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Industrial meaning of university basic research in modern economies

1. Introduction

The meaning of scientific knowledge in creating innovation and improving economies' growth potential is unquestioned. Universities play a vital role in national innovation systems, they are a source of both skilled labour and valuable scientific knowledge embodied in the R&D output. The role of basic research in modern economies seems to change. Previously, in the linear model of innovation, basic research has been the first stage of innovation process, followed by the applied research and experimental development. Nowadays, basic research seem to be a sterling product itself, ready to achieve the full market value. Basic research, nowadays conducted mainly at universities have some important advantages. First of all, they are publicly funded, as a basic universities' activity aimed at reducing the uncertainty of expanding the body of pure knowledge and creating potentially useful solutions. Secondly – thanks to the institutional change within modern universities, which is the emergence of the universities' "third mission" , there appeared the possibility of selling the basic research output thanks to the commercializing procedures adopted widely by research universities. Those procedures enable shortening the distance form the pure science to market-valuable solution.

The goal of the article is to show the changes in the approach to the university basic research as a part of the innovation process.

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2. Innovation models

Nowadays, as economic systems evolve in the direction of knowledge-oriented ones, the knowledge (and especially the scientific knowledge) is a factor of great importance for the economic development. Post industrial economies, according to Bell, differ from industrial ones, and the distinguishing factor is the attitude to the technological innovations. Formerly innovations resulted from business practice, nowadays they are the result of theoretical research [12]. According to Bell, the technological progress is dependent on the development of science . The development of technology is getting more and more similar to the scientific research because of the utilizing of typically scientific methods and research results. Naturally, knowledge has always been important for the economies, but post-industrial society is involved in research programs in order to broaden the theoretical knowledge which is useful in economies' problems solving. Post-industrial economy needs both highly qualified employees and advanced scientific research. Universities became the main institutions in modern economies. Bell said [1]: "if an enterprise has been the main institution through the past 100 years, according to its role in organizing production and economies of scale, the university is supposed to be the most important institution through the next 100 years, because of the innovation and knowledge it creates.

For decades after World War II the generally accepted model of innovation was the 'linear model of innovation'. This model explicitly and implicitly dominated much of the theoretical debates and science and technology policy formulations. In the model, basic research produces theories and findings that are redefined in applied research, tested in development processes and after that commercialized as industrial innovations. Each level in the linear model produces outputs that are transferred to the next level as inputs. The flow of knowledge is also unidirectional, i.e., later stages do not provide inputs for earlier stages[3].

This linear model of innovation and the idea of "public good " character of science laid the basis for academic autonomy. The fact, that they are mostly funded with public funds caused their greater autonomy in shaping both the scientific problems to solve and the methods to be used in problem solving. As the innovations were seen resulting automatically from basic research, they became a flagship activity of universities, which, from now on, got the autonomy of creation of the future.

The great change in the innovation process took place in the period of decade (mid 1970s – mid 1980s). In that time the attitude to the nature of knowledge changed. Polanyi (1966) demonstrated first that any knowledge was a combination of "tacit" and "explicit" dimensions [18]. The impact on fundamental research was demonstrated by Collins (1974), and his findings were, that the nearer to the discovery the most difficult it is to take-up knowledge and make it circulate – only those, who participate in a project can fully understand its nature [4]. The implication was that in high technology sectors, it was important for firms to develop strong connections with academic labs if they wished to be in a position to master new knowledge. The notion of "absorptive capacity" [9] translated this new understanding of the circulation of knowledge. This explains the exponential growth observed from the beginning of the 1980s in so-called "industry-university collaborations" (or said more precisely in joint research projects between public and private research actors) [10].

Also the understanding of the innovation process changed. The idea of a linear model of innovation was found as the oversimplified one. As an alternative to the linear model, Kline and Rosenberg [9] (presented a model they called 'the chain-linked model'). In this model, science exists alongside development processes, as it is used in any stage of such process when needed. Furthermore, science can be divided into two components: known, existing scientific knowledge and scientific research. If a problem is confronted in innovation, the existing knowledge is consulted first. Only if this consultation is not producing results, scientific research is needed. In this view, scientific research is not the initiating step, but a factor that is utilized at all the points in the innovation processes.

