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# Property Rights of Scientific Knowledge in Terms of Creating Innovation

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**Keywords:** *knowledge-based economies, post-academic science, industrial science, university-industry relations, academic innovation*

**Abstract:** *Scientific knowledge has nowadays became one of the most important factors which foster innovation-based development of economies. The key role here play universities and higher education institutions which – under market pressure – also change their attitude to the knowledge creation. Originally focused on their educational duties, nowadays universities have became the real research leaders – ready to answer the market needs. The growing importance of new knowledge application to the industry, the tightening university-industry links, the impact of industry funding on knowledge production within universities or even the emergence of industrial knowledge, show how important private funding becomes at present. On the other hand the dominant portion of universities research activity is covered by public funds which, from another point of view, is important for the future prospects of modern economies. The aim of the article is to show the dependence of private and public funding of academic innovations. Methods used are: critical analysis of the literature, analysis of the statistical data.*


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## Introduction

Modern economies often described as knowledge-, post-industrial- or cognitive economies, in spite of several differences, have one, common feature – they treat universities as the main institutions of the modern world. The importance of universities is strictly connected with their ability of creating knowledge – in the shape of both – well educated labour and scientific research. The growing role of universities in modern economies is strictly correlated with the evolution of their mission and the emergence of so-called "third mission" of universities. And the evolution of universities' mission caused the rise of new phenomena - academic capitalism or industrial science which substantially alter the approach to Mertonian norms that represent the public "pure" science. The role of universities in creating economically useful knowledge is unquestioned, the public funds devoted to universities' activities constitute the richest source of their funding. The output of scientific research, in the shape of industry-devoted commercialized academic innovation – is a totally private and for-profit created asset. Therefore comes the question of new goals of universities and new functions they accomplish. What is worth to underline here is that the main role of public funding of academic research is to reduce the uncertainty associated with new research areas. Moreover it is also worth underlining that public funding is useful to achieve a critical mass of research, beyond which research outcomes can be used as innovations in industry, which could imply that innovation rely on public funding.

## Academic Knowledge as a Useful tool in Creating Innovation

In 1944 Vannevar Bush published the report, Science the Endless Frontier which became the cornerstone of American postwar science policy. The report recommended that public funds should be used to support basic research in universities and that science should be given a high degree of self-governance and intellectual autonomy. In return, the benefits of science would be widely diffused throughout society and the economy (Nieminen et al. 2001, p. 17). The report laid down two major ideas about science. First, it introduced the idea of science as a public good, and second, it put implicitly forward the idea of a so-called linear model of innovation. These ideas were widely accepted as a model for thinking about relationships between science and society also in the other Western countries.

Nowadays as economic systems evolve in 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, an the distinguishing factor is the attitude to the technological innovations. Formerly innovations resulted from business practice, nowadays they are the result of theoretical research (Masuda 1980). 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 (Bell 1973): "if an enterprise has been the main institution through the past 100 years, according to its role in organizing production and economies of scale, 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 (Kline, Rosenberg 1986, p. 285).

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 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 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. 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. 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" (Cohen, Levinthal 1989) translated this new understanding on 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) (Laredo 2007).

Also the understanding of the innovation process changed. The idea of linear model of innovation was found as the oversimplified one. As an alternative to the linear model, Kline and Rosenberg (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 points in innovation processes.

Of course the chain linked model is not the only alternative here. The newest attitudes to innovation process are network model of innovation or open innovation (Nieminen 2001).

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.

## The Ownership of Science – The Changes in Status of Scientific Knowledge

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. The concept of market failure, rooted in neoclassical economic theory, is based on the assumption that a purely market relation would produce the optimal situation and that government policy should be limited to redressing situations where market failures have developed. The basic aim of the study was to understand why firms systematically under-invest in basic research, i.e., why perfect competition fails to achieve an optimal allocation of resources. The answer was that the 'public good' nature of scientific knowledge produces a 'free-rider' problem, and as a consequence, firms choose a lower amount of investment in research activities than is required by social optimality. New research findings were thought of as a public good on which society as a whole would be able to draw. Even though it is difficult to measure whether company financing of basic science is below the socially optimal level, the 'market failure' argument has been the central economic rationale for the public funding of science since then (Dasgupta, David 1994, pp. 490-491).

