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Technology Transfer Barriers and Challenges Faced by R&D Organisations

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Abstract

The paper presents the definition and classifications of barriers in the field of innovation activity. As opposed to the literature background, the authors propose their own classification of technology transfer barriers comprising the following: (1) technical, (2) organisational-economic, and (3) system barriers. Taking into account the barriers analysed in literature and our own experience in research projects execution and co-operation with industry, the authors present barriers that they met in practice in the period of several years of conducting research and implementation activity. Examples of technology transfer processes hampered by the influence of different types of barriers encountered in practice by a Polish research organisation (Institute for Sustainable Technologies – National Research Institute – ITeE-PIB) in the area of developing innovative technologies have also been illustrated.

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1. Introduction

Transfer of innovations is affected by numerous barriers understood as “any kind of limitations and features that hamper the 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]. Taking into account the importance of the problem from the scientific and practical points of view, the application of technological innovations is acknowledged as a driver for economic and social development.

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The topic of barriers concerning technology transfer, because of its importance for the economy, is a field of interest for numerous scholars and practitioners. The first studies on barriers to the successful movement of technologies from scientific organisation to industry can be found in the 1950s and 1960s [2], but the majority of early publications on this issue actually date back to the 1970s and 1980s [3–5]. One of the very first researchers to deal with this complex issue was Jung [4], who mainly focused on human and organisational barriers to the 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 only a particular domain [6–8].

The topic has also found wide coverage in Polish literature [1, 9–13]. Polish scholars and practitioners take the specificity of the Polish economy into consideration and analyse the barriers both on the macro – national level and less often on the micro level – namely on the level of an R&D organisation.

2. Research methodology

The genesis of the undertaken research stemmed from the need encountered in practice by R&D organisations involved in the development and implementation of innovations, which arises from the necessity of recognising technology transfer barriers and limiting or overcoming them. These problems have been observed and tackled in practice by the authors of the paper in the course of their many years of experience in conducting research projects, co-operation with industry, and the implementation of research results into practice. The authors were also involved in research projects devoted to the problems of effective support for the processes of technology generation [14], development, and commercialisation.

Taking into account our own practical experience and understanding the importance for the economy of overcoming technology transfer barrier, the authors of the paper conducted in-depth analyses of the literature in the field comprising definitions and classifications of technology transfer barriers, examples of barriers, and ideas how to overcome or limit them. The literature is rich; however, it is mainly focused on indicating barriers and proposing ways of overcoming them on the macro level with less emphasis paid to the ways they can be effectively hampered with reference to concrete operational barriers. A limited number of ideas encountered in literature on how to cope with a particular type of a barrier, particularly at the basic, operational level, is of great importance and help for those dealing with such problems in practice.

Against the conducted literature analyses, the authors of the paper proposed their own classification of barriers and indicated technology transfer barriers encountered in practice. The next step of continuously conducted work consists in developing ideas on how to cope with particular barriers that occur with reference to projects carried out at the Institute for Sustainable Technologies – National Research Institute in Radom, Poland.

3. Classification of barriers

Numerous classifications of barriers are proposed by scholars. In 1974, Mock [3] listed twenty-six barriers to technology transfer, particularly stressing the importance of the following barriers: financial, competence, communication, and market related barriers. Sharif [5] also divides technology transfer barriers into four groups: organisation-ware, information-ware, technique-ware, and human-ware. Mojaveri et al. [7] also use a four-group classification; however, the categories they use are different and include technical, attitudinal, cultural, and market barriers. Creighton et al. [15] indicate two groups of barriers, formal (procedural) and informal (behavioural), whereas Jervis and Sinclair [16] indicate political and institutional ones.

Taking into account the classifications of barriers proposed by other scholars and having in mind the authors' own experience in executing research projects and co-operating with industry, the authors propose their own classification of barriers comprising the following: (1) technical barriers, (2) organisational-economic barriers, and (3) system barriers to technology transfer. Furthermore, the authors want to stress that all the mentioned types of barriers may be observed at different levels: strategic, tactical, and operational ones [17].

