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DEVELOPMENT OF SCIENCE-INDUSTRY RELATIONSHIPS IN THE CONTEXT OF KNOWLEDGE CREATION

Nowadays the ability to innovate is the key factor in creating the innovative firm (in the micro-scale) or innovative economy (in a wider prospect). The important part of innovation system are universities where well-educated and well-skilled personnel, armed with the appropriate knowledge, competencies and equipment of academic research centres has the opportunity to discover new phenomena, and turn them into innovations. Lucrative relations of science and industry caused the emergence of new science types. These are post-academic and industrial sciences. The results of scientific research conducted within the post-academic or industrial science are company-dedicated solutions or inventions, which may be used after prior commercialization. The desired effect of cooperation between university and industry are commercialized effects of scientific research. There are various methods of university-industry cooperation. The goal of the article is to show the development and changes of university-industry relations on selected literature and empirical examples.
Keywords: knowledge based economy, knowledge production, academic science, post-academic science, industrial science, innovation, knowledge privatization

1. INTRODUCTION

There is no doubt that “knowledge” has acquired a more all-encompassing meaning today. It is a key word of modern economies, it is an asset for a firm and wealth for the lucky owner. Nowadays we create knowledge, we manage it, and try to sell it. But knowledge has always been the driving force of development. The Knowledge Based Economy which is a goal to reach for modern market economies assumes that knowledge is being nowadays a key asset creating wealth.

Knowledge as an economic asset has always been the source of innovations. Therefore one cannot say that knowledge is the distinctive feature of modern economies. The new approach to the problem of knowledge creation can be described as the conversion of scientific knowledge into an asset which brings wealth to the participants of the

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innovation creation process. Formerly, scientific knowledge has only been a potential asset because of the invisible boundary between science and the economy. The conversion of scientific knowledge into wealth-bringing asset is connected with the transformation of academic science into post-academic science or even industrial know-how. The difference between these science types is mainly about the level of their market orientation. Academic science responsible for academic knowledge is the least market-oriented example. It is the stereotype of science in its purest form. Post-academic science has a greater degree of market orientation. It is more concerned with solving urgent practical problems and treats knowledge as a result of intentional scientific research open to commercialisation. The strongest market orientation is dedicated to industrial science. Industrial science is the antithesis of academic science. It is very close to business, knowledge produced there is a response to business demand. The cooperation between science and industry in this case remains a contract with precisely defined conditions. Scientists commit themselves to the discovery of "the missing link"[1], or even just to working hard on this. They also commit themselves not to share the results of their work with anyone except the company they work for. "The industry" commits to pay well for scientists efforts and of course for their loyalty. The research outcomes are usually subject to the protection of property rights. The consequence of this completely private[2] process is private knowledge and very often the loss of scientist's independence[3]. Recognition of scientific research as a commodity open to market mechanism regulation seems to be a very tempting idea, although it is controversial among those to whom the Mertonian norms of science are close. Nevertheless, the tight science-business relations that result in industrial science or post-academic science outputs seems to be a noteworthy idea. There is no doubt that science which can produce "knowledge on demand" will always be a remarkable solution both for scientists and businessmen.

Universities and public research institutes have always been an important place for knowledge creation. Publicly funded scientific research outcomes have always been a tempting solution for business needs. But academic science has usually been resistant to the market mechanism. Focused on pure

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[1] Whatever that could be – missing DNA sequence, new vaccine, new engine or better winter tires.

[2] Paid by and dedicated to the same company.

[3] A contract has not much to do with independence.

science and its goals, it has avoided the market verification of its value. It is beyond doubt that the reduction of public funds dedicated to public research and academic centres has launched the cooperation between science and business. Pure science has been replaced by a post-academic one. The very important link between science and business are so called “bridging institutions”, which provide the professional organization of the knowledge market. Undoubtedly we are now facing a radical change in the attitude to knowledge creation. This process brings new opportunities both for universities and for industry, but brings also challenges concerning mainly the boundaries to cross in the case of knowledge commercialization.

2. KNOWLEDGE IN ACTION – LITERATURE REVIEW

Knowledge and different attitudes to its creation has a rich evidence in the economic literature. There are some important outcomes which point out the importance of knowledge production.