The traditional 'market failure' approach to the economics of publicly funded research centres 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 enhanced through the tradition of public disclosure in science (Salter et al. 2000, p. 511).

Metcalfe offers the evolutionary approach as an alternative to justifying the case for government funding of basic research. In evolutionary theory, the focus of attention ceases to be "market failure per se and instead becomes the enhancement of competitive performance and the promotion of structural change" (Metcalfe 1995, p. 6). The evolutionary approach to the economics of publicly funded research suggests that the informational view of knowledge substantially undervalues the extent to which knowledge is embodied in specific researchers and the institutional networks within which they conduct their research. One could say, that knowledge and information abound, it is the capacity to use them in meaningful ways that is in scarce supply.

One of the newer approach to the public knowledge focuses on the properties of knowledge captured by the information view described above. Influential here are Rosenberg (1990) and Pavitt (1991, 1998), who stress that scientific and technological knowledge often remains tacit – i.e. people may know more than they can say. Moreover, the development of tacit knowledge requires an extensive learning process, being based on skills accumulated through experience and often years of effort.

The idea of proprietary science appeared with the advent of the neoliberal era, which influenced modern, western economies. 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) (Rhoades et al. 2004). 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.

Recent academic attention on research and the role of university in society has focused on the "mode 2" form of knowledge production. The "mode 2" model first introduced by Gibbon et al. in 1994, described the changes in knowledge production in terms of movement from Mode 1 to Mode 2. Mode 1 emphasized the discipline as the centre of knowledge production in which homogenity of research and the context of discovery were pre-eminent. 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 mobilisation of a range of theoretical perspectives and practical methodologies to solve problems (Hessels et al. 2004). 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 organisations, 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.

The rise of the Mode 2 is followed by the phenomena of the academic capitalism – such as patents, licenses, joint-venture companies and associated science parks. These universities' activities constitute the core of university-industry link in the Mode 2 of knowledge production.

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 summarise, 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 characterised 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 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 "an impatient expectancy" of industry, government and the public. The expectancy refers to the scientific knowledge diffusion rate and its impact on company's profits and state's welfare. There is an increased pressure on scientists to deliver more expected and desired value that can provide the long-term gains. Moreover policy-making in science and technology has intensified the competition for resources. In such a situation competing for lucrative contract may diminish the significance of researcher's scientific credibility. Research teams can be conceived as small business enterprises, their staff as "technical consultants". Finally, science has become "industrialised": the links between academia and industry became close and the relationship has a financial dimension. This phenomenon is in contradiction to the Mertonian norms of academic science1. Due to the industrial orientation a new set of norms can be discerned, which Ziman labels as PLACE: Proprietary, Local, Authoritarian, Commissioned, and Expert 2. 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 future in which both develop in co-evolution, the post-academic science and even more - the industrial science - is a practice that replaces traditional academic research.

Neoliberal attitude to knowledge creation is based mainly on the expectancy of effective allocation of resources leading to the knowledge creation. Market mechanism, which is a basic tool regulating the knowledge flow obliges participants to exchange equivalence. This means, that price paid for knowledge (innovation) is equivalent to its value. The consequence of the market attitude to knowledge flow is the great emphasis on the profitability of investment in knowledge, and, in order to achieve this goal, promoting only the solutions with expected profitability forecast. Universities as the main "producers" of desired knowledge act under a great pressure. Firstly – the chance of improving the financial status thanks to revenues deriving from the scientific research is very tempting, it rises university's prestige, gives chance for personal development to university researchers, gives the financial sense of freedom. And this is a semblance of freedom because apart from financial freedom no other freedom is given. So important research autonomy – the possibility of independent defining the research subject, creating the knowledge "out of pure curiosity" - is being now endangered. The investor (industry) defines both the desired outcomes of research and resources available. However it is worth to notice that private assets have always been better managed than public ones. Undoubtedly publicly financed academic research are crucial in case of the academic autonomy, and what is most important, the imperative of applicable invention and profitable investment does not exist here. The funds are often wasted and the market failure problem seems to prejudge the ineffectiveness of such a form of academic research financing. But one must remem-

[1] 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, skepticism* (Ziman 2000).

