

INDICATORS MEASURING UNIVERSITY-INDUSTRY COOPERATION¹

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Abstract

The aim of this paper is to describe the indicators for measuring different types of collaboration activities between universities and industry. Popular indicators for measuring university-industry cooperation are the number and amount of patents or licences, but these do not express the knowledge transfer and university-industry cooperation most adequately, as the collaboration and knowledge transfer also takes place through other types of cooperation. Although it is easier use input and output indicators for measuring university-industry cooperation, the focus should be on the economic impact of the collaboration. Additionally, relationship-based indicators should also be used. In Estonia different input factors are widely used. As university-industry cooperation is an input in innovation processes, the desired outcome should be a higher level of innovation, productivity, competitiveness, and growth, which has to be considered in the development of policies.

Keywords: university-industry cooperation, types of cooperation, indicators, policy making

JEL Classification: O22, O32, O38

Introduction

The cooperation between universities and industry is currently in the focus of attention globally. The governments, universities, and industry are interested in good and effective collaboration which would be beneficial for all parties. To foster university-industry cooperation, and hence the knowledge and technology transfer between these two parties, academics, politicians and companies are paying attention to science and technology policies more than ever. For designing and evaluating the policies it is important to define and use proper indicators. Although several governments and research agencies are continually searching for ways to facilitate the interactions between industry and universities, hoping that they can increase the productive processes and the competitiveness of the collaboration environment, they still are struggling to find proper indicators to measure university-industry collaboration in order to make political decisions at the national level.

Additionally, universities and companies can use these indicators in evaluating the collaboration results. According to Gardner et al. (2010), the reasons to measure the

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effectiveness of knowledge transfer activity at public research organizations are to demonstrate the benefit to society from advances in knowledge, to ensure sufficient returns on investment, to provide benchmarks for comparison across the industry, to promote competition in the global marketplace, and to support future appeals for funding. The companies are interested in the returns on investment, which is also important to consider in the case of university-industry cooperation activities.

The knowledge transfer between universities and enterprises is conducted through various channels and practices. Therefore, in analysing and evaluating the cooperation between academia and industry, it is important to consider the diversity of connections.

Based on the analysis of university-industry collaboration types and possible indicators, the aim of the paper is to define different types of cooperation between universities and enterprises and describe the indicators for evaluating the collaboration activities. The structure of the paper as follows. In the first part of the paper, the cooperation between universities and enterprises is analysed, and the types of cooperation are defined. In the following two sections, the indicators for measuring university-industry cooperation are discussed and a system of indicators that comprise the plurality of interactions between universities and companies is described. Finally, suggestions for policy development for Estonia will be provided.

The nature of university-industry cooperation and types of collaboration

Since their foundation, the role of universities in society has changed over time. At first, the universities were apart from society and their role was to preserve the culture and knowledge of society (Brockliss 2000, Etzkowitz 2001). Over time, the interaction with institutions outside universities has increased considerably. The linkages between universities and enterprises have changed in both – in the forms and in the intensity of interaction. The oldest mission of university is teaching – to provide skilled and professional specialists for society. In the 19th century, the universities started to focus more on research (Brockliss 2000) and thereby the research universities started to evolve.

The research university produces and disseminates research results through publications, so that the industry can use it in their production. Nowadays universities are becoming more and more entrepreneurial themselves and the relationships with industry and university are more direct and interactive. (Etzkowitz 2001) The universities of today have to find the appropriate balance between teaching, basic and applied research, and entrepreneurship.

Santoro (2000) and Santoro, Chakrabarti (2002) distinguish four types of university-industry relationships:

- Research support, which embodies financial and equipment contributions made to universities by industry. These contributions can be unrestricted gifts of endowment trust funds that the university uses to upgrade laboratories, provide fellowships to students, or provide seed money for promising new projects.

Nowadays the support for university research is more targeted and often tied to specific research projects, which, in return, provide knowledge and new technologies to industry.

- Cooperative research includes contract research with individual investigators, consulting by faculty, and certain group arrangements specifically for addressing immediate industry problems. In the case of individual investigators or a consultancy there is usually only one faculty member involved who is working with a single firm on a targeted research project. Group arrangements involve more than just one faculty member and more than just one industrial firm.
- Knowledge transfer encompasses highly interactive activities that include on-going formal and informal personal interactions, cooperative education, curriculum development, and personnel exchanges. Knowledge transfer mechanisms are the recruitment of recent university graduates and employing student interns, co-authoring of research papers by university and industrial firm members, industry-university consortia and, for example, also trade associations.
- Technology transfer also involves highly interactive activities. Compared to knowledge transfer the focus here is on addressing immediate and more specific industry issues. In technology transfer the university-driven research and industry expertise make complementary contributions into commercialized technologies needed by market. Often the university provides basic and technical knowledge along with technology patent or licensing services. Industry members provide knowledge in a specific applied area along with a clear problem statement related to market demand. Technology transfer takes place through technological consulting arrangements, the firm's use of university's extension services, jointly owned or operated ventures.