4. State of the art

Organisational-economic barriers are the group of barriers that is the most often analysed in literature. A wide spectrum of barriers includes the following among others:

- Different orientations exist between the technology provider (R&D organisation) and its user (business) concerning the aspect of time (long vs. short term), goal (scientific vs. techno-economic market) and risk (high risk vs. low risk expectance), [4, 18]
- Large asymmetries exist between the provider and the recipient in terms of having different characteristics, e.g., skills, prices, endowments, internal structure, size, and experience, etc. [19]
- Different approaches are taken by the technology provider and recipient towards the desired results. Usually, these approaches include innovation-oriented vs. market-oriented approaches or focus on superior technologies vs. easily implemented technologies [20, 21]
- Imperfect technical information transmission and insufficient co-operation between the R&D organisation and the technology user at the stage of technology development are often evident [18, 20, 22]
- Unsatisfactory or poor business management and negotiation skills exist on both sides (the technology provider and recipient); however, this problem is usually mostly on the provider's side [23]
- There are often problems with selecting the most appropriate technology transfer mechanisms [15, 21, 24–26]
- The lack of an accurate assessment of technology transfer frequently exist [20]
- There is often the lack of a plan for the implementation of research results and ex-post analysis of implementation outcomes [20]
- R&D organisations focus too much on the advancement and dissemination of knowledge, e.g., making results public before their patenting, which deeply collide with the demands of industry [27]
- Technology providers frequently have insufficient knowledge about potential markets and consumers [19, 29]
- There is frequently insufficient time for testing and the demonstration of new technologies before they can compete with well-established technologies, which hampers the process of the practical application of technology [20].

Another group of barriers, which is also relatively frequently analysed in literature, comprise system barriers. The most often mentioned ones are as follows:

- The lack of developed infrastructures, market and public incentives exist [30, 31]
- The absence of a technological development plan is observed at a national level, because the public decision-making power is not able to create conditions of promotion, support, and a coherent target for public and private R&D and innovation [4, 23, 32]
- Standard-setting groups offer a safeguard against unexpected failure that often deliberate and can delay implementation of innovations [20]
- Lobbies or interest groups effectively impede change and amelioration in the legal system, making technology transfer impossible or inefficient [20, 23].

Technical barriers are analysed by a limited number of scholars. They are as follows:

- A high level of tacit knowledge included in technologies makes technology transfer more difficult (especially with regard to the newest solutions), [7, 29]
- New technologies need to be tested and demonstrated thoroughly before public agencies will accept them in competition with other, well-established technologies [20]
- Technology is too sophisticated, making it difficult or impossible to change in order to make it suitable for the requesting production/market [19, 23]
- The recipients are not able to discern the level and characteristics of the technology needed [19, 23].

In an R&D organisation's activity, as it stems from the authors' multi-year practice in the field of innovation development and implementation, technical barriers are the most important and occur the most frequently [33]. Usually, they are not very difficult to overcome for the experienced R&D organisations. With regard to this type of barriers the authors of the paper emphasise the importance of those observed mainly on the provider's side, attributable to the authors of technologies resulting from the existing production capacity of organisations developing innovative technologies. Therefore, a kind of barrier hindering technology transfer is created. It stems from the following examples:

- Multiplication of solutions: R&D organisations often have the capacity to develop a single professional solution. Since its development is connected with high technical and personnel requirements, problems concerning its acquisition by the potential producer may arise
- A long time is needed for technology development, resulting from the fact that the technologies offered are mainly of a unit character, which may lead to the discouragement of the potential clients who wish the technology to be developed as quickly as possible
- Innovative technologies represent a short series or unit character, which means that their production is very expensive; therefore, they are less competitive
- Technological concepts are changed in the course or even after the contract execution
- A prototype version of a technology is often not compatible with the demands of mass production – achieved high technical parameters vs. unsatisfactory economic parameters.

Apart from technical barriers, the authors of innovations face organisational-economic barriers, which are observed on the provider's side and concern other entities present on the market involved in the development of innovative technologies. They comprise the following among others:

- Problems concerning Intellectual Property Rights resulting from the joint development of an innovation by the consortium, particularly when one or more partners are from business
- Inspiring industry by ideas revealed or discussed at the early stages of co-operation preceding the signing of a contract, frequently stimulating ideas by industry, which tries to apply them by themselves
- The existing triad of co-operation extremely profitable only for the industry side: the lowest possible price (without costs of research and development) – complete takeover of property rights by enterprises – R&D organisation responsible for possible losses in the course of using the technology
- Organisational changes in industrial enterprises
- Different work organisation in business and in science
- The interest of industry in financing the final result, not the research process itself
- The lack of professional marketing as well as the lack of skills and practice in technology transfer resulting in the low effectiveness of such activities.

