TECHNOLOGICAL COOPERATION BETWEEN SCIENTIFIC AND RESEARCH INSTITUTIONS AND COMPANIES AS A CONDITION OF THE GROWTH OF INNOVATIVENESS AND COMPETITIVENESS OF POLISH ECONOMY[1]

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Abstract

The current position of Poland in rankings of economy innovativeness and competitiveness is not satisfactory. Insignificant innovativeness of Polish companies enforces an increase in connections between scientific institutions and enterprises in the scope of technology transfer.

The purpose of the paper is to present the importance and benefits of technological cooperation between scientific and research institutions and enterprises in Poland for the innovativeness and competition of both enterprises and the economy. The basis to draw up this article were the results of the authoress own research over the technological cooperation between scientists and entrepreneurs in Poland between 2004 and 2011.

For the needs of the article there were applied the methods of analysis of innovativeness and competitiveness survey ratios, publications of the Central Statistical Office, rankings of innovativeness of the European Union States and rankings of economic competitiveness. This allowed to set out the level of innovativeness of Polish enterprises and the status of their links with the sector of scholarship and research. This has an impact on the competitiveness of Polish economy. The results of the authoress' research indicate a necessity to intensify the technological cooperation between the scholarly sector and the industry. Presented examples of technological cooperation between scientists and entrepreneurs confirm that the technological partnership must become a development strategy of Polish entrepreneurs in view of changes in the world economy. The case study revealed its impact on the innovativeness and competitiveness of enterprises in Poland.

The type of article: *Research report.*

Keywords: *innovativeness, competitiveness, technological cooperation, R&D sector, industry.*

JEL Classification: *031, 033.*

1. Introduction

In the contemporary globalized world, the competitiveness of the economy in macro, meso and micro scale and its long-term development are determined by the effective use of knowledge and the implementation of its results. This means that the knowledge, human resources and innovations make up key factors for the growth, development and competitiveness of the economy. Currently, this is no more an issue of development route selection, but an absolute necessity for the economy to keep up and to achieve higher competitiveness (Goldberg *et al.*, 2011). In the economics theory, this is described by endogenic models of economic growth by Romer (1990), Lucas (1988) and Jones (1995) as well as Eicher &Turnovsky (1999). The empirical evidence, confirming these dependencies can be found when analyzing the experience of states recognized as European leaders of innovativeness and economy based on knowledge (for instance Sweden, Finland, Denmark, Germany or Great Britain).

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The innovativeness as a condition for the economic growth and development gets a particular significance in the light of problems which afflict the world economy i.e. long-term recession, disadvantageous demographic and social processes, climatic changes and challenges related to the demand for power. They relate also to the European Union States, Poland included. The European Commission recognized that the most important factors which make possible for the EU States pulling out from the recession and the growth of competitiveness of the European Union economy shall be innovations and creativeness of business entities (Europe 2020…2010). Unfortunately, the states characterized by a low level of innovativeness belonging to "moderate innovators" (for instance Poland) are not in a position to overcome the technological distance not only compared to the innovation leaders but also to the group of states designated by the name of "followers of the leader" (Innovation Union Scoreboard … 2012).

The experience of the most innovative states in the world (Scandinavian countries, USA, Japan, South Korea, Singapore, Taiwan) indicates, that the basis for the innovativeness growth in a state shall be strong relations between scientific and research institutions and enterprises, financial and non-financial institutions of knowledge transfer support and technology commercialization, local and regional authorities. Within such networks of innovation, an effective system of knowledge creation and transfer comes into being, together with technology diffusion and the implementation of new solutions in enterprises and then, their commercialization. Scholars and entrepreneurs can start technological cooperation to put into life joint basic and applied research and implementations. This ensures the penetration of R&D sector achievements to the economy, facilitating the development of innovative processes partners, the occurrence of new values and economic benefits (Benchmarking industry – science relations… 2001; Cogan, 2001; Tornatzky, 2002; Casey, 2004; Łącka, 2011).

The purpose of the paper is to present the importance and benefits of the technological cooperation between scientific and research institutions and enterprises in Poland for the innovativeness and competitiveness of enterprises and the economy. Such technological partnership shall become a development strategy of Polish enterprises in the conditions of changes in the world economy.