The first important knowledge production model which can be found in the literature is the New Production of Knowledge (Gibbons et al. 1994). The main proposition here is the emergence of a knowledge production system that is “socially distributed”. While knowledge production used to be located primarily at scientific institutions (universities, government institutes and industrial research laboratories) and structured by scientific disciplines, its new locations, practices and principles are much more heterogeneous. To clarify this assertion the authors introduce a distinction between Mode 1 knowledge production, which has always existed, and Mode 2 knowledge production, a new mode that is emerging next to it and is becoming more and more dominant. The five main attributes of Mode 2 summarize how it differs from Mode 1

Table 1

Attributes of Mode 1 and Mode 2 knowledge production

Mode 1	**Mode 2**
Academic context	Context of application
Disciplinary	Transdisciplinary
Homogeneity	Heterogeneity
Autonomy	Reflexivity / social accountability
Traditional quality control (peer review)	Novel quality control

Source: Hessels (2004)

Mode 2 knowledge is generated in a context of application. Of course, Mode 1 knowledge can also result in practical applications, but these are always separated from the actual knowledge production in space and time. This gap requires a so-called knowledge transfer. In Mode 2, such a distinction does not exist. A second characteristic of Mode 2 is transdisciplinarity, which refers to the mobilization of a range of theoretical perspectives and practical methodologies to solve problems (Hessels et al. 2002). Transdisciplinarity goes beyond interdisciplinarity in the sense that the interaction of scientific disciplines is much more dynamic. In addition, research results diffuse (to problem contexts and practitioners) already during the process of knowledge production. Thirdly, Mode 2 knowledge is produced in a diverse variety of organizations, resulting in a very heterogeneous practice. The range of potential places for knowledge generation includes not only universities and colleges, but also research centres, government agencies, industrial laboratories, think-tanks and consultancies. These sites are linked through networks of communication and research is conducted in mutual interaction. The fourth attribute is reflexivity. Compared to Mode 1, Mode 2 knowledge is rather a dialogic process, and has the capacity to incorporate multiple views. This relates to researchers becoming more aware of the social consequences of their work. Sensitivity to the impact of the research is built in from the start. Novel forms of quality control constitute the fifth characteristic of the new production of knowledge. Traditional discipline-based peer review systems are supplemented by the additional criteria of economic, political, social or cultural nature. Due to the wider set of quality criteria, it becomes more difficult to determine "good science", since this is no longer limited to the judgement of disciplinary peers. Participation of a wider range of non-scientific actors in the knowledge production process aims at enhancing its reliability.

The next concept of knowledge production is connected with the idea of systems. Systemic thinking in innovation studies emphasizes the importance of interactions and feedback mechanisms between all actors involved in innovation, including university researchers, industrial product developers, intermediary organizations and end-users. This concept is primarily applied as a framework in order to describe and explain the complexity of innovation systems. In addition, it is used in a prescriptive sense, by arguing for a more systemic innovation policy (Smits et al. 2004). The innovation systems perspective is applied on various levels of aggregation: national innovation systems, regional innovation systems and technological innovation systems (Laurens et al. 2004). However, all those aggregates share a consideration of the interactive nature of successful innovation processes (Edquist 2001) .

The approach of innovation systems and the concept of the New Production of Knowledge emphasize the non-linearity and heterogeneity of knowledge production. Moreover all of them deny the validity of the linear model of innovation. In Mode 2, the distinction between basic and applied science does not exist; in innovation systems such a distinction is conceived to be ineffective. Moreover, the organizational diversity of Mode 2 corresponds to the network character of innovation systems (Laurens et al. 2004). Collaboration between universities and industry, and in particular the role of bridging institutions, appear in both the innovation systems approach and the concept of New Production of Knowledge.

The more advanced concept of knowledge production is Ziman's concept of post-academic science and its more orthodox variation: industrial science (Ziman 2000). In Ziman's notion of post-academic science, he incorporates elements from several other approaches. Ziman intends to describe and explain a set of developments in scientific knowledge production. To summarize, post-academic science refers to a "radical, irreversible, worldwide transformation in the way science is organized, managed and performed"(Ziman 2000). Industrial science can be characterized by the following five (strongly connected) designations. First, science has become a collective activity: researchers share instruments and co-write articles. Moreover, both the practical and fundamental problems that scientists are concerned with are transdisciplinary in nature, calling for a collective effort. Second, the exponential growth of scientific activities has reached a financial ceiling. The resources available for research seem not to increase much more, creating a need for accountability and efficiency. Thirdly, but strongly related, there is a greater stress on the utility of knowledge being produced. Successful application of scientific knowledge in the creation of new products and practical solutions in certain types of business activity has caused "impatient expectations" of industry, government and the public. The expectancy refers to the scientific knowledge diffusion rate and its impact on the company's profits and the state's welfare. There is an increased pressure on scientists to deliver more expected and desired value that can provide long-term gains. Moreover policy-making in science and technology has intensified the competition for resources. In such a situation competing for a lucrative contract may diminish the significance of the researcher's scientific credibility. Research teams can be conceived as small business enterprises, their staff as "technical consultants". Finally, science has become "industrialized": the links between academia and industry have become close and the relationship has a financial dimension. This phenomenon is in contradiction to the Mertonian norms of academic science[4]. Due to the industrial orientation a new set of norms can be discerned, which Ziman labels as PLACE: *Proprietary, Local, Authoritarian, Commisioned,* and *Expert*[5]. The concept of post-academic science is quite similar to that of Mode 2 knowledge production. While New Production of Knowledge explicitly states that Mode 2 emerges "next to" Mode 1 research and suggests a future in which both develop in co-evolution, post-academic science and even more – the industrial science – is a practice that replaces traditional academic research.

