* **2021**, *14*, 385. [CrossRef]
41. Remneland-Wikhamn, B.; Wikhamn, W. Open innovation in practice: Diffusion of knowledge and use in Swedish bio-pharmaceutical firms. *Int. J. Bus. Innov. Res.* **2014**, *8*, 137–153. [CrossRef]
42. Koria, M.; Osorno-Hinojosa, R.; Ramírez-Vázquez, D.d.C.; van den Broek, A. One World, Two Ideas and Three Adaptations: Innovation Intermediaries Enabling Sustainable Open Innovation in University–Industry Collaboration in Finland, Mexico and Nicaragua. *Sustainability* **2022**, *14*, 11270. [CrossRef]
43. Cândido, A.C.; Sousa, C.J. Open innovation practices in strategic partnerships of cloud computing providers. *J. Technol. Manag. Innov.* **2017**, *12*, 59–67. [CrossRef]
44. Daniel, A.D.; Alves, L. University-industry technology transfer: The commercialization of university's patents. *Knowl. Manag. Res. Pract.* **2020**, *18*, 276–296. [CrossRef]
45. Bruce, J.R.; Figueiredo, J.M.; Silverman, B.S. Public contracting for private innovation: Government capabilities, decision rights, and performance outcomes. *Strateg. Manag. J.* **2019**, *40*, 533–555. [CrossRef]
46. Maditati, D.R.; Munim, Z.H.; Schramm, H.J.; Kummer, S. A review of green supply chain management: From bibliometric analysis to a conceptual framework and future research directions. *Resour. Conserv. Recycl.* **2018**, *139*, 150–162. [CrossRef]
47. Fahimnia, B.; Sarkis, J.; Davarzani, H. Green supply chain management: A review and bibliometric analysis. *Int. J. Prod. Econ.* **2015**, *162*, 101–114. [CrossRef]
48. Kitsios, F.; Kamariotou, M.; Grigoroudis, E. Digital Entrepreneurship Services Evolution: Analysis of Quadruple and Quintuple Helix Innovation Models for Open Data Ecosystems. *Sustainability* **2021**, *13*, 12183. [CrossRef]
49. Yokura, Y.; Matsubara, H.; Sternberg, R. R&D Networks and Regional Innovation: A Social Network Analysis of Joint Research Projects in Japan. *Area. R. Geogr. Soc.* **2013**, *45*, 493–503.
50. Yun, J.J.; Lee, M.; Park, K.; Zhao, X. Open innovation and serial entrepreneurs. *Sustainability* **2019**, *11*, 5055. [CrossRef]
51. Carayannis, E.G.; Dezi, L.; Gregori, G.; Calo, E. Smart Environments and Techno-centric and Human-Centric Innovations for Industry and Society 5.0: A Quintuple Helix Innovation System View Towards Smart, Sustainable, and Inclusive Solutions. *J. Knowl. Econ.* **2021**, *365*, 842. [CrossRef]
52. Chesbrough, H.; Bogers, M. Explicating open innovation: Clarifying an emerging paradigm for understanding innovation. In *Open Innovation: New Frontiers and Applications*; Chesbrough, H., Vanhaverbeke, W., West, J., Eds.; Oxford University Press: Oxford, UK, 2014.
53. Von Hippel, E. *Democratizing Innovation*; MIT Press: Cambridge, MA, USA, 2005.
54. Kaiser, R. *Innovationspolitik: Staatliche Steuerungskapazitäten Beim Aufbau Wissensbasierter Industrien im Internationalen Vergleich*, 1st ed.; Nomos: Baden-Baden, Germany, 2008.
55. Perkmann, M.; Walsh, K. University–industry relationships and open innovation: Towards a research agenda. *Int. J. Manag. Rev.* **2007**, *9*, 259–280. [CrossRef]
56. Meissner, D.; Kotsemir, M. Conceptualizing the innovation process towards the 'active innovation paradigm'-trends and outlook. *J. Innov. Entrep.* **2016**, *5*, 14. [CrossRef]
57. Chaminade, C.; Edquist, C. Rationales for Public Policy Intervention in the Innovation Process: Systems of Innovation Approach. In *The Theory and Practice of Innovation Policy: An International Research Handbook*; Smits, R., Kuhlmann, S., Shapira, P., Eds.; Edward Elgar: Cheltenham, UK, 2010; pp. 95–114.