Considering the concept of knowledge transfer, this kind of distinction is a rather limited one. Knowledge transfer can take place in all relationship types mentioned above. Gardner et al. (2010) indicated that the broader concept of knowledge transfer describes the movement of knowledge, ideas, concepts and techniques from a formative location, generally institutions of advanced education, out to all areas of the social and economic environment. This kind of broader approach is also used by the authors of this paper. Knowledge transfer between universities and industry can be considered the most important aim and also result in university-industry cooperation.

Polt et al. (2001) have considered the following channels of knowledge transfer and university-industry cooperation in their research:

- collaborative research,
- contract research and technology-related consulting,
- staff mobility between firms and public science institutions,
- co-operation in the education of graduate students,
- vocational training for employees,
- use of intellectual property rights (IPR) by public scientific organizations,

- spin-offs,
- informal contacts and personal networks.

According to an extensive study among European universities, there are eight types of university-industry cooperation (Davey et al. 2011): curriculum development and delivery, lifelong learning, student mobility, academic mobility, commercialization of R&D results, collaboration in R&D, entrepreneurship, and governance. The types of the cooperation are related quite directly to the missions of the universities and the needs of industry (see Figure 1).

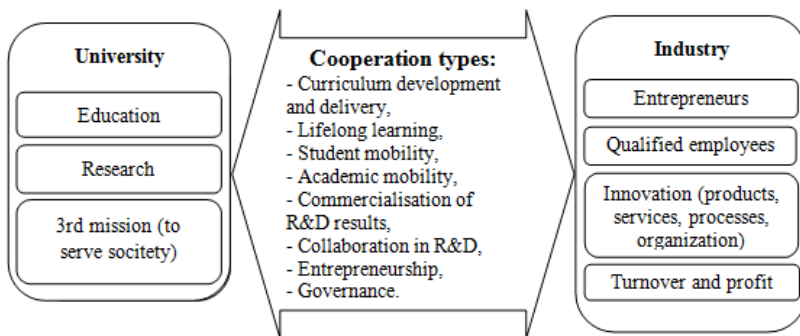


Figure 1. University-industry cooperation related to the missions of university and needs of industry.

The oldest mission of university is teaching and educating skilled professionals (Gibbons 2000), who after graduation start to work in society. Curriculum development and delivery is one type of university-industry cooperation, which aim is to develop human resources relevant to modern society. The firms can participate both in the development of curriculum and in the delivery of it by being guest lecturers in different courses and programs. Lifelong learning is also one way of developing human resources, but here the students are adults, who acquire additional skills, knowledge or attitudes. (Davey et al. 2011)

Student mobility is the temporary or permanent movement of students to enterprises. Academic mobility encompasses temporary or permanent movement of university researchers or lecturers to firms, and the movement of industry researchers to universities. (Davey et al. 2011) Knowledge transfer in the very direct sense takes place through this kind of cooperation, which is especially suitable for the transfer of tacit knowledge.

The knowledge intensity in industry has grown over time. In addition to the supply of knowledge, the demand of knowledge from the industry's side has also increased. Therefore, the need for universities' knowledge transfer and commercialisation has also increased. The universities can commercialize the research results with

enterprises through spin-offs, licenses or patenting. University-industry collaboration in research and development includes all the joint research activities, contract research, consulting, informal networks, joint publications, joint supervision of theses, and different student projects carried on together (Davey et al. 2011). The research and their results are important for industry for producing new products or services, improving processes and through all of that, achieving improved performance and larger profits.

Universities are becoming more entrepreneurial themselves and also take in to some degree the role of business (Etzkowitz 2003). In the frame of entrepreneurship, the universities are creating new ventures with enterprises or developing an entrepreneurial culture within university in cooperation with enterprises. Cooperation in governance means that the industry and university are cooperating at management level (e.g. business leaders are sitting on the boards of universities or are involved in decision-making, academics are sitting on the board of enterprises) (Davey et al. 2011).

The interaction and cooperation between universities and industry is not only in the interest of the two institutional partners involved. In an environment where international competition is constantly increasing and development of technology is very rapid, governments are also interested in good cooperation between universities and industry, in order to improve the effectiveness of innovation and with that, also to improve the economic development of the country (Barnes et al. 2002). Through laws, policies and incentive systems, the government is able to influence the cooperation between universities and industries. This means that the governments are also interested in measuring and evaluating the links between universities and industry for estimating the possible impact of their past actions and making strategies for the future.

For universities and enterprises there is a growing need for collaboration in order to survive in a highly competitive marketplace. The traditional culture of universities is evolving, not only with the development of universities but also because of the growing number of universities taking on entrepreneurial tasks and therefore becoming more industry-like. The linkages between universities and industry are very diverse and this should also be taken into account in defining the indicators of university-industry cooperation.

The indicators for measuring university-industry cooperation

Usually, the indicators measuring university-industry cooperation are established by the local government to measure the responsiveness of the knowledge transfer activities to the needs of the economy and public sector. The indicators are used to track performance of the universities and enterprises over time to see the effects of policies and collaboration.