Of course the chain linked model is not the only alternative here. The newest attitudes to the innovation process are network model of innovation or open innovation [16].

Innovation process – no matter what model we adopt, can be translated as a process of knowledge transformation – from purely scientific to practical one. Since the postwar period until now the most valuable type of knowledge is a scientific knowledge. Thanks to this knowledge dimension scientists have a vital impact on economies development direction. The institutions that are devoted to the research activity are universities. Universities also educate, and in some cases this is their dominant activity, but in case of research universities – their scientific, innovation-oriented output is the greatest value.

3. Scientific background of innovation

The role of science in creating the useful knowledge is unquestioned. On the theoretical background, the idea of science as a public good was forwarded by seminal analytical work by Nelson (1958) and Arrow (1962), who introduced the idea of 'market failure' in the behaviour of firms investing in scientific research [6].

The traditional 'market failure' approach to the economics of publicly funded research centers on the important role of information in economic activity. Drawing on the work of Arrow (1962), it underlines the informational properties of scientific knowledge, arguing that this knowledge is non-rival and non-excludable. Non-rival means that others can use the knowledge without detracting from the knowledge of the producers, and non-excludable means that other firms cannot be stopped from using the information. The main product from government-funded research is thus seen to be economically useful information, freely available to all firms. By increasing the funds for basic research, government can expand the pool of economically useful information. This information is also assumed to be durable and costless to use. Government funding overcomes the reluctance of firms to fund their own research (to a socially optimal extent) because of their inability to appropriate all the benefits. With government funding, new economically useful information is created and the distribution of this information is enhanced through the tradition of public disclosure in science [20].

The idea of proprietary science appeared with the advent of the neoliberal era, which influenced modern, western economies[17]. The development of the neoliberal attitude to universities brought into the existence the academic capitalism, where the profitability became a key-word for many spheres of economy, also for universities. Universities started to take part in different business-like activities. This goes far beyond nonacademic consumption items (such as logos, tee shirts, etc.). Today, higher education institutions are seeking to generate revenue from their core educational, research and service functions, ranging from the production of knowledge (such as research leading to patents) created by the faculty to the faculty's curriculum and instruction (teaching materials that can be copyrighted and marketed) [19]. The idea of engagement between universities and society - the "third mission" of universities (after teaching and research), which puts them close to the society and industry, became a source of knowledge production and introduced changes to the innovation process.

4. The new dimension of scientific research

Scientific knowledge, e.g. knowledge created by scientists, usually at universities evolves. The academic science model, which has separated academic from industrial science and basic research from technological application does not any longer fit to the requirements of modern economies. Changes in the model of knowledge creation entail a change in the approach to the ethos of science.

The academic science has been researched by Merton [14], who constructed four norms or “institutional imperatives” defining its ethos. These are universalism, communism, disinterestedness, and organized skepticism.

The great dimension in the attitude to the scientific knowledge is discovering its market values. The possibility of using scientific research outputs as a commodity was possible thanks to emergence of knowledge transfer institutions, eg. intellectual property rights. Since that time one can easily say that knowledge creation has been replaced by the knowledge production.

The first important knowledge production model which can be found in the literature is the New Production of Knowledge [7]. 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 (which can be a synonym of the academic science).

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 [8]. 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 centers, 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 is based on an instant dialogue of knowledge-producing actors, and has the capacity to incorporate multiple views.

The more advanced concept of knowledge production is Ziman's concept of post-academic science and its more orthodox variation: industrial science [22]. 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"[22]. 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 growth of scientific activities needs capital support. 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. Due to the industrial orientation a new set of norms can be discerned, which Ziman labels as PLACE: *Proprietary, Local, Authoritarian, Commissioned,* and *Expert*.