[2] 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).

ber – thanks to the public funding the academic research it is possible. University-based research is of particular importance to innovation, as the early-stage research that is typically performed at universities serves to expand the knowledge pool from which the private sector draws ideas and innovation.

## Funding Sources of University's Research in Europe

University research consist mainly of basic research. There are of course applied research and experimental development conducted by research universities but the greatest share of university research constitute basic research. The main source of funding of the academic research is state's (or federal as in case of the US) budget (de Dominicis et al. 2011).

Funding sources of universities in Europe differ to a large extent and have an impact on the accounting system and, as such, on the financial management of the institution. The components of most European countries funding sources are: governments (public funding), industry (private funding), non-profit organizations, and foreign funding sources (at present mainly EU funds).

Government funding refers to public funds coming from government (national/regional). Government funding to universities includes core funding and competitive funding:

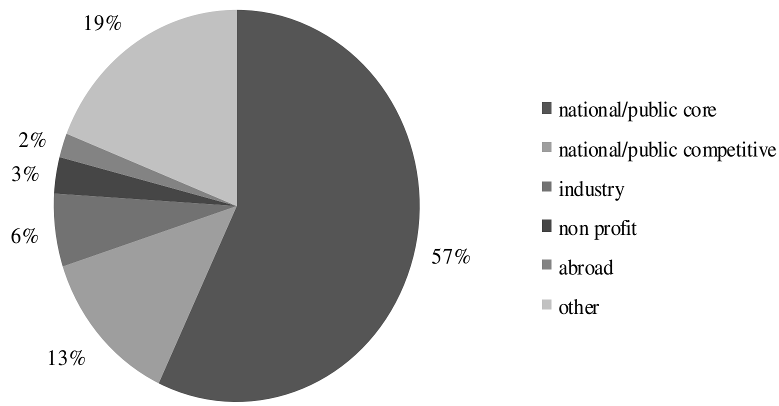
- Core funding includes the general block grant coming from governmental authorities (national/regional) to support the university as a whole (including all activities: teaching, research and third mission).
- Competitive funding includes contracts and grants coming from governmental authorities (national/regional) distributed on a competitive basis. It also includes research funds distributed through Research Councils or similar funding bodies on a competitive basis.

Industry funding refers to the income coming from contracts with private companies.

Non-profit funding includes the funding that comes from non-profit organisations, foundations, philanthropic sources, or donations.

Abroad funding is absorbed mainly form the EU. It includes funds received from various programmes in Europe.

**Figure 1**. Shares of university total funds by source of income




Source: de Dominicis et al. (2011).

## Universities' General Budget: Structure and Degree of Diversification

Results from the analysis of the general budget of the selected universities3 show that about 70% of the total university income comes from government allocations, of which 57% represents core funding and the remaining 13% is assigned on a competitive basis. As Figure 1 shows, around 6% of income is from private companies, around 3% from the nonprofit sector, and approximately 2% is from abroad. The category 'Other' represents about 19%. Note that this category is residual.

The analysis of the different sources of income reveals several interesting facts:

– Government is still today the main funding source for European universities. For the majority of universities in the European Research Area (ERA) countries, government core funds account for around 60% or more of the total university income. The share of government competitive funds

[3] According to the report that has been prepared by the Institute for Prospective Technology Studies (IPTS) of the EU's Joint Research Centre (JRC) as a formal deliverable under Work Package 3 (Monitoring and analysis of the reforms of research universities in the ERA) of the FP7 ERAWATCH2 contract.