For analysing interactions between universities and industry it is possible to use the channels of interaction as indicators of university-industry performance. However,

in the cooperation between universities and enterprises, not only is the cooperation itself important, but also the outcomes of this cooperation. Pertuzé et al. (2010: 83) argue even further that not the outcome of the cooperation is important but the impact – “how the new knowledge derived from collaboration with a university can contribute to a company’s performance”. The outcomes are the results of cooperation, which create an opportunity for a company, but the research outcome has only incidental importance for companies as it has little or no impact on the company’s productivity or competitiveness. Therefore, it is much more important to focus on the “impact of the collaboration on company products, processes or people” (Pertuzé et al. 2010: 83). The same applies to the interest of other partners – universities and government.

At the macro level the impact should be measured in the areas of well-being (e.g. health and quality of life, working life, living environment); economic; knowledge, education and culture; and environment (e.g. climate change) (Luoma et al. 2011). This kind of impact can also be considered a long-term outcome. In Figure 2, the input-impact process is described.

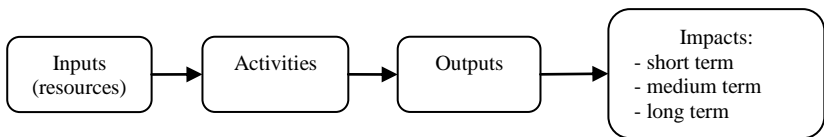


Figure 2. The input-impact process (compiled by authors based on Luoma et al. 2011, *Establishing ... 2008*).

Performance measurement indicators can be divided into the same categories: inputs, activities, outputs and impacts. The input indicators are foremost suitable for evaluating the intent of a desired output, but do not guarantee it (Langford et al. 2006). Output and impact indicators deal with results of the cooperation, but it is important to make the distinction that the outputs are the outcomes which are the direct results of the cooperation. Often the activity indicators are also considered as outputs. The impact refers to direct or indirect effects that cooperation has on the different parties (Establishing ... 2008).

Perkmann et al. (2011) distinguishes three major input factors – resources, researchers’ capabilities and researchers’ motivation. The number of researchers involved in collaboration with enterprises can also be considered as an input and the increase of this number also allows assuming the increase in the amount of university-industry cooperation.

R&D expenditures and finances given to universities are important input indicators for any type of R&D activity. While sharing R&D costs offers benefits to alliances generally, university–industry alliances can usually gain additional leverage via public funding. The contributions from government granting agencies, businesses, individuals and foundations can be input indicators of university research. The most

direct indicator of university-industry cooperation is the level of industry sponsorship and financing of university research (Langford et al. 2006). The financial support and benefits are important for universities and make it possible to establish and also maintain the relationships with industry (Davey et al. 2011).

Bibliographic metrics can be used to measure researchers' capabilities. Although the publications are usually defined as output in academia, a primary performance measure of researcher quality is journal publications. Since a simple publication count is not a reliable way of assessing a researcher's impact, as journals and individual journal articles differ in terms of quality, citation counts provide a better measure (Moed 2005). Citation counts record the number of times an author's publications are cited by other publications, recorded in bibliographic databases and can be measured via the h-index².

The problem with estimating the researchers' capabilities by the number of publications and citations is that the aim of university-industry cooperation is often not a publication. Industry is interested in applied research, and from the industry side, the publications are not necessary. When defining the indicators concerning the measurement of researchers' capabilities, the aim of the cooperation should be taken into account. Depending on that, all outcomes achieved in the past can be considered (e.g. reports, patents etc.).

Although it might not easy be to evaluate researcher motivation directly, the researcher also wants to focus on interesting projects and the impact of the career model is as important to him or her as for other professionals (Lee et al. 2010). For encouraging scientists to do cooperation with enterprises, the stimulation system and career model in university, and also in academia more generally are also important. Based on Bercovitz and Feldman (2008) and Perkmann et al. (2011), previous research has indicated that departmental climate is one of predictors of involvement in industry activity. Since it is difficult to obtain measures for the presence of norms favouring industry involvement and positive attitudes of departmental heads facilitate individual engagement, an 'industry-friendly' climate can be proxied by the department's track record of industry engagement. The favour and attitude of a university or department can also be estimated by the existence of documented strategies embracing university-industry cooperation and implementation of these strategies (e.g. dedication of resources to support cooperation, provision of incentives for academics, considering the cooperation with enterprises in the assessment of work performance, existence of cooperation supporting stimulation system) (Davey et al. 2011). Alternatively, researcher motivation may also be captured via a suitable survey instrument, such as, for instance, a scale measuring researchers' views of the benefits they derive from industry contact.

² The h-index reflects both the number of publications and the number of citations per publication. The h-index shows that scientist with an index h has published h papers each of which has been cited at least h times in other papers.

In the same way as evaluating the capabilities and motivation of researchers in university, the industry's side should be taken into account. Research has shown that there are certain characteristics of a company that influence its ability to utilize externally generated scientific knowledge, and thus the knowledge transferred from universities (Agrawal 2001). From the absorptive capacity of the firm depends, how well the enterprise can recognize the value of new, external information, in order to assimilate and commercialize it. The level of absorptive capacity depends on prior related knowledge and experience (Cohen, Levinthal 1990). The absorptive capacity and technological competence of the company show the capabilities of the company as an input in the university-industry cooperation.