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 (which means that academic science still exists) and suggests a future in which both develop in co-evolution.

As the short literature review shows, the change in the attitude to knowledge creation is evolving, and the direction of this evolution is to treat knowledge as a commodity. Universities as the sources scientific knowledge and of course well-educated scientific personnel are the significant chain of the knowledge creation. But using its potential in purpose of creating innovations faces several problems. First of all the problem of transmitting the results of scientific research into the market. This matter concerns mainly the process of commercialization, e.g. the subject of commercialization, the IPRs and commercialization process organization. Besides the industry is willing to achieve valuable knowledge from universities (embodied in the outcomes of university research and development (R&D) activity). The problem of knowledge commercialization affects the science- industry relations and results in different forms of fruitful cooperation.

5. Basic research in use – new growth areas

Basic research may be considered as the first step in the knowledge generation or in the innovation process. Since the basic research is conduced mainly at publicly funded universities, nowadays the new phenomena in knowledge creation (Mode 2 or industrial science described in previous sections) can be easily adopted. It is worth to underline here that basic research financed publicly can be attractive especially for new-potentially profitable science areas. Indubitably, the growth of economies in industrialized countries has been driven mainly by the pursuit of scientific research, the implementation of innovative engineering solutions and a constant flow of technological innovation. Basic research is basically conduced at the universities and public research institutions. Its role is mainly to advance the knowledge and scientific discoveries. Scientists often endeavor to solve purely scholar problems, where there are no direct expectations (or even interest) to utility implication. As a consequence of such an activity basic research may produce results of vast scientific value, but not necessarily with plausible economic significance [11]. It is worth to underline here, that the increased importance of basic research is strictly connected with the emergence of new technologies and knowledge, that have the ability to change the direction or accelerate the economies development. The scientific fields of such an importance undoubtedly are information technology, health innovations (like biotechnology), energy-saving and environmental innovation. They depend on and require very basic research that might eventually materialize to marketable assets.

After information technology, biotechnology is increasingly recognized as the next wave in the knowledge-based economy. A recent estimate of the European Commission suggests that by the end of the decade the global biotechnology market could amount to over 2,000 billion Euro. Despite the capital intensity of the industry, the growth rate of the biotechnology industry during the 1990s, and to a lesser extent, the beginning of the 21st century has been impressive. Biotechnology has been at the core of a number of important developments in the pharmaceutical, agrochemical, energy and environmental sectors. In particular, progress in the field of molecular biology, biotechnology and molecular medicine has highlighted the potential of biotechnology for the pharmaceutical industry [2].

The literature shows there is a dispute on the importance to drug discovery of basic research conducted at Public Sector Research Institutions. Zycher et al [21] found that at least 80% of 35 major drugs were based on scientific discoveries made by public institutions. Toole found a quantifiable correlation between investment in publicly funded basic research and corporately funded applied research: 1% increase in the funding in public basic research led to increase of 1,8% in the number of successful applications for new molecular entities in the lag of 17 years. The research conducted by Zycher et al shows also that, public research institutions have contributed to the discovery of 9,3% to 21,2% of all drugs involved in new-drugs applications approved during the period from 1990–2007. These proportions are higher than those identified before [21]. The examined data also suggest that public research institutions in USA tend to discover drugs that are expected to have a disproportionately important clinical effect.

The strong growth of the biotechnology industry in the recent years has been mirrored by the stronger than average growth rate for patent applications and patent grants that relate to biotechnology inventions. According to the OECD data, a number of patents granted in biotechnology rose 15% a year at the USPTO during the period 1990–2000, and 10,5% at the EPO (it is worth to notice, that the overall increase in patents reached 5% in the requested period). Patenting and licensing from universities and public research centers are a particularly important phenomena in health-sciences. in the USA licensing revenues reached 1.6 billion $ in 2005 [15].

