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BARRIERS OF PRACTICAL APPLICATION OF INNOVATIVE TECHNOLOGIES IN ECONOMY

Key words

Strategic programme, innovative technological solutions, technology transfer barriers, commercialisation.

Abstract

The article presents a case study concerning a successfully carried out Strategic Programme entitled "Innovative Systems of Technical Support for Sustainable Development of Economy" executed in Poland within the Innovative Economy Operational Programme co-financed from the EU structural funds in the 2010–2015 period. The Strategic Programme is aimed at the development of the advanced product and process solutions ready to be practically implemented in industrial practice. In the process of implementing the developed technological solutions into industrial practice, numerous barriers are encountered. The article indicates possible commercialisation barriers as well as examples of barriers that occurred in the course of executing the Strategic Programme and implementation of its results. Against this background, examples of successful commercialisation are given. Furthermore, as a way for limiting the influence of barriers on commercialisation processes, the authors propose to combine processes of technological solutions development with support activities.

Introduction

Nowadays, in the situation of a general expectation to increase the level of innovativeness and competitiveness both at the macro – national economy level and the micro level – at enterprises and research organisations, the development and implementation of innovative technologies meeting the market needs are of key importance.

The system in which innovative technologies are developed and applied in practice (Fig. 1) comprises the key groups: 1) enterprises or networks of enterprises, 2) organisations involved in the core innovation process, including public and industry R&D organisations, organisations involved in technology transfer and organisations dealing with the implementation of innovative products as well as 3) the changing environment, in which the mentioned organisations function. The expected objective of the innovation development is their supply to the market called technology transfer.

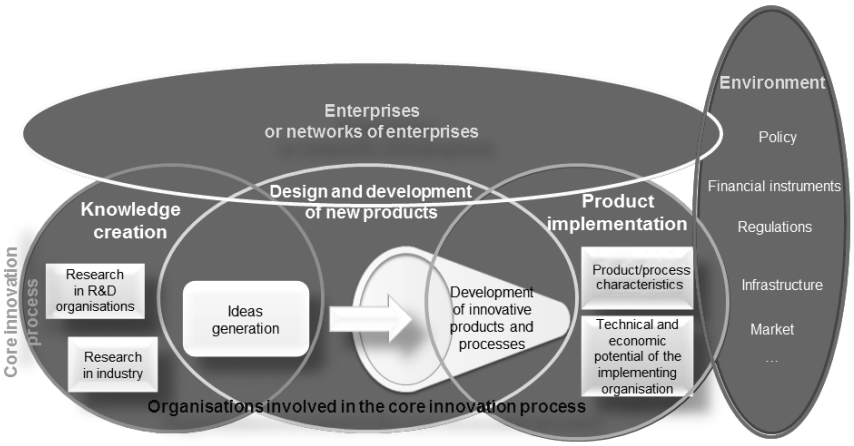

Fig. 1. Innovation system
Source: Authors.

The innovations are acknowledged as a driver for the economic and social development. The creation or absorption of new technologies has become an important element for enterprises in the process of improving or maintaining their competitive position on the market. Furthermore, it provides a source of the competitive advantage of research organisations involved in the development and implementation of innovative solutions.

However, a more problematic area than technology development is its transfer understood as the process of transferring scientific results from one organisation to another for the purpose of further development and commercialisation. The process is hampered by numerous barriers.

1. Literature review

Technology barriers are understood as "any kind of limitations and features that hamper effective functioning of a technology transfer and research commercialisation system, and, as a result, block interactions between the R&D sector and enterprises; therefore, impeding the development of innovative entrepreneurship" [1].

The topic of barriers to technology transfer has been covered by many authors, but one of the very first researchers to deal with this complex issue was Jung [2], who mainly focused on human and organisation related barriers to successful transfer of technologies. Most authors concentrate on the relation between barriers and the socio-political and economic situation of a given country, and their analyses typically concern a particular domain only [3-6].