Barnes, Pashby and Gibbons (2002) defined in their research the complementary expertise or strengths, history as collaboration partners in the past, shared vision or strategic importance, complementary aims, and collaborative experience generally as important firm characteristics, which are good prerequisites for successful cooperation. Additionally, the quality of staff can be considered as firm capabilities. The problem here is that it is hard to measure it objectively. The indicators of firm capability can be, for example, quality certificates (ISO certificates), number of previous projects with universities, membership in some research group or collaborative network, number of scientists, education of employees, and the involvement of staff in the activities of university (e.g. guest lecturers in university).

Perkmann et al. (2011) pointed out that there are several metrics available to operationalize outputs from university–industry alliances. Patent applications or patents granted can be used as measures of the technological output of university–industry projects. However, patents are only one among several appropriation mechanisms used by companies. Also, some university–industry alliances are based on explicit ‘open science’ rules that stipulate that all knowledge generated should flow into the public domain with no restrictions.

The number of publications in peer-reviewed journals is used in academia as a major performance metric. Perkmann et al. (2011) believe that publications are an indicator of quality as they are subject to a peer review process. The number of joint publications of university and industry scientists is a very explicit indicator of university-industry collaboration (Langford et al. 2006). Tijssen et al. (2009) use joint research publications which are co-produced by R&D staff from private sector organizations and universities for evaluating university-industry research cooperation. The joint research publications focus on longer-term perspectives while applied research with a short- or medium-term commercialization focus are usually not disseminated in the peer-reviewed literature, but as reports, patents or other form, which often are also confidential. The co-authored publications are considered to be a good indicator of diffusion of knowledge and skills, and informal network between academia and companies. The indicator is also quantifiable, available, and easy to collect. However, it is important to note that this indicator should not be used alone for defining university-industry cooperation as there are many cases where no co-authored papers are published. (Lundberg 2006)

In terms of staff skills and training, there are several available metrics for assessing success. These include the number of doctoral and postdoctoral positions offered within the alliance, the number of co-supervision arrangements between industry and university, and the number of secondments of research scientists to partner organizations. The number of master and doctoral theses derived from the collaborative work or supervision is the outcome of cooperation (Iqbal et al. 2011).

Perkmann et al. (2011) believes that intensity of the collaboration is another measure of an alliance, which indicates the training and learning opportunities between universities and industry. Frequent interaction between the partners facilitates the transmission of know-how and tacit knowledge as opposed to the formal exchange of codified research results. From research it appears that the more there are different meetings for educational or contact making purposes, the stronger the linkage between university and the firm also is (Iqbal et al. 2011). Workshops, seminars and meetings, where the participants are from both university and industry, can be considered as the outputs of university-industry cooperation. The high number of personal contacts also indicates a higher intensity of collaboration and knowledge transfer between the partners.

The input of social or commercial actors and the transferred knowledge in the university-industry cooperation create an economic or social impact. To measure the impact of university-industry collaboration outputs, the indicators should show if the collaboration achieved its aim and what have been the consequences of the collaboration for the partners (Pertuzé et al. 2010). In the current paper the focus is on the economic impact. There are different indicators, such as GDP per capita, productivity, turnover growth, export growth or employment growth, to measure the impact of university-industry cooperation on a more general level. For example, increasing productivity means that businesses are improving the size of their income relative to their expenses – thus becoming more competitive.

More specific impact indicators are, for example, license revenues and success of spin-off companies (Langford et al. 2006). The success of university-industry cooperation can be estimated by the rate of recent graduates' hiring and their employment in the field of their studies. The science citation index enables to evaluate the impact of publications, as outputs of cooperation, in the research. In Table 1, some possible indicators are defined in the categories of inputs, outputs and impact.

A number of reports (i.e. European Commission (European Commission 2009), UNICO (Holi et al. 2008), SPRU (Molas-Gallart et al. 2002), etc.) have focused on the issue of the measurement of activities between universities and industry. These studies advocate a broader set of interactions – knowledge transfer metrics. Based on the European Commission Report, there are two commonly used alternatives for measuring knowledge transfer (European Commission 2009):

- The first approach is to estimate the value of the knowledge transferred in its different forms. The dominant approach is to equate this value with its price – what someone is willing to pay for it.

- The second approach is to measure not the knowledge but the transfer of it: to count the number of manifestations of knowledge transfer as activities in various transfer channels (e.g. number of consultancy contracts, number of spin-off firms, number of lectures given in network seminars, etc.).

Table 1. University-industry cooperation measurement indicators

Categories	Indicators
Inputs	<p>Resources: R&D expenditure; university's governmental income; non-government donations, grants and contracts; industry sponsorship of university research; scholarships; number of researchers.</p> <p>Researchers' capabilities: number of publications, citations, projects, reports or patents done in the past.</p> <p>Researchers' motivation: number of previous industry contracts in the department/university; number of strategies concerning industry-university cooperation in the department/university; amount of resources dedicated to support cooperation in department/university; perception of researcher about the benefits from the cooperation with industry.</p> <p>Firms' capabilities: quality certificates (ISO); previous collaboration with academia; membership of some association or research group; number of scientists; structure of employees by occupation and education.</p> <p>Firms' motivation: number of previous contracts with universities; involvement with university (e.g. alumni, lecturer); perception of the firm about the benefits from the cooperation with university.</p>
Outputs	Patent applications; patents; license revenues; publications; joint publications; postdoctoral or doctoral positions offered within alliance; joint supervision; master and/or doctoral theses; secondment of researchers; intensity of collaboration; spin-offs; meetings; seminars; workshops.
Impact	GDP per capita; total factor productivity; productivity renewal indicator; number and share of high growth enterprises; renewal rate of enterprises; share of inward FDI per GDP; knowledge intensity of production; success of spin-off companies; productivity growth; turnover growth, export growth, the increase in exports created by new inventions; net increase of jobs, employment growth; recruitment of graduates; science citation index.