It should be noted here, that patent is very often just a beginning of a very costly process of developing a marketable commodity [12]. The biotechnology industry exemplifies this problem. It is a common knowledge that the development of medical innovations (and especially new drugs) requires massive long-term investments in R&D, expertise in pharmaceuticals development, obtaining regulatory approval, production and marketing capacities [12]. On average – developing a new drug takes about 12 years. A recent estimate of the average cost of developing an innovative new drug is over $800 million, including expenditures on failed projects and the value of forgone alternative investments. That is probably why pharmaceutical companies find viable innovation to be much more accomplish internally – within firm's capacities. The challenges encourage large pharmaceutical firms to pursue collaborative alliances. As the Table 1 shows majority of these alliances materialize through licensing transactions with university scientists, which is the pure industrial science example. The publicly funded academic research serves both the industry and the society.

Table 1

List of patented new drugs from universities in Israel

Product	**Indication**	**Licensee**	**Sales in 2011 (in milions)**	**Licensor**
Copaxone	Multiple Sclerosis	Teva	$ 3,570	Weizmann Institute
Rebif	Multiple Sclerosis	Merck-Serono	Eur 1,691	Weizmann Institute
Exelon	Alzheimer	Novartis	$1,067	Hebrew University
Doxil/Caelyx	Cancer	Scheering--Plough	$ 320	Hebrew University and Hadassah Hospital
Aziltec	Parkinson	Teva	$290	Technion Medical Scholl
Erbitux	Cancer	Merck-Serono	EUR 855	Weizmann Institut

Source: [12]

The data presented in the chapter 5 show that there is a great correlation between university R&D in the field of biotechnology and biotechnology development. Moreover, one can easily see that universities tend to attract biotechnological companies as competent research partners. Thanks to the development of economic institutions enabling knowledge transfer form public universities to private corporations, the scientific output originating at universities can achieve marketable properties and be the source of income.

The changes in the attitude to the role of academic science in modern economies can be easily noticed on examples of new, innovative, economic growth generating areas of industry. Chemical industry, information technology, life sciences – all those industry branches derive from the university laboratory. Consequent shortening of the distance between science and industry causes the change both in the shape of modern scientific research and the innovation process. The academic R&D is nowadays more the output of industrial science than of academic one. Proprietary, local, authoritary, commissioned and expert are adjectives describing the attributes of modern scientific research model.

Research conducted at universities has also a great advantage in comparison to the corporate ones. It is financed by the state. The issue of knowledge commercialization still causes heated controversies among scientists, managers and technology transfer practitioners. Violation of the rules of open, public science, especially in the field of life sciences, can be harmful especially for the cumulative innovations and for developing countries [20]. The basic economic justification for university patenting is based on the idea that it facilitates the commercialization of the discoveries produced by scientific research. Thanks to well defined IPRs, firms or individuals have the incentives to invest additional R&D in product development because imitation is deterred and they can appropriate the related monopoly rents. Without a patent, the non-rival and non-excludable nature of knowledge would dissipate the expected profits and, therefore, the incentives to have extra R&D to bring such a product into the market [15].

The possibility of using publicly funded research for private (corporate) purposes gives rise to a new phenomena. The idea of industrial science which caused more direct and close relations between scientists and businessmen primarily could be understood as a trial of privatizing scientists instead of their scientific research output. The industrial science attitude often meant that those were people – scientists who took up work at huge laboratories financed by large corporations, loosing scientific independence but gaining good work conditions and money. The commercialization process affected more people and their peculiarities (like the tacit dimension of knowledge they are part of) than research results they were authors of.

Modern economies' economic policy puts an emphasis on the knowledge-directed development and growth. It means that a lot of public money is addressed to research institutions in order to provoke better economic performance. In the years of economic crisis corporations, which in the years of economic growth spent a lot of money on R&D activity, do savings using the possibility of market interplay with public research institutions like universities. And the biotech- and, in a wider prospect, health-sciences as the flagships of the economic- and social-quality change scientific disciplines, do realize such a crisis scenario.