Different classifications of barriers can be found in literature. Sharif [7] divides them into four groups: organisation-ware, information-ware, technique-ware, and human-ware. Mojaveri, et.al [5] also use a four-group classification; however, the categories they use are different and include technical, attitudinal, cultural, and market barriers.

The topic has also found wide coverage in Polish literature, and the analyses conducted by Polish scientists and researchers take the specificity of the Polish economy into consideration [8]. K. Matusiak and J. Guliński [3] identify the following barriers characteristic for Poland's National Innovation System (NIS): structural, system, cultural, and competence barriers. W. Orłowski [9], on the other hand, is of the opinion that the main barriers to technology transfer in Poland include barriers deciding on the weaknesses of the demand and supply chains, transmission mechanisms, and market regulation policies. A different view on barriers to technology transfer is presented by D. Trzmielak [10], who indicates that behind unsuccessful attempts to commercialise research results are in fact barriers connected with finances, quality, management, as well as human and knowledge resources. The studies on the importance of barriers to technology transfer in Poland [11] show that the structural and cultural areas are most affected. As far as the structural area is concerned, the problems refer to the instability and ineffectiveness of innovation centres and technology transfer intermediaries, whereas as for the cultural area – the lack of knowledge on and understanding of the complexity of technology transfer processes. Relatively fewer problems have been observed in the competence area (concerning skills and qualifications of technology transfer actors) and the system area (concerning national policy on innovation and entrepreneurship).

The empirical research conducted [10] indicated that the main barriers to technology transfer in Poland are the lack of funding and the insufficient knowledge on the commercialisation of research results. The conclusion that stemmed from this research is that individuals trying to develop and implement new technologies do manage to successfully deal with all the obstacles and to

commercialise the results of their research. Therefore, it means that they are aware of the potential barriers and prepared to deal with them.

2. Identified technology transfer barriers

The experience the authors have in execution of research projects and programmes of strategic nature helps to distinguish the existing barriers in transferring research results into economic practice that prevent the use of the full potential of the commercialisation opportunity.

The barriers identified relate to commercialisation and transfer processes, aimed particularly at the introduction to the market of innovative incremental technologies supporting sustainable economic development. The main important groups of barriers hindering commercialisation are distinguished as follows:

1) Barriers of a technical nature,
2) Problems of an organisational and legal nature, and
3) System barriers to commercialisation stemming from the imperfect system for the financing of implementation processes and the ineffective activity of organisations supporting commercialisation processes.

The first group comprises **barriers of a technical nature** observed on the supplier side, attributable to the authors of the solutions resulting from the existing production capacity of organisations developing innovative technological solutions. A kind of gap hindering commercialisation is therefore created. It stems from the following examples:

1. Multiplication of solutions: A research organisation has the capacity to develop a single professional solution. As its development is connected with high technical and personnel requirements, problems concerning its acquisition by the potential producer may arise.
2. The long time is needed for solution development resulting from the fact that the solutions offered are mainly of unit character, and they can be manufactured only by a particular research organisation, which in case when it is a large one, is responsible for the concurrent execution of numerous research tasks, which in turn may lead to the discouragement of the potential clients, who wish the solution to be developed as quickly as possible.
3. Solutions, however highly innovative, represent a short series or unit character, which means that their production is very expensive; therefore, they are less competitive.

Moreover, the authors of innovative solutions have to face **problems of an organisational and legal nature:** firstly, on the supplier side and, secondly, concerning other entities, including intermediary organisations facilitating technology transfer and enterprises.

Organisational and legal barriers on the supplier side comprise as follows:

- Applying for funds from various sources leads to the fragmentation of activities, taking up new topics, which results in the lack of specialisation.
- The existing system of business contacts force R&D organisations to undertake various commissioned jobs, so as to stay on the market, which hinders the development of a single specialisation recognised as a priority, and at the same time, this makes it difficult to provide professional, top notch services for the business.
- Not regulated IPR is problematic when signing implementation contracts.
- The lack of skills and practice in commercialisation results in the low effectiveness of such activities.
- Internal competition between research organisations in applying for funding results in the creation of solutions of a lower technological and innovative level than when synergy occurs.
- Polish R&D organisations usually settle for their academic achievements, publications or the number of patents, not the scale and effectiveness of the implementation of innovative solutions.