Both in the literature and in practice, system barriers are of great importance. They stem from the imperfect system for the financing and supporting the implementation processes, met by R&D organisations in practice and include the following:

- The lack of skills and procedures necessary for the effective commercialisation of research results
- The assessment system of R&D organisations focused on research results, not implementations
- The lack of funding, e.g., from the state budget, for the very costly phase of the implementation of technologies in business practice, particularly in the SME sector, resulting in a limited scale of implementations
- Project proposals submitted by SMEs rejected by evaluators because of a low scientific level of technologies planned for the development within the project, although bringing potentially huge income
- The lack of effective organisational structures supporting the implementation of the advanced technologies to the market, mainly in the transnational dimension, and particularly in the situation when an institution developing even significant technologies does not have a well-known brand.

All the mentioned types of barriers may occur at different levels: strategic, tactical, and operational ones. Barriers that are at present the most difficult to overcome at the strategic national level comprise the following [17]:

- The constant process of restructuring the sector of research entities resulting in a lack of scientific specialisation and in focusing largely on administrative matters rather than scientific
- The clash of different attitudes in science and industry: in science – stable academic structure based on years of professional advancement – in the industry: mobility, flexibility, commitment, and change
- Generating research problems by the industry – most of the financial resources in the operational programmes are directed to the industry.

At the tactic level the most important barriers comprise as follows:

- A lack of high specialisation of R&D organisations, which is a key to success for science-industry co-operation, requires continuous development of the research potential
- During the preparation stage of project proposals, research entities provide their ideas, but during the implementation stage, they can be excluded as a result of tenders or the taking over of their ideas by industry
- Preparation of an application for a project requires expertise and operational competence. Project proposals are submitted by the companies on the formal level, but they are prepared by the research entities
- The evaluation of research projects is carried out by experts selected regardless of the importance of the projects and their budgets. Key projects of strategic importance to the economy with large budgets should be evaluated by experts with the highest practical experience and competence.

Last, but not least, at the operational level concerning the execution of individual projects, the most important barriers comprise the following:

- The developed solutions are characterised by a high level of innovation and market demand, but often have a high unit price unacceptable for the industry
- The salaries of research staff are inadequate to qualifications at both a national and international level
- There is a need for sustainable development of scientific solutions that have achieved successful application
- Dissemination of the results of projects requires specialised marketing skills, which is often missing in research entities
- Innovation must be effectively correlated with management and commercialisation processes.

R&D organisations involved in innovative technologies development and transfer meet the above listed barriers in their everyday activity. In the next chapter, a few examples of technology transfer barriers that the authors of the paper encountered in practice in the period of several years of conducting research and implementation activity by ITeE-PIB are presented.

5. Examples of technology transfer barriers encountered in practice

The technical barriers occur relatively frequently in the activity of ITeE-PIB, and they must be effectively tackled by researchers and engineers involved in the development and implementation of innovations. Rendering high-tech services with the use of highly advanced or unique technologies and devices in the field of surface engineering may serve as an example of a technical barrier. At ITeE-PIB services are provided with regard to surface engineering material solutions for special applications for military purposes and material solutions for multifunctional protection applied in manufacturing companies, among others. The services are provided for numerous enterprises, mainly from the metallurgical sector. However, the existing production capacity needs to be taken into account, because its limitation prevents the use of the full potential commercialisation opportunity. Therefore, 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.

Apart from technical barriers, the processes of providing services are also often hampered by barriers of an organisational-economic character, including the limited flexibility of ITeE-PIB and the slow reaction to market needs. To overcome these barriers, it was planned to establish a special innovative entity in a form of a spin-off, offering unique technological services for industry. However, in the course of this process, again the organisational-economic barriers were encountered, as follows: the lengthy process of spin-off creation and the difficulties in finding industrial partners for co-financing and joint establishment of a spin-off company; the need of the high engagement of the institute's researchers in the activity of a spin-off company; and, the problems with marketing and legal regulations, making the process of creating spin-off by R&D organisation difficult (e.g., very high taxes, which have to be paid before starting the activity and obtaining benefits).

Organisational-economic barriers are met in the ITeE-PIB's activity with regard to numerous services and products not only in the field of surface engineering. For example, the direct sale of products is hampered by the lack of proper service providers, who would offer service for the sold products. Another common problem is the lack of well-trained and experienced specialists for the marketing and sale of innovative products, who would effectively increase the scale of sales and effectiveness of technology transfer activities.