Source: compiled by authors based on Barnes et al. 2002, Bercovitz, Feldman 2008, Perkmann et al. 2011, Langford et al. 2006, Iqbal et al. 2011, Tijssen et al. 2009, Luoma et al. 2011.

In order to measure the performance of different knowledge transfer activities, organizations use different metrics. The collected data is commonly of a quantitative nature, although some organizations appear to be moving towards more abstract, subjective measures (e.g. case studies). Jensen et al. (2009) propose quantitative and qualitative metrics for measuring the extent of knowledge transfer activities between universities and industry. The proposed metrics are based on measures of knowledge transfer activities and their immediate effects. Nine categories of indicators to measure knowledge transfer activities can be distinguished: networks, continuing professional development, consultancy, collaborative research, contract research, licensing, spin-offs, teaching, and other indicators of knowledge transfer (see Appendix 1).

Quantitative data is an important source of information about the university-industry cooperation, and it is relatively easy to gather and also analyse. The problem with quantitative data is that it does not answer the “why” and the “how” questions. Qualitative survey methods (e.g. interviews, focus groups, workshops) make it possible to understand the changes better and also to map the problems and difficulties maybe earlier – before the problems appear in the statistics (Ravetz et al. 2007). Therefore, the qualitative approach to data gathering and analysis should also be used.

There are various indicators for measuring university-industry cooperation. In general input, output and impact indicators can be distinguished. Although the input indicators show only the intent of cooperation and not the outcome of it, they are used more broadly. Considering that the results of the cooperation are important, the output and impact indicators are more appropriate in evaluating the cooperation efficiency between universities and industry. Therefore, the qualitative metrics should also be used more often.

Indicators for different types of cooperation between universities and industry

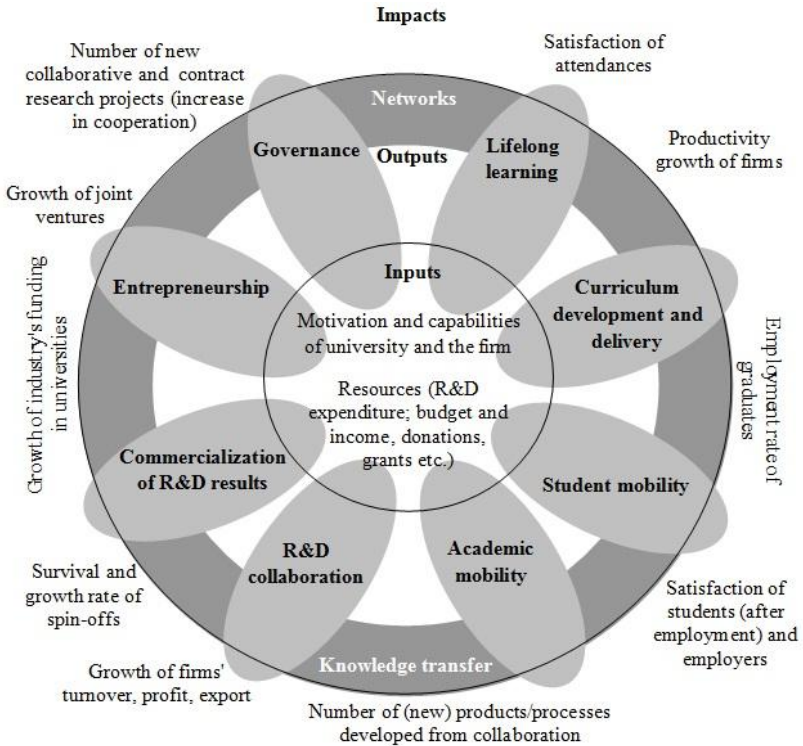
The forms, motivations and also objectives of the cooperation between universities and enterprises can be very different. For that reason the indicators of university-industry cooperation are also different. Based on the previous discussion, Figure 3 describes the relationship between different indicators for measuring university-industry cooperation and different types of cooperation.

A very definite distinction cannot be made between input indicators for different types of cooperation, except R&D expenditure, which relates more to research than educational activities. Otherwise, all collaboration types need more or less financing, motivation and also capabilities of researchers, university, and firms. The output indicators are defined in Table 2.

All types of cooperation should lead to the creation and development of networks between people in university and in the firm. As networks are important for the knowledge transfer, especially tacit knowledge, the measurement of university-industry cooperation should definitely also incorporate indicators about networks and knowledge transfer. Castro-Martinez et al. (2009) propose that seminar and course participation feedback survey data, if standardized, are potential sources of information on networking and informal contacts. In order to capture which activities lead to other activities of cooperation and knowledge transfer, a couple of questions such as how did it materialize, over what period did the relationship evolve before the cooperation proposal was made, or will it continue in the future (i.e. after the project) can be asked at the end of each collaboration.