With regard to other entities present on the market that are involved in the development, transfer or application of innovative technological solutions, the barriers can concern organisations supporting commercialisation processes and enterprises. Barriers concerning the first group of entities mentioned comprise as follows:

- The lack of organisations supporting the introduction of the solution to the market, particularly on the transnational scale, which is essential in the case when numerous institutions developing highly innovative technological solutions that do not have a recognised market brand;
- The very low effectiveness of intermediary organisations in commercialisation, both in terms of their organisation, as well as technical and financial support.

Barriers encountered by enterprises comprise as follows:

- Orientation of enterprises mainly on short-term operation, not long-term strategic activity;
- Different orientations of a user of the technology (business) than of its provider (R&D organisation) concerning the aspect of time (short vs long term) and goal (techno-economic market vs scientific objectives)
- The lack of financial means of enterprises, mainly of SMEs, for financing research;
- Limited confidence of enterprises, mainly SMEs, in R&D organisations developing innovative technologies;

The **system barriers** to commercialisation stemming from the imperfect system for the financing of implementation processes include the following:

- The lack of funding, such as from the state budget, for the very costly phase of implementation of solutions in business practice resulting in a limited scale implementations; and,
- The lack of clear guidelines concerning the definition and understanding of commercialisation and implementation, which are different in various projects, e.g. depending on the financing source.

The above listed barriers to innovation and commercialisation mean that it is much safer for research organisations to constantly undertake new challenges and R&D works rather than to aim at their successful commercialisation and building specialisation leading nationally or even internationally.

3. Combining the development of innovative solutions with system activities as a way for facilitating effective commercialisation

3.1. Strategic Programme as a source of innovative technologies

The indicated barriers concern the commercialisation of innovative incremental technologies developed by research institutes, among others as a result of research projects and programmes. Such solutions are developed, among others, within the framework of the "Innovative Systems of Technical Support for Sustainable Development of Economy" Strategic Programme, co-ordinated by the Institute for Sustainable Technologies – National Research Institute in Radom, Poland. It won over other prominent competitors, and it was approved for realisation in 2010–2015 within the Innovative Economy Operational Programme co-financed from EU structural funds. The fact that the strategic programme was granted the funds for its realisation strongly confirms that the proposed research directions are of priority to the development of the economy and of the perspective character.

The Strategic Programme aims at the development of advanced product and process solutions that are ready for practical industrial implementation in the area of the manufacturing and maintenance of technical objects and system solutions supporting their application. The R&D matters revolve around four main technological areas concerning advanced mechatronics and surface engineering technologies supporting production and maintenance processes, test apparatus and unique technological devices, systems and methods for the utilisation of natural resources, and diagnostics and safe maintenance systems. Due to the vastness of the customised research area covered, which arose from the specificity of the issues to be solved, it was also necessary to develop original methodologies of knowledge transformation and advanced technology transfer concerning mechanisms and structures of innovation commercialisation and diffusion, and generate new research directions, particularly with regard to emerging technologies.

The outcomes of the Strategic Programme comprise over 170 new technological devices and 90 non-material solutions including evaluation methodologies and innovation commercialisation procedures. So far, 100 material and 87 non-material solutions have been developed and several dozen have been practically utilised.

After five years of the Strategic Programme execution, the real revenue from the commercialisation of the developed solutions, mainly in the field of apparatus, specialised equipment and services, is estimated to amount to approximately 18–20% of its budget, but in this value, the effects the implementation of these solutions has on the purchasers are not taken into consideration. Therefore, it can be concluded that, even at the present stage, during the execution of the Programme, the cumulative value of revenue is approximately 60–80% of the Programme's budget. At the same time, the rules concerning the execution of programmes co-financed by the European Structural Funds indicate that their primary financial effects are expected within 5 years after the completion of the programme.