2. Methods

For the needs of the article, the method of ratio analysis in the field of innovativeness and competitiveness survey was applied with the use of the Central Statistical Office publications, *the Innovation Union Scoreboard*, rankings of the European Union States innovativeness, reports *by the European Innovation Scoreboard* and rankings of economy competitiveness. This allowed to set out the level of innovativeness and competitiveness of Polish economy and its enterprises between 2004-2011 and the status of their relations with the sector of science and research. The method of case study made it possible to present examples of technological cooperation between scientists and entrepreneurs.

3. Results

Innovativeness of Polish economy – results of analyses of EU innovativeness rankings

In 2012, the second edition of the report by the European Union *Innovation Union Scoreboard 2011. Research and Innovation Union Scoreboard* (2012) appeared. This document makes up a comparative analysis of the innovativeness level of individual European Union Member States, the efficiency of innovativeness policy conducted and its strong and weak sides. This report allows to assess the innovativeness of other selected European States, i.e. Croatia, Iceland, the Republic of Macedonia, Norway, Serbia, Switzerland and Turkey. It is also a tool to monitor the implementation of the European 2020 strategy recommendations and to compare the innovativeness of EU in relation to selected states, USA and Japan. For analytical purposes, its authors apply the methodology, used in the paper *European Innovation Scoreboard. Comparative analysis of innovation performance* prepared before 2009. Its basis is made up by a complex innovativeness index Summary Innovation Index (SII), which is created as a result of taking into account 25

indices describing the innovative efficiency of individual states. These indices belong to three categories, of which the first two ones relate to innovation conditions and the last one to its symptoms. We can distinguish between them:

1. Innovation drivers (*enablers*) which encompass: human resources, open perfect and attractive research system and financing together with support;
2. Firm activities, investment of enterprises (outlays for innovations), relations and entrepreneurship and assets of intellectual property;
3. Innovative activities outputs, innovators and economic effects.

The data coming from this report indicate for another time the low innovativeness of Poland compared to other states belonging to the Union. In 2011, SII for our State was 0.296 (the scale is from 0 to 1) and compared to the previous year, it lowered which caused the worsening of the place in the innovativeness ranking compared to 2010 (drop by one place). The value of this index in 2011 placed our State in the group of "moderate innovators" on 23rd position amongst 27 Member States. Between 2004 and 2011, Poland most frequently had a similar position, although SII grew in subsequent years. This allowed to pass from the group of **catching-up countries**[2] in 2008 to the group of "moderate innovators" in 2009. However, Poland is still at the end of the innovativeness ranking of the Union States. In 2011, higher indices in this ranking belonged not only to the States of the so-called old Union, but also to most states admitted to the Community in 2004 together with Poland. The lower positions in the ranking were held only by Latvia, Bulgaria, Lithuania and Romania (Figure 1).

It was also similar in the previous years. This is confirmed by innovativeness indices placed in Table 1 of the European Union Member States between 2004 and 2011. In 2012, the SII index for Poland was 0.270 and in the ranking, it was preceded by Lithuania with SII equal to 0.280 (Innovation Union Scoreboard 2013).