- varies considerably, ranging from an average of 1% for Italian universities to an average of 28% for Belgian institutions.
- Funding data show that universities, generally, have less than 10% of their budget coming from industry. Only in the case of institutions in France, Greece and Croatia, more than 10% of the total budget comes from the private sector.
- Philanthropic sources could potentially be an important source of income for universities, particularly for research. However, it is not nearly as well developed in Europe as elsewhere, particularly in the US (European Commission 2008). The non-profit sector could be an important source of income, as proved by universities in Iceland and in Portugal, where, on average, it represents 18% and 10% of the total university budget, respectively.
- Finally, income coming from 'abroad' represents less than 10 per cent of the total budget for the great majority of universities in the sample, from which 83 per cent is below five per cent. With particular regard to government allocations of public funds, it has been a clear policy priority to decrease the core funding while increasing the funds allocated on a competitive basis.

Core funding represents around 80% over the total government allocations for most of the selected universities across Europe while competitive funds represent around 20%. Universities in Italy, Malta, Cyprus, Croatia or Turkey have budgets with a clear dependency on core funding, while universities in Belgium, Sweden, the UK and Ireland have a more compensated allocation of public funds: approximately 70% core funding and 30% competitive funding.

Dominant role of public funding of university research in Europe shows that university research is treated as the source of public knowledge. As if was mentioned before, such attitude to research funding can cause different results. Firstly – the problem of allocation of public money can result in the ineffectiveness of nations research policy. Secondly as the public money is spent on the basic research one can notice that university-based basic research is of particular importance to innovation, as the early-stage research that is typically performed at universities serves to expand the knowledge pool from which the private sector draws ideas and innovation. It is also worth to underline that academic research can draw the new knowledge pools that, in the future constitute new branches of industry. For example biotechnology or nanotechnology are the industry branches that were created in university labs. When we observe the emerging areas of science, technology and innovation we can notice biotechnology in agriculture and natural resources, biotechnology in human health, “general purpose” nanotechnology (OECD 2010). All of these are university driven industry branches that develop thanks to the initial publicly funded basic research.

As one can notice – a successful innovation needs public money, but its market success is connected also to the private funds.

## Private Knowledge our of Public Knowledge?

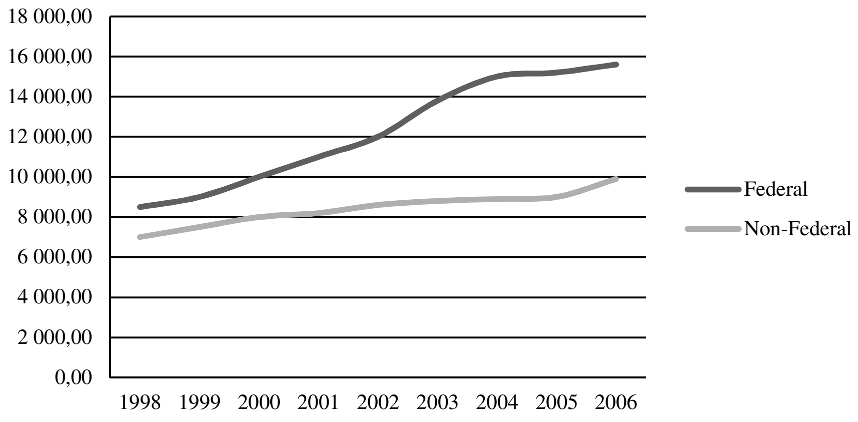
There is no doubt, that knowledge is a very important factor in creating innovation. The role of academic knowledge in this case is also unquestioned. The changes in both innovation process construction and knowledge creation (production) process shows the direction of innovation activity development. The growing importance of new knowledge application to the industry, the tightening university-industry links, the impact of industry funding on knowledge production within universities or even the emergence of industrial knowledge, show how important private funding becomes at present. On the other hand the dominant portion of universities research activity is covered by public funds which, from another point of view, is important for the future prospects of modern economies. There is no doubt that nor sole private funding neither sole public funding is able to meet the demands of modern economies. The question here is if the private and public funding complement or substitute each other. Or maybe there is some other relation between them.

As research shows (Blume-Kohout et al. 2008, David et al. 2000) private and public funding might be complementary or private funders might correctly consider public funding (as a signal of quality). In this case, private funding agencies might be more willing to fund research at universities that obtain federal funding; consequently an increase in federal funding will lead to more than a dollar-for-dollar increase in total funding (a "crowding in" effect). The effect of public research funding on private funding is an issue of much debate. A priori, there could be a negative effect since researchers could stop seeking other sources of funding when they receive public funding, or a positive effect since public and private funding could be complements in the production of applied knowledge and the receipt of a competitive public award could signal quality to other funding organizations.