3.2. System support for technology development

Due to the fact that the development of innovative solutions faces a number of substantial, technical, and organisational barriers, there is a need to find ways to overcome them. One of the ideas proposed by the paper's authors consists in combining activities aimed at the development of innovative product and process solutions with those providing system support facilitating technology transfer. The system approach comprises activities facilitating the generation, development, and commercialisation of innovative technological solutions.

The importance of system tasks arises from the fact that technological solutions are considered a basic, but not sufficient, determinant of innovation implementation deciding the competitiveness of a company; therefore, it is essential to undertake activities aimed at the effective transfer of innovations to industrial practice.

Within the framework of the "Innovative Systems of Technical Support for Sustainable Development of Economy" Strategic Programme system activities include the following interrelated issues:

- Regular foresight activities aimed at the generation of research priorities for the future R&D investigations;
- Activities directly supporting the processes of technology development, including application of an original complex technology assessment system comprising the aspects of implementation maturity, commercial potential and the innovativeness level, and methodologies for strategic programmes evaluation;
- Activities aimed at the commercialisation and dissemination of developed innovative solutions, including searching for effective mechanisms and

structures for innovation deployment, and launching platforms supporting the dissemination of technological solutions; and,
- Analysis of micro and macroeconomic conditions determining the processes of technology development and dissemination as well as the organisation of the education of personnel both developing and using advanced technologies.

The article presents selected forms of organisational support for the technology development processes to the greatest extent contributing to effective commercialisation. They comprise the following:
- Analysis of the progress concerning the technological solution development, as well as its commercial potential and innovativeness level – with the use of an original complex innovative technology assessment system;
- Selection of technology transfer mechanisms and structures; and,
- Promotion and dissemination of activity executed by means of the set up by the authors of the article Platform for the dissemination of innovative solutions in the economy, among others.

The assessment of technological solutions developed within a research programme with regard to the progress in their development and the possibilities of market success is highly important. For this purpose, a complex technology assessment system has been co-developed [12] by the authors of the article and implemented at ITeE – PIB. The system, intended for the assessment of innovations in the area of technical support for sustainable development, is composed of the three following main modules: the implementation maturity level assessment module comprising detailed assessment procedures depending on the type of innovative solution (product, technology, system, service); the commercial potential assessment module; and, the innovativeness level assessment module. The forth module concerning risk assessment is currently designed. The implementation maturity level assessment (SDW) aims at the identification of the level of the advancement of R&D activities and a precise assessment of the implementation readiness of an innovative technical solution. The commercial potential assessment (PK) is used to evaluate the market need for a particular technological solution. The innovativeness level assessment (PI) enables the identification of the level of the innovativeness of a technological solution expressed by the solution's added value for potential buyers. The system enables the identification of technological solutions with high implementation and business potential.

The results of the complex technology assessment can be used when the solution is still being developed, which supports decisions concerning the future of the solution (whether the development process should be continued or terminated) and decisions concerning the selection of appropriate tools enabling innovation commercialisation.

The results of the complex technology assessment show potential possibilities for the commercialisation of an innovation.

In order to stimulate practical application of innovative product and process solutions, suitable mechanisms of technology transfer are proposed for individual results of the Programme. The mechanisms are selected while taking into account the results of the SDW, PK, and PI assessments and the character of a solution, including the potential areas of application (market sectors, industry branches, actual end users (enterprises)). Next, depending on the character of the solution and the proposed transfer mechanism, suitable promotion and marketing tools are selected and particular end users are sought.

The practical implementation of developed innovative solutions is supported, among others, by means of the specially set up within the framework of Strategic Programme technological platform [13]. The main aim of the platform is to disseminate information about ITeE – PIB's R&D activity, undertaken implementation tasks, innovative projects, and new technologies, particularly those developed within the Strategic Programme. The operation of the platform facilitates cooperation and networking between the R&D organisations and the business sector and stimulates commercialisation of research results. It is mainly focused on facilitating co-operation in a regional dimension, as geographical closeness of co-operating partners contributes to more effective co-operation among others, thanks to the possibility of quick reaction to occurring problems, easiness to organise meeting, discuss problems, etc.