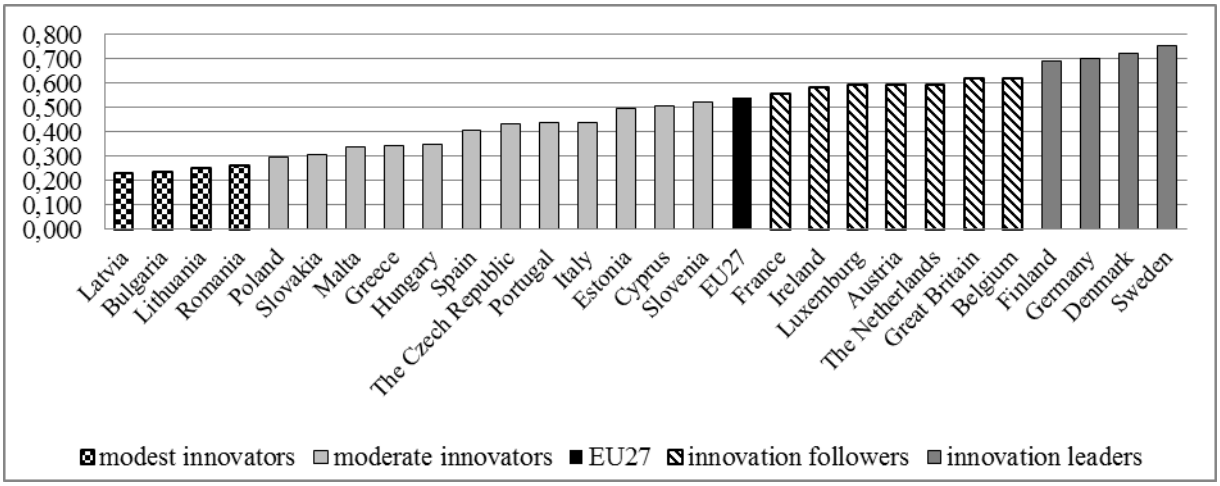

Figure 1. Ranking of innovativeness of European States in 2011 (pursuant to SII)

Table 1. Compound innovativeness index SII for European Union Member States between 2004 and 2011

Specification	2004	2005	2006	2007	2008	2009	2010	2011
EU27	0.429	0.431	0.505	0.517	0.526	0.526	0.533	0.539
Belgium	0.467	0.477	0.578	0.606	0.617	0.604	0.625	0.621
Bulgaria (in EU from 2007)	0.172	0.174	0.159	0.173	0.192	0.205	0.216	0.239
The Czech Republic	0.344	0.346	0.379	0.397	0.404	0.386	0.400	0.436
Denmark	0.566	0.572	0.734	0.727	0.718	0.688	0.704	0.727
Germany	0.538	0.543	0.639	0.660	0.668	0.693	0.711	0.700
Estonia	0.413	0.409	0.388	0.395	0.410	0.476	0.492	0.496

[2] Currently the States of the lowest SII indices are included into the group of „modest innovators".

Specification	2004	2005	2006	2007	2008	2009	2010	2011
Ireland	0.486	0.504	0.553	0.576	0.597	0.574	0.571	0.582
Greece	0.271	0.279	0.322	0.329	0.355	0.343	0.339	0.343
Spain	0.329	0.344	0.379	0.397	0.404	0.408	0.410	0.406
France	0.460	0.461	0.439	0.505	0.515	0.531	0.540	0.558
Italy	0.314	0.320	0.380	0.413	0.423	0.424	0.429	0.441
Cyprus	0.370	0.363	0.411	0.418	0.474	0.474	0.483	0.509
Latvia	0.194	0.204	0.163	0.191	0.205	0.215	0.213	0.230
Lithuania	0.264	0.273	0.244	0.265	0.272	0.242	0.258	0.255
Luxemburg	0.486	0.486	0.576	0.610	0.622	0.624	0.651	0.595
Hungary	0.266	0.273	0.298	0.314	0.316	0.320	0.333	0.352
Malta	0.274	0.280	0.276	0.292	0.312	0.345	0.383	0.340
The Netherlands	0.450	0.447	0.545	0.570	0.575	0.590	0.595	0.596
Austria	0.480	0.494	0.562	0.576	0.593	0.613	0.626	0.595
Poland	0.264	0.272	0.273	0.284	0.293	0.292	0.304	0.296
Portugal	0.290	0.317	0.320	0.340	0.372	0.412	0.426	0.438
Romania (in EU from 2007)	0.209	0.205	0.195	0.226	0.242	0.265	0.259	0.263
Slovenia	0.388	0.393	0.404	0.431	0.454	0.485	0.499	0.521
Slovakia	0.257	0.273	0.265	0.295	0.309	0.307	0.322	0.305
Finland	0.551	0.546	0.638	0.643	0.642	0.687	0.708	0.691
Sweden	0.607	0.610	0.758	0.746	0.767	0.753	0.766	0.755
Great Britain	0.522	0.534	0.600	0.620	0.625	0.600	0.599	0.620

Source: The authoress' own table based on: Innovation Union Scoreboard 2011; European Innovation Scoreboard (EIS) 2009; European Innovation Scoreboard 2008.