58. Becker, B.A.; Eube, C. Open innovation concept: Integrating universities and business in digital age. *J. Open Innov. Technol. Mark. Complex.* **2018**, *4*, 12. [CrossRef]
59. Ober, J. Innovation Adoption: Empirical Analysis on the Example of Selected Factors of Organizational Culture in the IT Industry in Poland. *Sustainability* **2020**, *12*, 8630. [CrossRef]

60. Karwot, J.; Ober, J. Safety Management of Water Economy. Case Study of the Water and Sewerage Company. *Manag. Syst. Prod. Eng.* **2019**, *3*, 189–196. [CrossRef]
61. Ober, J.; Karwot, J. Tap Water Quality: Seasonal User Surveys in Poland. *Energies* **2021**, *14*, 3841. [CrossRef]
62. Rakthai, T.; Aujirapongpan, S.; Suanpong, K. Innovative Capacity and the Performance of Businesses Incubated in University Incubator Units: Empirical Study from Universities in Thailand. *J. Open Innov. Technol. Mark. Complex.* **2019**, *5*, 33. [CrossRef]
63. Ortega, L.M.; Bagnato, V.S. The practice of innovation at Brazilian public university: The case of the University of São Paulo. *Braz. J. Sci. Technol.* **2015**, *2*, 6. [CrossRef]
64. Liefner, I.; Schiller, D. Academic capabilities in developing countries—A conceptual framework with empirical illustrations from Thailand. *Res. Policy* **2008**, *37*, 276–293. [CrossRef]
65. Sánchez-Teba, E.M.; Rodríguez-Fernández, M.; Gaspar-González, A.I. Social Networks and Open Innovation: Business Academic Productivity. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 158. [CrossRef]
66. Shmeleva, N.; Gamidullaeva, L.; Tolstykh, T.; Lazarenko, D. Challenges and Opportunities for Technology Transfer Networks in the Context of Open Innovation: Russian Experience. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 197. [CrossRef]
67. Ko, S.; Kim, W.; Lee, K. Exploring the Factors Affecting Technology Transfer in Government-Funded Research Institutes: The Korean Case. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 228. [CrossRef]
68. Zhang, B.; Wang, H. Network Proximity Evolution of Open Innovation Diffusion: A Case of Artificial Intelligence for Healthcare. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 222. [CrossRef]
69. Pan, W.; Zhao, P.; Ding, X. The effects of network structure on research innovation: An analysis from a content perspective using the data of R&D funding. *Technol. Anal. Strateg. Manag.* **2019**, *31*, 1430–1446. [CrossRef]
70. Liu, J. Dynamics of technological innovation network and its impact on organisational learning and innovation performance. *Innov. Dev.* **2012**, *2*, 159–174. [CrossRef]
71. Beck, S.; Bergenholtz, C.; Bogers, M.; Brasseur, T.-M.; Conradsen, M.L.; Di Marco, D.; Distel, A.P.; Dobusch, L.; Dörler, D.; Effert, A.; et al. The Open Innovation in Science research field: A collaborative conceptualisation approach. *Ind. Innov.* **2022**, *29*, 136–185. [CrossRef]
72. Klinke, A. Public understanding of risk and risk governance. *J. Risk Res.* **2021**, *24*, 2–13. [CrossRef]
73. Sarin, S.; Sego, T.; Chanvarasuth, N. Strategic Use of Bundling for Reducing Consumers' Perceived Risk Associated with the Purchase of New High-Tech Products. *J. Mark. Theory Pract.* **2003**, *11*, 71–83. [CrossRef]
74. Jarus, T. Nie ma Ryzyka, nie ma Innowacji. Available online: http://www.pi.gov.pl/parp/chapter_86196.asp?soid=A805BEAED1F24A8890FCF66E4AE57D13 (accessed on 15 June 2015).
75. Keizer, J.A.; Halman, J.I.M. Diagnosing risk in radical innovation projects. *Res. Technol. Manag.* **2007**, *50*, 30–36. [CrossRef]
76. Roper, S.; Tapinos, E. Taking risks in the face of uncertainty: An exploratory analysis of green innovation. *Technol. Forecast. Soc. Change* **2016**, *112*, 357–363. [CrossRef]
77. Green, S.G.; Gavin, M.B.; Aiman-Smith, L. Assessing a multidimensional measure of radical technological innovation. *IEEE Trans. Eng. Manag.* **1995**, *42*, 203–214. [CrossRef]
78. Heidenreich, S.; Spieth, P.; Petschnig, M. Ready, Steady, Green: Examining the Effectiveness of External Policies to Enhance the Adoption of Eco-Friendly Innovations. *J. Prod. Innov. Manag.* **2017**, *34*, 343–359. [CrossRef]
79. Knut, F.L.; Simlai, P. The value premium, aggregate risk innovations, and average stock returns. *Financ. Res. Lett.* **2014**, *11*, 303–317. [CrossRef]
80. Romanowska, M. Determinanty innowacyjności polskich przedsiębiorstw. *Przegląd Organ.* **2016**, *2*, 25–35. [CrossRef]
81. Janasz, W.; Janasz, K. Determinanty innowacyjności organizacji. *Studia I Pr. WNEIZ US* **2017**, *48*, 10–20.
82. Nawrocki, T. Problematyka pomiaru i oceny innowacyjności przedsiębiorstw. *Zeszyty Naukowe Politechniki Śląskiej. Organ. I Zarządzanie* **2015**, *79*, 217–226.