The platform is proved to be an effective tool supporting the integration of science and industry, and the transfer of research results, and advanced technologies developed in the Strategic Programme. The marketing and promotion activities are also conducted, apart from those within the platform, in cooperation with intermediary organisations that seek possible ways to commercialise the developed technological solutions. Intermediary organisations support commercialisation activities undertaken by ITeE-PIB; however, their effectiveness in this field is still unsatisfactory.

4. Examples of successful commercialisation of innovative technological solutions – results of the Strategic Programme

4.1. Examples of effective application of technology transfer mechanisms

In case of the "Innovative Systems of Technical Support for Sustainable Development of Economy" Strategic Programme the presented system of combining the development of technological solutions with system support activities is applied in practice to all technological solutions developed within the programme. They undergo, prior to their industrial implementation, a thorough assessment focused on the implementation maturity, commercial potential, and the level of their innovativeness. Next, the mechanisms for

practical industrial implementation and promotion are proposed for each individual technological solution.

Among the available technology transfer mechanisms, ITeE-PIB already has significant experience in direct and indirect sales as well as rendering services. With respect to applying these mechanisms, examples of successful commercialisation comprise the following, among others:

- Direct sale of products, e.g. devices supporting ecological use of industrial oils implemented in numerous enterprises, a chamber for testing the emission of volatile organic compounds sold to manufacturing companies, among others, a recognised factory producing paints and varnishes, multi-functional bearing lubricants sold in numerous SMEs companies (mainly from the food industry) as well as of systems (e.g. automated optical inspection systems implemented in numerous manufacturing firms for quality control, and a computer system for the support of work of interdisciplinary research teams applied in innovative consulting firms);
- Indirect sale of products, e.g. penetrometers sold with the assistance of firms acting as agents in selling;
- Rendering services, e.g. surface engineering material solutions meant for special applications for military purposes, and material solutions for multifunctional protection applied in manufacturing companies, heat recuperation efficiency tests for recuperators used in ventilation systems in modern buildings, a method for the implementation maturity level assessment applied for the assessment of technological investments for the needs of technological parks and enterprises.

Other technology transfer mechanisms applied in the processes of the commercialisation of innovative technological solutions developed within the Strategic Programme without significant successes so far include licensing and creating spin-offs.

Promotion and commercialisation is often carried out through the technological platform, mainly fostering regional co-operation. Strengthening co-operation in a regional dimension is, in case of ITeE-PIB, one of the proven methods for limiting or overcoming commercialisation barriers. Regional co-operation is also treated as a generator of new projects. With this respect two situations are the most common. Firstly, as a result of undertaken regional co-operation of science and industry, single project ideas meant for small firms are generated. Secondly, medium or large firms are interested in a block of projects, because from their point of view co-operation with one, reliable research organisation is more effective that dispersed research co-operation.

4.2. Example of effective commercialisation

In general, with regard to the commercialisation of the Strategic Programme results, three of the most effective ways of co-operation of ITeE-PIB and industry can be indicated as follows:

– Organising technological centres meant for rendering highly qualified, unique services (in case of ITeE in the field of surface engineering and 3D Printing);
– Implementing highly specialised technological solutions adjusted to the needs of particular firms; and,
– Developing and implementing unique research and technological devices.

Examples of where commercialisations of the Strategic Programme results are carried out successfully concern rendering services in the field of advanced layers and coatings in surface engineering. At present, services are offered and rendered with the use of technological devices located at the Plasma Technology Centre situated at ITeE-PIB. One of devices applied is the PVD technological test stand developed within the Strategic Programme (Fig. 2). It is a ready solution with an increasing level of commercial potential and innovativeness (four implementation maturity assessments, three commercial potential assessments, and the level of innovativeness assessed twice).