Apart from technical and organisational-economic barriers, the biggest problem concerns dealing with system barriers on the national level where the influence of individual R&D organisations is strictly limited. System barriers observed on the national level are met by individual R&D organisations and comprise, including the lack of proper mechanisms, such as financial instruments or research projects, which would facilitate the creation of structures applied for effective technology transfer.

The necessity of dealing with various types of technology transfer barriers at ITeE-PIB concerns for example the coating deposition on precise elements for car engines. The quality and parameters achieved are at a very high level and fully meet industrial expectations. However, an excessive price of an element, not acceptable for the industry (an organisational-economic barrier) results in the necessity of inventing and manufacturing a new device, whose application would enable the deposition of a bigger number of elements in one batch, which would decrease the unit cost of an element. The process of the development of a unique adequate device is burdened by technical barriers. On the other hand, a lack of necessary financial resources for further investigations and development of the device is a system barrier. Based on the presented example, it is evident that technology transfer processes may be simultaneously hampered by different types of barriers – in this case, by organisational-economic, technical and systems barriers. In practice, it often happens that different types of barriers occur with regard to the process of the development and implementation of a particular technology or a product.

6. Methods of dealing with technology transfer barriers

It is of key importance to recognise, in a systematic way, barriers that may occur with regard to a particular technology development and application and to develop ways of weakening or eliminating them. This approach should be applied both before the decision of developing the technology is made (*ex-ante* recognition) and in the course of its development (*on going*). Depending on the type of a barrier (strategic, tactic and operational as well as technical, organisational-economic, system) activities should be undertaken individually at an organisational level or jointly with other institutions.

Carrying out the work at the strategic level primarily means program, legislative, and financial stabilisation. The development directions programmed at the national scale should be effectively implemented and enforced. It should be ensured that the proposed mechanisms for the acquisition of government or structural-fund subsidised projects are stable, so that research staff and beneficiaries of these programs, once they have mastered the formal aspects, can focus on the substance of their projects for many years, rather than on their constantly changing organisational and formal aspects. Naturally, the development of science and innovation does not allow for too extensive stabilisation of the system, but it should be remembered that the system needs to be systematically improved by basing it on solid research and staff support, and not on constant changes without significant substantive reasons. It is necessary to have stable mechanisms for the generation of research directions, including the use of technological foresight methods; the mechanisms for the generation of national, regional, and sectoral specialisations both in the substantive and organisational-economic aspects; the development of instrumental, experimental, demonstration infrastructure; the

advancement of training specialist personnel; and, the construction of a scientific community that is able to take on breakthrough and emerging undertakings.

On the tactical level in the long term, the emphasis should be placed on the consistent construction of specialised centres and research teams that are able to meet those needs of entrepreneurs that are inaccessible to them at the scientific or cognitive level or carry out projects that are unprofitable to run by enterprises themselves due to small-scale fabrication, uniqueness, or costs. An important role involves building cooperation and mutual trust through the implementation of further ventures that are beneficial for both parties of the innovation process. In order to achieve the long-term objectives, it is necessary – in the short term – to identify the current economic needs in the area of innovation correlated with competence and abilities, to undertake direct cooperation between providers and recipients of innovations, to perform in-depth study of customer requirements with taking into account the deadline and financial capability, and to recognise and confirm cooperation opportunities both on the merits and performance.

At the operational level, the suggested path towards diminishing the significance of technology transfer barriers includes an efficient system for selecting projects that are possible to carry out at a research centre taking into account scientific, technical, financial, and organisational aspects. This can be accomplished using a project generator, which is an idea based on the assumption of the close cooperation of a research unit with potential industrial partners consisting in gathering information about the research needs of the economic milieu and the suggested innovative undertakings. Moreover, the path should include a system for the efficient supervision of the executed innovative projects, including an analysis of technological advancement, implementation readiness, and supervision in terms of deadlines and expenses (using a complex technology assessment system), [17, 33].

7. Conclusion

The processes of technology development and transfer conducted by R&D organisations are hampered by various barriers hindering the practical application of innovative technologies and products in the economy. The barriers must be recognised before making the decisions concerning technology development as well as in the course of the process. Some methods of weakening or eliminating barriers are already known and applied; however, there is a need to develop more efficient ones.

The authors of the paper, based on their experience in conducting research and implementation projects, propose ways to cope with the occurring technology transfer barriers and challenges. However, each situation must be analysed and tackled individually taking into account type of the barriers, the possessed infrastructural and human potential, and type of co-operating institutions.

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