The analysis of data placed in Figure 1 and in Table 1 indicates a differentiation of the level of innovativeness amongst the Union States and the occurrence of four groups of states. The states with the highest SII (much over the Union average, which in 2011 was 0.539) are called "innovation leaders". In 2011, they were Sweden, Denmark, Germany and Finland. The second group is made up by states included into the group of "innovation followers"; they achieve SII over the average for the Union. In 2011, they included Great Britain, the Netherlands, Austria, Luxemburg, Ireland and France. Another, the most numerous group is made up by states which are called "moderate innovators", with the index at a level close to or lower than the average for the whole EU. In 2011, they included Slovenia, Cyprus, Estonia, Italy, Portugal, the Czech Republic, Spain, Hungary, Greece, Malta, Slovakia and Poland. The last group of "modest innovators" covers states with very low innovativeness index, much below the Union average, a significant distance away from the innovation leaders. In 2011, it included Romania, Lithuania, Bulgaria and Latvia.

The innovativeness index is under the impact of its components. Their analysis allows to notice success factors in the field of innovativeness of the states, belonging to the first and second groups. At the same time, it makes up a basis for conclusions on reasons of low innovativeness in the states which make up the remaining two groups.

It is the opinion of the European Commission that the most innovative states of the Union achieve such good results, as they have some joint strong sides in the field of domestic research and innovativeness systems. Innovative entrepreneurship and well-developed university education are of great importance. In these states, there is a perfect system of connections between the industry and the scholarship. Outlays for scholarly research and development are characteristic for innovation leaders where the private sector has a significant share. These states achieve also very high indices in the category of intellectual property, they take first positions in the submission of patent applications. The driving force of the innovativeness increase are small and medium-sized innovative enterprises and the commercialization of innovations which come into being within the national R&D system (Innovation Union Scoreboard 2011).

Comparing partial indices of innovativeness for Poland with the results of leaders or the average for the EU, we may note that the key areas of leaders success make up Poland's weak sides. Only in relation to two ratios (related to education) from the category of "human resources" does Poland achieve better or comparable results. A detailed analysis allows to note that the reason of low innovativeness of Polish economy is the national research system; hardly opened, ineffective and imperfect which shows too little international links and weak connections with the sector of enterprises. This, among others, contributes to insufficient commercialization of new solutions. The factors which have an impact on low innovativeness of Polish economy include (Science and technology …2012; Innovation activities … 2012):

- too little money spent on research and development and too small share of the private sector in the financing of innovativeness,
- drastically small share of v*enture capital* investment in the financing of innovativeness,
- very small share of innovative SMEs,
- very small proneness of entrepreneurs from the SME sector to cooperate in the field of innovativeness with various entities, scientific and research institutions included,
- very weak links between the private and public sector,
- very small number of patent applications and patents granted and in consequence very small share of proceeds, arising from the sale of licences and patents,
- too small activity of small and medium-sized entrepreneurs in innovativeness – a small share of SMEs, implementing product and process innovations, as well as marketing and organisational ones; this has an impact on the low ratio of revenues from sales of products new for the market and new for the firm.

To sum up, we may assume that the most important factors which have an impact on the low innovativeness of Polish economy are (Łącka, 2011):

- insufficiently developed system of links in the innovative processes,
- many financial, legal and fiscal barriers for innovative activities,
- too small technological cooperation between firms and scientific and research institutions,
- insufficiently developed innovative awareness and entrepreneurship amongst the representatives of SMEs and scientists.

Innovativeness and competitiveness of Polish economy

Analyses of various international comparisons of competitiveness lead to a conclusion that Polish economy does not classify amongst highly competitive ones. Despite of positive changes in this field between 2004 and 2011, the competitiveness measured with the help of various criteria (economic liberty index, world competitiveness ranking IMD, attractiveness of location for direct foreign investments, ranking of investment attractiveness, ranking of freedom of establishment, ranking of global competitiveness) is low. Depending upon the type of ranking and the methodology applied while generating it, Poland generally does not hold high positions (Table 2).