In-licensing is understood as the licences bought by pharmaceutical industry from universities and public R&D laboratories. Out-licensing means licenses sold by pharmaceutical corporations to other entities. As the Figure 1 shows, the number of licenses bought from the universities grows in the two consecutive years with the stable number of licenses sold by the pharmaceutical corporations to other entities.

As the Figure 1 shows, pharmaceutical companies limit their research activity and in return they concentrate on buying licenses from public research entities like universities etc. The example of Sanosfi-Aventis shows that this company switched to the external sources of R&D. The numbers representative for this company prove that the internal R&D practically does not exist (minimal focus on out-licensing). The very similar data one can easily see on the example of Roche or Abbott, but with smaller engagement in in-licensing.

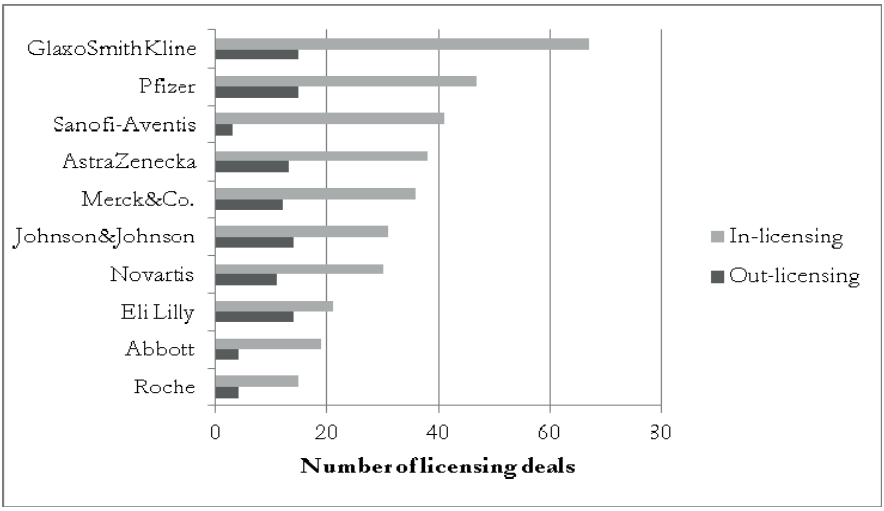

Figure 1. Licensing agreements in the pharmaceutical industry in 2008 and 2009, by the company name

Source: [5]

University basic research are nowadays the key point in fostering of development of new, innovative industries. Publicly funded university research became the very important part of the innovation process in pharmaceutical industry. Undoubtedly those are symptoms of the reversed trend in the knowledge privatization. As described above, primarily scientific research outputs privatization was associated with the personal dimension of knowledge – scientists. Nowadays the situation looks diverse – scientists sell their research output using the university technology transfer channels, but do not lose their relationship with the university. For the company university affiliation of a scientist is the guarantee of cost saving.

6. Conclusions

University basic research are the research of key importance for innovative industries. Primarily presumed as the first part of the innovation process, nowadays constitute a quite new phenomenon on the innovation scene.

Thanks to the introduction of economic institutions like IPR's the market exchange of basic research output is possible. It is a factor of a great importance because basic research conducted at the publicly funded universities are a source of public knowledge, which aim is enlarging the existing knowledge pool, not giving private profits. Thanks to the IPRs one can say, that the academic science (or even post-academic one) changed to the industrial science. Industrial science primarily described the situation when scientists decided to loose their research autonomy in return of the great research conditions in corporations' lab followed by satisfactory salary. Nowadays one can easily notice, that in the matter of innovative industries like biotechnology, information technology etc. the process of knowledge privatizing is reversed. At present pharmaceutical companies more and more often look for savings outsourcing R&D to the university laboratories. It means, that universities do license the rights to inventions the university scientists are authors of. Scientists earn royalties. It means that the product – a research output is privatized, with no additional personal costs connected with scientists employment.

As the research show – new drugs are produced mainly thanks to university basic research. Thanks to public funds and laboratories. It makes university research an attractive source of potentially useful innovation, and public funds devoted to them rise their attractiveness even more.

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