In Figure 3 the impact indicators are also defined, which show the impact of cooperation. The impact of successful cooperation in curriculum development and student mobility should result in a high rate of students’ recruitment. In addition to quantitative indicators, the impact of cooperation can also be measured by the

satisfaction of graduates and employers. The development of human resources (curriculum development and delivery, student mobility, lifelong learning) should lead to improved performance and productivity of the firms. In the case of lifelong learning, the satisfaction of attendees can also be taken into account.



Medium and long term impact indicators:

Knowledge intensity of production, total factor productivity, productivity renewal indicator, number and share of high growth enterprises, renewal rate of enterprises, net increase of jobs, employment growth, GDP per capita, share of inward FDI per GDP.

Figure 3. The framework of university-industry cooperation indicators.

Academic mobility, R&D collaboration and commercialization of R&D results relate more to research activities and the impact of these can be new products and processes derived not directly in the cooperation, but due to the cooperation. The most important impact of cooperation is definitely the increase in the income of firms and also university. In the case of universities the growth of industry's funding indicates a directly increased cooperation between universities and industry. The commercialization of R&D also encompasses the formation of spin-offs and therefore the survival and growth of spin-offs can be considered as an impact

indicator. In the same way, the impact of entrepreneurship is the growth of joint ventures. The impact of governance, but also other types of cooperation, should be the cultural development of universities and industry, which can be evaluated by increased cooperation between universities and companies. The medium- and long-term impacts can be measured by indicators which would allow the evaluation of increased knowledge intensity in industry, overall productivity of economy, development of high growth enterprises, employment, and national prosperity.

Table 2. Output indicators of university-industry cooperation and knowledge transfer by the types of collaboration.

Type of cooperation	Output indicators	Indicators of networks and knowledge transfer
Curriculum development and delivery	Number of programmes/curricula developed in cooperation with industry; number of courses with guest lectures from industry and attendees in these courses; joint supervision and number of master and/or doctoral theses; number of graduates.	Intensity of cooperation: number of meetings, seminars, workshops; number of attendances/presentations at conference/seminar with industry (non-academic) participants; number of collaborative and contract research projects as a result of knowledge exchange or networking activities; length of relationship; feedback of participant/employer/graduate.
Lifelong learning	Number of courses held; number of attendees and graduates at these courses; number of researcher exchanges between university and industry; number of other scientific and research training schemes for industry.	
Student mobility	Number of student trainees in industry; number of student placements in industry; number of PhD student exchanges (with industry); number of industry funded postgraduate positions/scholarships.	
Academic mobility	Number of researcher exchanges between university and industry; postdoctoral or doctoral positions offered within alliance.	
Commercialization of R&D results	Patent applications; number of patents granted; number of plant variety rights; number and value of copyright licenses; provision of training in research commercialization; number of spin-offs formed; market value of spin-offs; value of revenue generated by the spin-offs; number of staff working on commercialization activity in dedicated and support roles.	
Collaboration in R&D	Number of consultancy contracts; number and value of contract research projects; number and value of collaborative research projects; number of joint publications; number of joint inventions; number of (new) products/processes successfully created in collaborative research (e.g. as reported in the final report), number of invention disclosures.	
Entrepreneurship	Number of joint ventures; number of entrepreneurship courses to students and researchers in university; number of attendees at entrepreneurship courses.	
Governance	Number of business actors on the board of university; number of academics on the boards of firms.	

In choosing the appropriate indicators for measurement, there are also some important aspects to consider. Langford et al. (2006) bring forth the problem that the indicators which should measure the achievement of an aim may become the aim itself. For example, by counting the number of patents a university or scientists apply, the aim of academia may become to “produce” as many patents as is possible (patenting for the sake of patenting) rather than to protect a valuable intellectual property.

Gardner et al. (2010) compare the quality and the quantity of different knowledge transfer activities and conclude that there is currently no mechanism to distinguish between the quality and quantity of the results being measured. Since these metrics evaluate effectiveness and may in turn affect funding and other considerations, there is an incentive to overstate the numbers. For example, the number of spin-offs does not explicitly take into account how successful the venture becomes or if it is commercially viable at all. In comparing universities, smaller institutions may have fewer spin-offs, but they may create more positive economic and social benefits for the community.

In defining and choosing the indicators of cooperation, the type of cooperation should definitely be taken into account. Although some indicators are more or less universal, there are also very specific indicators, which do not encompass all the cooperation activities between universities and enterprises and this way indicates the actual collaboration inaccurately.

Policy suggestions for defining university-industry cooperation indicators

The indicators of university-industry cooperation are important in planning and evaluating the policies of R&D and higher education. Due to the diversity of knowledge transfer channels between universities and enterprises it is important to analyse the university-industry cooperation in a systematic way. To get an adequate understanding of the collaboration between universities and industry and its economic impact on society, appropriate indicators should be used.