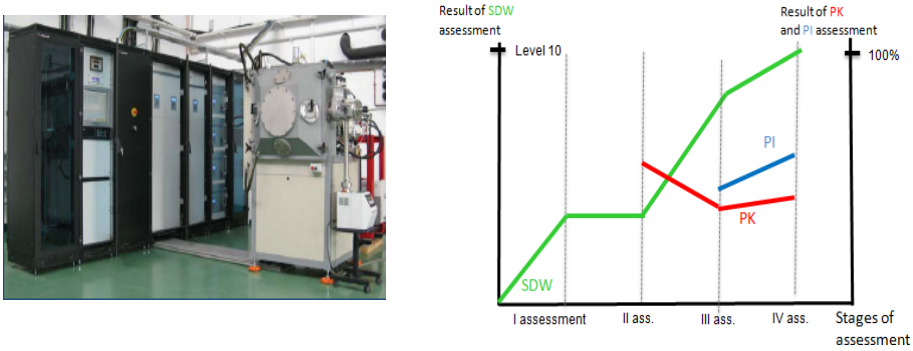

Fig. 2. PVD technological test stand (photo – general view of the test stand and results of complex technology assessment)
Source: Authors.

The services are rendered for numerous enterprises, mainly from the metallurgical sector. However, the existing production capacity of the ITeE – PIB needs to be taken into account, because its limitation prevents the use of the full potential commercialisation opportunity. Thus, a barrier of a technical nature is observed on the supply side, because the scale of possible services is limited due to the parallel involvement in research. The fact that the ITeE – PIB is oriented at the execution of R&D tasks influenced the decision to set up external structures offering services based on the solutions developed in the Programme.

In the case of solutions in the area of surface engineering, the establishment of a special innovative entity in a form of a spin-off, offering unique technological services for industry, including deposition of layers increasing the durability of specialised tools, is considered the most effective commercialisation mechanism. Formal actions directed at the establishment of such a unit have already been undertaken, i.e. with a strategically important partner – the Polish Agency of Industry Development (ARP Poland).

Conclusions

Strategic programmes are a source of outstanding innovative technological solutions. Various barriers hindering commercialisation of the solutions developed can be indicated. The paper is focused on barriers of key importance for research organisations involved in the process of the innovative solutions development.

One of the proposed methods of overcoming or limiting barriers consists in ensuring the interrelation of the processes of technological solutions development with system support for their generation, development, and practical implementation. This type of activity is undertaken within the "Innovative Systems of Technical Support for Sustainable Development of Economy" Strategic Programme. Within the programme, the system support comprises complex technology assessment, including the assessment of innovation's implementation maturity, commercial potential, level of innovativeness, and the selection of effective commercialisation mechanisms. The programme also stimulates networking between all the actors involved in the technology development and implementation process within the technological platform. The Strategic Programme can be treated as a large-scale laboratory; on the one hand, devices, technologies, and systems are developed, and, on the other hand, mechanisms for their effective transfer and overcoming commercialisation barriers are proposed and verified in practice. This is a solution of a unique character, which enables one to test the proposed technology transfer mechanisms in real conditions.

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Bariery wdrażania innowacyjnych rozwiązań technologicznych w gospodarce

Słowa kluczowe

Program strategiczny, innowacyjne rozwiązania technologiczne, bariery transferu technologii, komercjalizacja.

Streszczenie

Autorzy prezentują studium przypadku dotyczące Programu Strategicznego „Innowacyjne systemy wspomagania technicznego zrównoważonego rozwoju gospodarki" realizowanego w latach 2010–2015 w ramach Programu Operacyjnego Innowacyjna Gospodarka. Program Strategiczny ma na celu opracowanie zaawansowanych rozwiązań produktowych i procesowych przygotowanych do wdrożeń gospodarczych w obszarze wytwarzania i eksploatacji obiektów technicznych. Proces wdrażania opracowanych rozwiązań technologicznych do przemysłu utrudniany jest przez liczne bariery. W artykule wskazano możliwe rodzaje barier komercjalizacji, a także przykłady barier, jakie pojawiły się w trakcie wdrażania rezultatów Programu Strategicznego. Ponadto przedstawiono przykłady zakończonych sukcesem komercjalizacji dotyczących rozwiązań technologicznych opracowanych w ramach Programu.