Table 2. Competitive position of Poland in 2011, as compared to other EU states, in various competitiveness comparisons

Economic Freedom Ranking									
State	***Great Britain***	***Germany***	***France***	***Spain***	***Lithuania***	***Czech Republic***	***Italy***	***Slovakia***	***Poland***
position	16	23	64	31	24	28	87	37	68
IMD Ranking									
State	***Great Britain***	***Germany***	***France***	***Spain***	***Lithuania***	***Czech Republic***	***Italy***	***Slovakia***	***Poland***
position	20	10	29	35	45	30	42	48	34

The most attractive states of the world in terms of business investments location between 2011 and 2013									
State	***Great Britain***	***Germany***	***France***	***Spain***	***Lithuania***	***Czech Republic***	***Italy***	***Slovakia***	***Poland***
position	13	9	20	NA	NA	17	NA	NA	6
Ranking of freedom of establishing									
State	***Great Britain***	***Germany***	***France***	***Spain***	***Lithuania***	***Czech Republic***	***Italy***	***Slovakia***	***Poland***
position	6	19	26	45	25	70	83	43	70
Global Competitiveness Index (GCI)									
State	***Great Britain***	***Germany***	***France***	***Spain***	***Lithuania***	***Czech Republic***	***Italy***	***Slovakia***	***Poland***
position	10	6	18	36	44	38	43	69	41

Source: author's own elaboration based on: Index of Economic Freedom 2011. http://www.heritage.org/index/ranking; The World Competitiveness Scoreboard 2011. http://www.imd.org/news/IMD-announces-the-2011-World-Competitiveness-Rankings-and-the-results-of-the-Government-Efficiency-Gap.cfm; UNCTAD's World Investment Prospects Survey 2010-2012. http://unctad.org/en/Docs/diaeia20104_en.pdf; World Investment Report 2011. http://www.businessinmalopolska.pl/public/upload/fck/file/WIR2011FULLREPORT_1.pdf; Doing Business 2011. http://www.doingbusiness.org/data/exploreeconomies/poland/; The Global Competitiveness Report 2010-2011. http://reports.weforum.org/global-competitiveness-2011-2012.

In 2011, only one ranking classified Poland at very high, 6th position. Poland was recognised as a most attractive country to implement direct foreign investment between 2011 and 2013. In this aspect, it preceded all the remaining states of the Union. In the ranking higher positions were obtained by such countries like: China, USA, India, Brazil and Russia.

The last global competitiveness ranking used in Table 2 allows to link directly the innovativeness of the economy with its competitiveness. It is drawn up every year by the World Economic Forum, using 12 pillars of competitiveness, grouped into three categories: basic factors (competitiveness of institutions, infrastructure, macroeconomic stability, competitiveness of healthcare and basic education), effectiveness (evaluation of higher education, effectiveness of labour markets and their flexibility, development of financial markets, capacity to absorb technology and size of market), as well as innovativeness (evaluation of economy innovativeness and level of business environment development).

The two last areas of competitiveness analysis relate to factors, having a very strong impact on the potential to create and introduce innovations. This indicates a growing influence of these conditions on economic competitiveness and its development possibilities. In 2010, the position of Poland in the Global Competitiveness Index (41st place) results, to a large degree, from its low innovativeness and numerous barriers in this area, limited capacity to absorb technological innovations and little demand for new solutions on the part of entrepreneurs, as well as insignificant - and not always adjusted to the needs of SMEs - supply of technology from the scholarly sector.

The factors of low innovativeness and competitiveness of the Polish economy presented in this paper may be limited by the creation of stronger and more effective connections between scientific and research institutions and enterprises. Thus, it is necessary to increase the technological cooperation between scholars and entrepreneurs in the field of innovativeness, to bring closer the supply of technology to the demand for it, to intensify the transfer of knowledge and the commercialization of technology, to increase academic entrepreneurship and the proneness of small and medium-sized entrepreneurs to start their cooperation with all elements of regional innovative systems. Since 2010, the country (after starting the reform of the sector of science and research) has had a larger impact on the cooperation to be started between scientists and entrepreneurs, using various tools of innovativeness policy. However, it is a long-term process whose effects will be visible only in many years.