The Triple Helix model (Etzkowitz 2008) is based on the assumption that industry, university and government are increasingly interdependent. This implies that these different institutional spheres have to be studied in co-evolution.

The role of universities in this configuration is often referred to as its "third mission". Making a contribution to economic growth is becoming a central task next to teaching and research. Within the Triple Helix literature, research of such a specific mission constitutes "entrepreneurial science". This new role of universities and its new relations with government and industry are roughly in agreement with the idea of Mode 2 science. Especially the context of application and organizational diversity are apparent. The transdisciplinarity is also very important here. However the view of Mode 1 as the original format of knowledge production is questioned. Mode 2 is considered as an "emerging" system emphasizing historical dynamics. According to the Triple Helix model the current knowledge infrastructure is characterized by mixes of Mode 1 and Mode 2.

As the short literature review shows, the change in the attitude to knowledge creation is evolving, and the direction of this evolution is knowledge as a commodity. Problems with this attitude concern mainly the process of commercialization, e.g. the subject of commercialization, the IPRs and commercialization process organization.

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4 Those norms can be described by the acronym CUDOS and they refer to: *communalism* (fruits of academic science should be regarded as public knowledge), *universalism, disinterestedness, originality, scepticism* (Ziman 2000).

5 It produces *proprietary* knowledge that is not necessarily made public. It is focussed on *local* technical problems rather than on general understanding. Industrial researchers act under managerial *authority* rather than as individuals. Their research is *commissioned* to achieve practical goals rather than undertaken in the pursuit of knowledge creation (?). They are employed as *expert* problem solvers rather than for their personal creativity (Ziman 2000).

3. KNOWLEDGE TRANSFER IN POST-ACADEMIC SCIENCE

As the previous part of the article shows, the concept of knowledge creation evolves (knowledge as the codified result of scientific research). According to J. Ziman (2000), till the mid 20th century scientific research was carried out under the academic model of science. Modern science operates within the post-academic model, which is a hybrid of academic and industrial science (Matysiak 2009). The most important part of the concept is that knowledge generated in mostly public universities and research institutes is privatized. Although post-academic science seems to be just the academic type of science but with the stress put on the commercial use of scientific research results, industrial knowledge is a result of close, multidimensional cooperation between science and business. There is no doubt that privatizing knowledge is the activity that is possible thanks to the "bridging institutions" which coordinate the knowledge market, make it more transparent and matche the relevant knowledge with the appropriate enterprise.

There is a view that Europe today is not receiving an adequate return on its investments into research and technology because of less and slower commercialization of research results (Dosi et al. 2006). Science-industry relations have many different facets and knowledge is transferred via many different channels. One of these channels is transfer institutions, which may be organized in a variety of ways and play different roles in various national innovation systems. The recent dynamic development of such institutions, in Europe as well as in the US and elsewhere, has arguably been stimulated by the formation of new forms of intellectual property rights and the recognition of a need for closer collaboration and more intensive communication between research organizations and enterprises. This has been reflected not only in the establishment of new transfer organizations, but also in the professionalization of their services and efforts to create more supportive framework conditions. It is also argued that in most cases more systematic and better transfer mechanisms will positively affect the quality of research and the frequency as well as quality of innovation. A pro-active researchers approach to commercialization is supposed to benefit particularly small and medium sized companies, which, because of real or imaginary barriers in communications with universities, are generally hesitant in cooperating with them.

4. KNOWLEDGE TRANSFER INSTITUTIONS

The research organization must be motivated to transfer its knowledge and to communicate with enterprises. Weak or blatantly absent technology transfer activities by public research organizations reflect either unfavourable regulations or an absence of motivation. Key motivators can be benefits such as financial rewards, better reputation, or access to competence held by an industrial organization. The relative importance of particular motivators varies by type of research organization and the various regulatory provisions as well as traditions. It can also vary between individuals according to personal preferences and may even be different from case to case according to the type of project.