In Europe, the advancement of knowledge transfer is promoted through establishing good practices and providing networking opportunities for its members. Many European countries have not adopted the US practice of ownership of results. For example, employees at many European public research organizations are allowed to retain the rights to their intellectual property. These employees may lack the resources or interest to commercialize their technologies to the same extent as technology transfer offices. Furthermore, the patenting process at the European Patent Office is much less efficient than that of the US Patent and Trademark Office (Gardner et al. 2010). For that reason, the number and the amount of patents or licenses does not express the knowledge transfer and university-industry cooperation most adequately, as the knowledge transfer also takes place in other types of collaboration.

According to the OECD report and the Australian Government, with regards to the university-industry relationships, “formal collaboration is the tip of the iceberg, which is underpinned by many less formal links” and that “firms in the United States and the United Kingdom regard informal contacts as the most important type of university-industry interaction contributing to innovation, ahead of graduate employment, research publications and technology licensing” (Jensen et al. 2009: 6). Research has revealed that for companies relationship-based benefits are much more important than the patents or other university-generated intellectual property (Perkmann, Walsh 2007). Therefore, the evaluation of cooperation should also definitely consider relationship-based indicators.

Castro-Martinez et al. (2009) point out that for designing and implementing effective science and technology policies based on long-term structural changes, a change of culture among all parties in the innovation system is required. It also has to be considered that it takes time before the knowledge created in universities reaches the market. This should be recognized by setting the appropriate cooperation and commercialization indicators.

Polt et al. (2001) have compared industry-science relations and the role of framework conditions and have emphasised several aspects needed to be taken into account. The university-industry relations are interlinked and the channels of interaction may be either substitutive or complementary. That means that weaker performance in one type of collaboration may be compensated by an alternative cooperation type. The university-industry relations are also specific to a certain environment and the framework conditions may affect the cooperation in different sectors or technology fields in different ways. This means that there should be caution when taking over good practices from different sectors and areas of technology.

In policy creation the goal may not necessarily be the “good performance” itself. If university-industry cooperation is an input in the innovation processes, the desired outcome is rather a higher level of innovation, productivity, competitiveness, and growth. The problem with these variables is that they may be affected by university-industry relationships and cooperation in quite limited way, compared to other factors. (Polt et al. 2001)

In Estonia, the emphasis of the measurement of university and industry collaboration is currently on measuring different input factors, such as the number of R&D personnel or number of staff supporting knowledge and technology transfer, rather than on impact factors. An additional focus is on different output factors like income from training and education, income from patents and licenses or income from R&D contracts and consultation services. Although these indicators show the direct results and can be measured quite easily, attention should be turned to the impact indicators which can appear in the distant future, but are more important in the broader economic sense.

The Institute of Baltic Studies, Praxis Center of Policy Studies and Technopolis Group describe in their mid-term evaluation of the implementation of measures in favour of R&D and higher education in the framework of the EU co-financed Structural Funds during the period 2007-13, that in order to achieve the objectives, major problems of the present system are the deficiencies in the strategic view at the national level, which can be considered a serious bottleneck based on the aspect of the regional and sector development support system (see Appendix 2). Their findings are similar to those that can be found in the literature described above.

In operational terms, it would appear most cost-effective for Estonia to try to evaluate the currently collected different input and output factors in order to find the value of the economic impact based on secondary data, before proceeding with small scale testing. As a next step, the impact indicators can be directly implemented to the questionnaire, in order to calculate the effect of the policy decisions made in influencing input and output measures.

The updated indicators would allow the measuring of new data. The main effort required would be to extend the current efficiency screening method to include impact factors, despite the fact that it could be difficult to measure and evaluate if these impact indicators are affected by policies made to boost university-industry collaboration or are influenced by other state policies in that sense.

Conclusions

There are a variety of different cooperation types between universities and industry ranging from simple collaboration in R&D to lifelong learning and curriculum development. Apart from the universities oldest mission of teaching and educating skilled professionals, the universities have become more and more entrepreneurial today. Universities are willing to see their knowledge set to practice and they are joining forces with industry to do so.

Despite the set of indicators available, it is difficult to distinguish what are the most appropriate indicators which give the most precise picture about the various policies made by the state. Also, there is a need to distinguish what is the aim which should be achieved. The measurement of different state policies is done via input, output and impact measures, but mostly quantitative input metrics are being used because it is easiest to get data about those indicators. From the state perspective, the most important indicators should be impact indicators that show us whether the resources are allocated correctly.

The findings of the present paper indicate the importance of diverse performance indicators and their usage to measure the inputs, outputs and impact of university-industry collaboration. Thus, policies for university-industry collaboration should pay attention not only to the input and output measures as they mostly do today, but look also into the future and measure the possible effects of the created policies. Also, universities and enterprises should evaluate the cooperation and knowledge transfer between the parties.

The limitation of the study concerns the proposed indicators for measuring university-industry cooperation, which were derived from previous studies and findings. To confirm the appropriateness of the indicators and specify the indicators of different types of cooperation more precisely, an empirical study should be conducted in the future.

In the future research a more complete picture of the extent of knowledge transfer from universities to industry in the longer term should also be obtained. Research investigations need to be conducted using longer term data, possibly collected from specialized surveys. Considering the policies, further research is needed to understand the role of sector specifics. The firms are very heterogeneous in their nature, but the policies are homogeneous, that is, the same for all firms. From the sector specifics indicators for measuring the success of university-industry cooperation may also be different.