The hitherto results of the innovativeness policy used to create strong connections between the scholarly environment and the industry in Poland show, on the one hand, innovation indices, and on the other, examples of technological cooperation between entrepreneurs and scientists, while creating and implementing innovations. Between 2004 and 2011, such a cooperation was a rarity in the scale of the whole Polish scholarly sector and the number of agreements with entrepreneurs in the field of research and development activity together with innovativeness too small, compared to the potential of the sector. The transfer of technology from scientific and research institutions to enterprises was not satisfactory, which is testified by the size of revenues gained by them from target projects, the sale of research projects, the sale of patent rights and licences. However, the authoress' research allowed to find examples of technological cooperation between scientific and research units and enterprises which confirm the potential to gain many benefits from such partnership in micro, meso and macro scale. Because of the limited framework of this paper, only a few of them could be presented.

Cooperation between Industrial Institute of Agricultural Engineering and "AKPIL" company

The Industrial Institute of Agricultural Engineering in Poznań most frequently implements its research projects in cooperation with enterprises from the SME sector. The target projects are aimed at creating new solutions which shall allow the industrial partner to implement them in the form of a new, innovative and highly competitive product. Such was the case of technological cooperation between the Institute and the Pilzno "AKPIL" production, servicing and commercial company owned by Kazimierz Anioł. "AKPIL" company is one of the largest producers of agricultural machines in Poland. It offers 40 different types of machines (not only agricultural ones), which are mostly exported to the EU and Eastern Europe markets, as well as to USA and Tunisia.

As a result of cooperation of the Poznań IIAE scientists and the constructors from "AKPIL" company, in 2010, a combined harvester for root vegetables was constructed. Research and development works over this new machine were conducted with the use of highly advanced computer techniques, modern CAD 3D systems and resistance programmes. Owing to innovative solutions and high usability values, this harvester is a very advanced construction, which precedes products of foreign competitors. It shall replace ordinary diggers or simple-furrow ploughs for vegetables harvesting and allow to reduce high costs of labour in the harvesting process. The machine is designated to carry out one-stage harvest technology of such vegetables like: carrot, parsley, parsnip, beetroot, and it is also adjusted for a double-stage harvest of onion.

The global innovativeness of the harvester's construction arises from the application of a system of horizontal conveyors. This allows to reduce the degree of damage to vegetables and to improve their cleaning. The innovativeness of the solution is also linked with the application of replaceable working adapters for harvesting vegetables, an automatic device that guides to the ridge, cleaning and waste separation assemblies as well as the torsion axis of the harvester. The innovative advantages of the machine include its ergonomics and safety of use, energy saving, reduction of fuel consumption, reduction of exhaust fumes emissions, reduction of noise and minimizing the adverse impact on the soil structure. The above features and, at the same time, a lower price of the harvester determine the high competitiveness of this product on the global market. This is confirmed by the results of the sales of the harvester, as the machine has already found buyers outside Poland, on the Italian, Russian, Ukrainian and Croatian markets.

One more time, the technological cooperation between the Industrial Institute of Agricultural Engineering in Poznań and "AKPIL" enterprise resulted in the invention of an innovative and globally competitive product, that broadened the company's offer and strengthened its position on the agricultural machines market.

Cooperation between the Metal Forming Institute and the industry

The Metal Forming Institute handles drawing up, researching and implementing technologies, machines and facilities for non-metallurgic metal forming. From its beginnings (it was founded in 1948), it has been carrying out research for the needs of the economy, in particular the metal industry, as a result of which hundreds of innovative technological solutions, machines and facilities have been applied in numerous domestic and foreign enterprises. Within the market economy, scholars of the Institute successfully propagate and implement in industrial enterprises the results of their research work, very frequently in cooperation with enterprises, domestic and international research institutes and university units.