Table 2

Incentives and barriers for science and industry relations

Science sector	Relations	Enterprise sector
	Incentives	
Secure alternative sources of funding Prospective income for researchers from licensing Better labour market opportunities for graduates	Cross learning Personnel mobility Exchange of knowledge and experience Knowledge network externalities Synergies	Access to new knowledge Access to R&D resources and infrastructures Opportunities to open up new business fields Recruitment of R&D personnel
	Barriers	
Lack of qualified personnel necessary for handling the interaction Bureaucratic structures and decision procedures High cost of interaction, contracting licensing, etc. Lack of sufficient information on supply and demand Uncertainty	Information asymmetries and low market transparency Different cultures and incompatible objectives High transaction cost Uncertainty of outcome Large spillovers	Risk averse behaviour Lack of knowledge absorption capacities and innovation management capabilities Lack of qualified personnel Fear of losing confidential knowledge

Source: based on Polt et al (2001)

The research organization must establish a transfer mechanism that is transparent to the potential user and capable of combining and integrating (research) competences according to the needs of client enterprises.

More specifically technology transfer institutions can help to reduce the lack of information regarding what is available in public research organizations and what is needed by the enterprise sector. They can also help to diminish high transaction costs especially of ad hoc efforts at an individual base; the differences in cultures and objectives and the uncertainty of the collaboration's outcome, and the side effects of science-industry co-operations such as revealing one's own strategy to competitors (Laurens 2004).

Because universities play an important role as a source of fundamental knowledge and, occasionally, technology relevant for industry in modern knowledge-based economies, they became the goal of different governmental initiatives. The objectives of those initiatives are to link universities to industrial innovation more closely. Many of them seek to spur local economic development based on university research, e.g. by creating "scientific parks" located near to research university campuses, support for "business incubators" and public "seed capital" funds, and the organization of other forms of "bridging institutions" that are believed to link universities to industrial innovation.

5. UNIVERSITY-INDUSTRY RELATIONS ON THE EXAMPLE OF SELECTED COUNTRIES

5.1. Finland

After the economic collapse of its principal trading partner, Soviet Russia, Finland experienced a deep recession with high unemployment during the early nineties. Universities at that time became important engines of economic development. The Helsinki University of Technology became a major centre for growth in wireless communication and information technology (Chakrabarti et al. 2003). The University of Oulu helped build up Oulu region's capabilities in electronics and information technology. Tampere focused on electro-mechanical and automation industries. The University of Turku contributed to the development of pharmaceuticals and chemistry based innovations.

Nowadays Finland is one of leading countries in the area of technology parks. In Finnish technology parks there are 1,600 enterprises and other organizations who associate 32,000 experts from different technology areas like: information, telecommunication, energy, technologies for health and medical, etc. The Finnish index of technology cooperation is on the level of 7.7 (in a scale 0-10), which means a "pole position" before Sweden, USA and Israel (Dzierżanowski et al. 2005).

Parks in Finland usually deal with different technologies mainly high and middle tech. Technopolis and Culminatum parks, Kuopio Technology Centre Teknia Ltd. focus firms from over 10 different branches.

5.2. Great Britain

Great Britain is the home of two splendid universities. Cambridge and Oxford are the synonyms of education of the highest quality. They are also great research centres. As some papers show (Calvert et al. 2002), the main interaction between science and industry in Britain is measured by the number of co-publications. Co-publishing is an important research-related activity of universities and shows fields of interest in which cooperation is vital.

The strong impact of a university's activity on the region where it is located can be easily shown with the example of Cambridge. The progressive aggregation of high technology companies around the University of Cambridge has transformed the economy of its region since 1960. Nowadays it is Europe's leading technology cluster with a concentration of life science and information technology companies which now numbers around 900 innovation based companies. 51 companies have spun-out directly from the University, a further 250 trace their origins to the University, and most of the rest have been attracted by the talents and opportunities available from within the growing cluster. The combination of Cambridge's reputation for research and the Cambridge Cluster has attracted global organizations to establish research and development facilities in close proximity to the University. Examples include Genzyme, Intel, Microsoft and Toshiba.