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Appendix 1. The indicators of knowledge transfer

Category	Indicators
Networks	<ul style="list-style-type: none"> • Number of attendances/presentations at a conference/seminar with industry (non-academic) participants; • Number of PhD student exchanges (with industry); • Number of collaborative and contract research projects as a result of knowledge exchange or networking activities;
Continuing professional development (CPD)	<ul style="list-style-type: none"> • Number of CPD courses held and attendees at these courses; • Number of university-industry laboratory researcher exchanges; • Number of other scientific and research training schemes for industry; • Participation feedback;
Consultancy	<ul style="list-style-type: none"> • Number and value of consultancy contracts; • Number of collaborative research projects generated by consultancies;
Collaborative research	<ul style="list-style-type: none"> • Number and value of projects and collaborative research agreements; • Number and value of joint ventures; • Number of (new) products/processes successfully created from collaborative research (e.g. as reported in the final report);
Contract research	<ul style="list-style-type: none"> • Number and value of contract research projects; • Length of client relationship; • Number of contract research projects which led to other flow-on knowledge transfer activities such as collaborative research, licensing, and industry sponsored conferences;
Licensing	<ul style="list-style-type: none"> • Number of invention disclosures; • Number of complete standard patent applications; • Number of patents granted; • Number of plant variety rights; • Value of copyright licenses; • Number and income from licenses; • Long-term relationships created following licensing;
Spin-offs	<ul style="list-style-type: none"> • Number of spin-offs formed; • Value of revenue generated by the spin-offs; • Value of external investment raised; • Market value at flotation (or initial public offering); • Exit value (i.e. at trade sale or buy-out); • Survival rate/viability and growth rate of spin-offs;
Teaching	<ul style="list-style-type: none"> • Number of student graduation by course type; • Rate at which students get hired (in industry); • Student satisfaction (after employment); • Employer satisfaction with graduates;
Other	<ul style="list-style-type: none"> • Number of research student placements in industry; • Number of industry funded postgraduate positions/scholarships; • Number of staff working on commercialization activity in dedicated and support roles; • Provision of training in research commercialization; • Citation received (citation impacts analysis) from articles and patents with industry co-author(s) or inventor(s); • Joint publications and inventions.

Source: Jensen et al. 2009

Appendix 2. Main problems and suggestions related to different performance indicators in Estonia

Problems	Suggestions
<p>There are several problems in the set of indicators. There are several examples in the current implementation plans, where the indicators (in particular, output indicators, which should be directly proportional to the measure) are weakly related to the content of the measures. The main cause for that is that the objectives and indicators were developed before they worked out the actions.</p>	<p>The consortium suggests that during the preparation for the new program, first the goals and output and impact indicators should be set. Output indicators should focus on evaluating the contents of measures to ensure that they measure the supported actions and not vice versa.</p>
<p>Inaccurate or ambiguous definitions of the indicators are problematic. Problems have also occurred for those indicators for which the definition is simple at first glance (e.g. number of participants in training – in which case there is confusion, whether individuals or training times are taken into account).</p>	<p>A Round Table (probably several), should be conducted prior to the new programming period, where the unit specialists could discuss the problems encountered with indicators in practice. Also, clear guidelines should be established, where among other things, the methodology of finding indicators is explained. This instruction should be left as a so-called living document that is constantly being updated.</p>
<p>The problems moving towards the objectives are also caused by the fact that mainly output measurements are used rather than outcome or impact indicators. The output indicators do not provide enough information in many cases about the impact. Also, the problem is that the impact indicators are too general, so the contribution of the structural funds is difficult to distinguish from other factors.</p>	<p>For each objective, the long-term impact indicators to measure (preferably outcome indicators) should be defined in order to distinguish between the contributions of structural funds from other factors affecting it.</p>
<p>There are some examples, where it can be seen, the indicators in the application programs are only loosely related or benchmarks are not in accordance with the national strategy documents. As the latter are more important for the promoters of policies, sometimes the target operational objectives are pushed to the background.</p>	<p>Ensure that the indicators used in the operational programs are in line with targets contained in other strategic documents. It will also bring greater coherence and clarity in the purpose of the documents.</p>
<p>In case of the horizontal activities, the problem is that the level of the projects are in many cases more indirect. This problem is more general and not only specific to Estonia. Another issue with the horizontal activities is that it is not measured if they are moving in the right direction.</p>	<p>Horizontal issues should be considered particularly at the level of action and to decide on possible planning of the action, in which the measure contributes to horizontal activities. Artificial links should be avoided. Indicators to measure the progress towards goals should be developed.</p>

Problems	Suggestions
<p>Today's system has to deal with significant challenges – especially weaknesses in strategic planning, performance objectives, indicators, measuring system and the lack of substantive follow-up monitoring. Solving these problems is necessary in order to effectively organize and implement appropriate measures in accordance with the objectives set out in the transformation.</p>	<p>If there are free resources left after the currently planned activities, a referral for additional activities and / or action that would contribute to the priority axis objectives could be considered. This should take into account the possibilities to combine the long- and short-term activities.</p>

Source: Euroopa Liidu tõukefondide ... 2011.