The Metal Forming Institute runs research and implementation in three main areas: volumetric forming, sheet metal forming, and the technology of products forming from metal powder. The effects of cooperation of the Institute with enterprises in this field were machines constructed in the Institute and applied in various enterprises, such as: MR-005 rotary plodder for siphon bottles manufacturing (Myszków Factory of Enamelware), MWH-600 spinner for manufacturing various products from metal sheets up to 5 mm thick (SPOMASZ Gniezno), MZWH-160 rotary plodder for lengthening and smoothing surfaces of thick-bottomed high-pressure bottles (PREMA-MILMET Sosnowiec), MWH-700 spinner for forming lamps elements (Zakłady Sprzętu Oświetleniowego ELGO Gostynin). In 2009, in the Institute, an innovative technology of forming rings for elastic shock absorbers was developed, and implemented in Więcborskie Zakłady Metalowe WIZAMOR (The Więcbork WIZAMOR Metal Works). This highly effective, energy saving and low-waste technology of metal spinning has replaced the previous costly and material-consuming machining of metal rings. The new solution allowed for forming rings from sheet metal circles, on one machine, in one operation, in a multi-purpose process. The new production method allowed to produce rings with high precision and repeatability of dimensions and shapes, as well as higher resistance properties.

Thus, flexible absorbers manufactured with their application represent the highest standards and are currently used on ships of global shipowners.

Another innovative solution designed by the Institute in 2010 is a modern MWS 700 spinner, with numerical control for rotary shaping of compound sheet metal products. This machine, with an innovative tool head serves to shape products of sheet metal designated for ventilation, air conditioning and cooling facilities. It was implemented in Fläkt Bovent Sp. z o.o. Ltd. Company from Ożarów Mazowiecki (belonging to the global Fläkt Woods concern). The new technology replaced the manufacture of products from a few separate parts, joined by welding. This allows to manufacture products from sheet metal circles in one operation, in an automated multi-cut process. Fläkt Bovent Company which applies the new solution, managed to gain such benefits as: an improvement in the resistance properties and precision of products, a reduction in manufacturing time, a reduction in material consumption, an increase in manufacture output and the safety of manufacturing process.

Cooperation between Łódź University of Technology and Green Point Sp. z. o.o. while manufacturing „glasses for the blind“

Scientists from the Medical Electronics Division in the Institute of Electronics of the Łódź University of Technology, together with Green Point Sp. z o.o., designed an innovative electronic device composed of a system of cameras, a sound module and a processor to support the movements of the blind. This device communicates with a computer through a USB port and its elements are built into the glasses frame. Its prototype (after successful tests) functions on the principle of sound emission which is supposed to warn the blind person about any obstacles. This means that its operation consists in passive recognition of the surroundings (it does not emit laser light nor ultrasound). Due to the registration of stereoscopic images, it allows to determine the user’s distance from various types of obstacles. The camera registers synchronic images which are

transferred to the computer and analysed. The sound module contains stereophonic headphones and a microphone - a set which makes it possible for the user to communicate with the system. As emphasized by the inventors, this device allows to trace the location of obstacles detected with the imaging method, without the necessity on the part of a blind person to move their head. An additional advantage of this innovative solution is its shape and light weight (this allows to use the device for a long time, without getting tired), as well as the potential to function in a broad range of temperatures (at home and outside).

„Glasses for the blind" are the first solution of this type, integrating electronic circuits. After their implementation, they shall be able to replace successfully guide dogs and improve the quality of life of the blind in Poland and in the world.

Cooperation between the Silesian University of Technology in Gliwice and EgzoTech company

M.Sc. Michał Mikulski – graduate and doctorant of the Silesian University of Technology in Gliwice – is the inventor of an innovative solution under the name of uniaxial exoskeleton controlled by an electromyogram. The project of biomedical prototype of an arm controlled by electromyogram, was the subject of his master's degree thesis in 2011, in cooperation with the Silesian University of Technology in Gliwice. Further joint works of the inventor and the university over this project allowed to prepare a uniaxial exoskeleton of an arm, controlled by an electromyogram. To commercialise the new solution, in January 2013, the inventor founded the EgzoTech company, which he invented as his own business concept in 2012. It is intended to bring about the market success of the technology of active rehabilitation with the use of the electromyogram (EMG) for orthopaedic and neurological patients.