The research was done on a sample of around 300 universities with data on federal and non-federal funding for the life sciences spanning nearly a decade. The results of the research showed that increased federal funding is associated with increased non-federal funding. The evidence also suggests that in addition to providing research resources, NIH (National Institute of Health – the public institution responsible for life science funding) funding also provides a signal to the private organizations about the quality of the recipient institutions through its screening process. Universities that have historically received low amounts of federal funding and non-research universities receive the highest boost in non-federal funding due to increased federal funding. This is consistent with the view that federal organizations such as the NIH may have an advantage in correcting for the asymmetry in information about university quality that exists between universities and other funding organizations. Finally, juxtaposing the results with estimates of the multiplier effects of R&D spending suggests that increase in NIH funding could significantly affect economic output. For example, the U.S. Department of Commerce Bureau of Economic Analysis (BEA) estimates that a dollar increase in R&D expenditures is associated with a 2.2 dollar increase in business activity.

The cited analysis on life-sciences funding (Blume-Kohout et al. 2008) indicates that a dollar increases in NIH research spending leads to 1.35 dollar increase in total R&D expenditures; combining this result with the multiplier effect suggest that a dollar increase in NIH funding is associated with a $3 increase in economic activity. The results from analysis also suggest that federal funding might influence the commercialization of university research by enabling them to attract more private resources. While results suggest that public organizations such as the NIH provide a signalling function on the quality of award recipients.

**Figure 2.** Federal and Non-Federal R&D Expenditures for Life Sciences




Source: Blume-Kohout et al. (2008).

As the Figure 2 shows there is an interdependence between public and private funding in life sciences in the USA. The growing share of public funds attracts private funding in the life sciences. The important feature here is the role of public institution – it is not only the donor, its role is of greater importance – it exhibits the trustful development directions worth private investment.

It is worth to notice that the situation described on an example of life sciences in the USA can cause some general effects. In case of academic research which is predominantly a basic, publicly funded research, the state – the main funder – acts as the guarantor of the profitability of private investments. This shows that the Mode 2 production of knowledge and even the industrial science, can be an attractive, profitable solution only when some "critical mass" of innovation is achieved thanks to publicly funded academic research. It means that public funds increase universities attractiveness as the source of innovation.

## Conclusions

Nowadays modern economies strongly rely on knowledge, because of its ability to support economic development and wealth. The knowledge, and especially the scientific knowledge is a factor of great importance for the economic development. Innovations at present, more often result from theoretical research than form business practice. The innovation process, traditionally shaped in a 3 level process of basic, applied research and experimental development is a subject to change. The change concerns both the presence of science in the innovation process as a whole (chain linked model) and the change in the essence of knowledge – important notice on the "tacit" nature of knowledge shows that the human factor in innovation process broadens the sense of innovation process. The networked or open innovation models also encompass scientific research as a part of the process.

The change in innovation process goes further. The public character of scientific knowledge is contrasted to the proprietary character of the New Model of Knowledge Production. While Mode 1 of knowledge creation is based on the linear model of innovation, Mode 2 provides commercialization of scientific outputs or even commercialization of scientists per se (which is a part of industrial science model). Nowadays there is no clear divide between public and proprietary knowledge. University-industry links show that market allocation of resources brings bigger profits than public one. Public funds can be wasted on irrational scientific research which never transform into any sort of invention. On the other hand, private firms usually invest in applied research, using the findings of basic research which are – on the contrary – predominantly publicly funded. Basic, public research is able to create new industrial branches, like biotechnology or nanotechnology, which emerged in the university laboratories not in the industry. And finally – the role of public funding is even greater. The results from research cited suggest that federal funding might influence the commercialization of university research by enabling them to attract more private resources. While results suggest that public organizations provide a signalling function on the quality of award recipients. It means that public funds increase universities attractiveness as the source of applicable, marketable innovation.

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