83. Nawrocki, T.; Jonek-Kowalska, I. Fuzzy aproach to corporate potential innovativeness assessment. In *Trends of Management in the Contemporary Society, Proceedings of the International Conference on Management, Brno, Czech Republic, 9–10 June 2016*; Formankova, S., Ed.; Mendelova Univerzita v Brne: Brno, Czech Republic, 2016; pp. 321–324.
84. Pichlak, M. *Innowacje Ekologiczne, Zdolności Dynamiczne i Efektywność Organizacji*; CeDeWu: Warszawa, Poland, 2020.
85. Pichlak, M. Relational capability, technological eco-innovation and performance: Evidence from Polish green companies. *JIBBP* **2021**, *2021*, 312930. [CrossRef]
86. Ryszko, A. Eco innovation performance and selected competitiveness issues perceived by managers in the EU member states—A cross country analysis. *Acta Univ. Agric. Silvic. Mendel. Brun.* **2017**, *65*, 1751–1760. [CrossRef]
87. Ryszko, A. Eco-innovation performance and selected competitiveness issues perceived by managers in the EU member states—A cross-country analysis. In *Enterprise and Competitive Environment, Proceedings of the 20th Annual International Conference, Brno, Czech Republic, 9–10 March 2017*; Kapounek, S., Ed.; Mendel University: Brno, Czech Republic, 2017; pp. 741–751.
88. Pichlak, M. Uwarunkowania innowacyjności organizacji. In *Studium Teoretyczne i Wyniki Badań*; Difin: Warszawa, Poland, 2012.
89. Kraśnicka, T. Innowacyjność przedsiębiorstw—Uwarunkowania organizacyjne. *Studia Ekonomiczne. Uniw. Ekon. W Katowicach* **2013**, *136*, 165–179.
90. Okoń-Horodyńska, E.; Zachorowska-Mazurkiewicz, A.; Wisła, R.; Sierotowicz, T. Gender, innovative capacity, and the process of innovation: A case of Poland. *Econ. Sociol.* **2016**, *9*, 252–261. [CrossRef]
91. Gajda, W. Innowacyjność polskiej gospodarki—Stan i perspektywy. *Studia I Pr. WNEIZ US* **2017**, *48*, 164–177. [CrossRef]

92. Kansy, D. Innowacyjność polskiej gospodarki na tle Unii Europejskiej z uwzględnieniem specyfiki sektora informatycznego. *Studia Ekon. Zesz. Nauk. Uniw. Ekon. W Katowicach* **2018**, *362*, 111–126.
93. Kowalik, J. Innowacyjność gospodarki polskiej na tle innych państw UE. In *Współczesne Wyzwania Rozwoju Gospodarczego: Polityka i Kreacja Potencjału*, 1st ed.; Gruszewska, E., Ed.; Kreacja, Innowacyjność, Handel Zagraniczny: Białystok, Poland, 2015; pp. 143–157.
94. Ciborowski, R.W.; Grabowiecki, J. Innovation capacity adjustment: The case of Poland. *Int. J. Technol. Policy Manag.* **2003**, *3*, 56–69. [CrossRef]
95. Czerniak, J. Polityka innowacyjna w Polsce. In *Analiza i Proponowane Kierunki Zmian*; Difin: Warszawa, Poland, 2013.
96. Białoń, L. *Zarządzanie Dzielnością Innowacyjną*; Placet: Warszawa, Poland, 2010.
97. Available online: https://ekrs.ms.gov.pl/rdf/pd/search_df (accessed on 1 July 2022).
98. Trzmielak, D.M. *Komercjalizacja Wiedzy i Technologii—Determinanty i Strategie*; Wydawnictwo Uniwersytetu Łódzkiego: Łódź, Poland, 2013.
99. Gryzik, A. *Instytuty Badawcze w Nowoczesnej Gospodarce*; Ośrodek Przetwarzania Informacji—Państwowy Instytut Badawczy: Warszawa, Poland, 2017.
100. Ustawa z Dnia 30 Kwietnia 2010 r. o Instytutach Badawczych [Dz. U. 2010 Nr 96 poz. 618]. Available online: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu20100960618 (accessed on 1 July 2022).
101. Available online: https://www.gov.pl/web/edukacja-i-nauka/lukasiewicz (accessed on 18 July 2022).
102. Available online: https://lukasiewicz.gov.pl/o-nas/grupy-badawcze (accessed on 18 July 2022).
103. Available online: https://www.itee.lukasiewicz.gov.pl (accessed on 18 July 2022).
104. Alvarez-Meaza, I.; Pikatza-Gorrotxategi, N.; Rio-Belver, R.M. Knowledge Sharing and Transfer in an Open Innovation Context: Mapping Scientific Evolution. *J. Open Innov. Technol. Mark. Complex.* **2020**, *6*, 186. [CrossRef]
105. Simões, P.C.; Moreira, A.C.; Mendes Dias, C. Portugal's Changing Defense Industry: Is the Triple Helix Model of Knowledge Society Replacing State Leadership Model? *J. Open Innov. Technol. Mark. Complex.* **2020**, *6*, 183. [CrossRef]