An exoskeleton is a particular form of a robotic construction to be worn, which is equipped with an electric servomotor which performs the flexing and extending movements. It facilitates the movement therapy for persons with muscle atrophy, multiple-sclerosis or those requiring long-term rehabilitation and convalescence. It is possible to modify it for the needs of lower limbs rehabilitation. Because of the applied method of electric activity measurement in human muscles, the users of these devices may be patients with a significant impairment of motor activity of limbs, or healthy persons who only require support for movement. Apart from the active motor functions therapy, the exoskeleton allows the doctors to diagnose the muscle condition in real time.

The device uses the electromyogram as a control signal and feedback. The electric potentials in the patients' muscles are used to control the rehabilitation robot, which improves the process of independent execution of physical exercises. Owing to a significant strengthening of signals and joining the patient's body with the robot skeleton, the movement of limbs may be controlled at any moment of practicing. The exoskeleton facilitates the use of a single muscle, for instance the biceps and triceps muscles.

The basic purpose of the device is to support movement therapy of patients in rehabilitation centres. It is particularly efficient for loosening muscle spasticity, post isometric relaxation with the method of muscle extension, therapy of muscle dystrophy, therapy of partial spinal cord trauma, therapy after cerebral strokes, rehabilitation of rheumatoid conditions, etc.

As indicated by the inventor, rehabilitation robots are sold in the international market, however, most frequently they do not use biomedical signals for control, making possible only a passive motor rehabilitation. The advantage of the Polish solution is its innovativeness and, at the same time, a stronger engagement of the patient in the rehabilitation carried out.

4. Discussion

The above-presented examples of technological cooperation between scientific and research institutions and enterprises confirm the conclusion that such cooperation brings about significant advantages for both partners and the economy. The transfer of knowledge and conduct of joint

research to generate new solutions and implement them allows the scholars, among others, to approach the supply of innovations to the demand for them, to implement the results of R&D sector institutions' research into the economy, to acquire additional resources for applied and development research, to rationalise the use of scientific-research potential, to acquire new skills and competences, allowing to increase the research possibilities. Another advantage of such cooperation is founding of *spin-off* or *spin-out* companies, used to commercialise the technology.

As a result of technological cooperation with the scientists, entrepreneurs obtain the possibility to manufacture a new innovative product or technological solution for the market (domestic or foreign). This is possible at a lower cost than in the case of independent research and development works. In addition, such a cooperation ensures their access to the support of innovative activities from public domestic and foreign resources. Implementation of innovative solutions, which are an effect of cooperation with the institutions of public R&D sector, makes it possible for industrial partners to:

- strengthen their competitive position,
- gain significant economic benefits in the form of a growth in revenues from sales, or reduce the cost of business (for instance, costs of raw material consumption, materials and power),
- obtain unique skills and competences,
- export innovative products and technologies,
- renew the enterprise's offer and increase the demand for its products,
- launch innovative products into new markets or conquer new markets through the application of innovative solutions in other sectors of economy than earlier,
- get new development chances in consequence of taking up subsequent joint projects with researchers,
- achieve ecological benefits – in the form of reduction of raw material consumption, reduction of waste, industrial waste recycling, limiting adverse external impacts (for instance, noise, odours, excessive consumption of electricity).

The above-mentioned advantages of technological cooperation between scientist and entrepreneurs also influence the growth in innovativeness of both industrial sectors and the economy. Creation of strong and effective connections between scholarship and the industry fosters innovativeness of scientific and research institutions, the growth in the number of small and medium-sized innovative enterprises, the diffusion of technology, the improvement in the research and development potential of the scholarship sector, the quality of education at the universities, as well as the programmes of studies created by them, that are compliant with the needs of the economy.

Polish economy is characterized by a low level of innovativeness, which influences its competitiveness. This is due to the presence of weak connections between enterprises and an imperfect research system, too little spending on research and development, small involvement of entrepreneurs from SMEs sector in innovation activity as well as many financial, legal and tax barriers to innovation.

Intensifying the technological cooperation between scientific institutions and enterprises is an opportunity to increase innovativeness of Polish enterprises and economy. Presented examples of such cooperation confirms that technological partnership should become a development strategy of Polish enterprises in a changing global economy.

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