5.3. United States of America

The relationship between the U.S. university research and innovation in industry is a long and close one. Indeed, organized industrial research and the U.S. research university both first appeared in the late 19th century and have developed a complex interactive relationship (Mowery 2004) The

Department of Agriculture in the United States developed the agricultural extension service model for transferring agricultural technology to the farmers where the universities were key sources of information. Major public universities in the U.S. have been established as land grant institutions with a clear mandate for knowledge and technology transfer[6]. From that tradition, different models of interaction with the industry have evolved. Universities have taken active roles in establishing various types of organizations, such as business incubators, science parks, technology parks, etc. to foster entrepreneurship and business development.

American universities act as normal market-related entities which sell their scientific output in different forms of IPR which is possible thanks to the Bayh-Dole Act. The American interactions between different actors which lead to innovation creation has received the name "The Silicone Valley Model".

5.4. Poland

Since 1990, the number of centres of innovation and entrepreneurship in Poland has been increasing steadily, reaching in the mid-2009 the number of 717. Those are: 23 technology parks, 17 technology incubators, 51 academic business incubators (pre-incubators), 46 business incubators, 87 technology transfer centres, 9 seed capital funds, 7 business angels networks, 82 local and regional loan funds, 54 credit guarantee funds, 318 training, consultancy and information centres (Matusiak et al. 2009).

Technology transfer centres are probably the most important platform of communication between research and business spheres. In Poland one can see two lines of evolution of such centres. Some of them are focused on promoting academic contacts and turning them into legal forms (agreements, contracts), while others operate on a wider field and specialize in dealing with SMEs offering them assistance in obtaining new technologies and adequate knowledge.

Transfer became the essential component of higher education policy, allowing universities to contact with the business sphere and to participate in activities that stimulate economic development. The growing importance of technology transfer units in universities can be seen in the increasing

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[6] The concept of "land grant" college was developed by an act of the U.S. Congress in 1862 for "agriculture and mechanic arts, scientific and classical studies, and military tactics for the liberal and practical education of the industrial classes."

participation of so-called "third funds" in a university budget. These are funds obtained from commercial use of projects. In recent years, one can observe a trend of supporting academic entrepreneurship and consolidation of relationships with academic spillovers.

However, the bureaucracy of universities caused academic technology transfer structures to be relatively inflexible in relation to changing market conditions. This has resulted in finding a more flexible organizational and legal form, providing a better adaptation to market requirements, simultaneously more satisfying for the scientific community. Third sector organizations – foundations and associations, proved to be a remedy for the stiff bureaucratic structure of the university. This has resulted in the necessity of adopting more flexible organizational and legal forms, e.g. those making part of the third sector organizations, like foundations and associations. They proved to adjust better to market requirements and can be treated as a remedy for the stiff bureaucratic structure of universities.

SUMMARY

Undoubtedly, nowadays one can observe the process of closer relations between industry and science. The pressure to create knowledge relevant to industry needs resulted in the emergence of new phenomena, like knowledge production or industrial science. Knowledge production became a phenomenon most often described in the economic literature. The Mode 2 (Gibbons et al 1994) and post-academic and industrial science (Ziman 2000), both show that science and knowledge became more "industry related". Scientific research is a result of close business-science interaction. The idea of innovation systems in the context of knowledge production represents another approach to the issue. Systemic treatment of innovation emphasizes the importance of interactions and feedback mechanisms between all actors involved in innovation, including university researchers, industrial product developers, intermediary organizations as well as end-users (Smits et al. 2004, Laurens et al. 2004, Edquist 2001).

The concept of industrial science seems to be a sign of our times. The gradual change of the science generation – from pure science embodied in academic science, through post-academic science to industrial science emergence. The purpose of academic science is to explain the nature of things. Its main features are selflessness and objectivity. Basic research conducted in academic and public research centres are the answer for this sort of curiosity. But pure curiosity does not sell well and is definitely not a wealth generating factor. Scientific entities can afford this activity only if they are public and the State is generous. But reduction of State expenditure on public R&D organizations caused the quest for alternative funding sources. Post-academic science seems to be the answer for that situation. Therefore, in many European countries one can notice the emergence of post-academic science relations with business. This type of relationship is focused on the adequacy of knowledge and methods of its acquisition. Perfect science and business match needs support – an institution which will organize the knowledge market, and facilitate its production and flow.

A much more orthodox type of science is industrial science, where both the scientists' skills and knowledge and the science are subject to privatisation. It is a tempting but risky solution, because of the loss of sciences' selflessness and objectivity as well as the norms of science described by Merton (2002).

Undoubtedly new types of science are the result of the strengthening of the relationship between science and industry. The race for higher productivity, modern products, innovation and competitive advantage has its roots in knowledge – and finally universities have been discovered as its unlimited source.

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