1 Introduction

We described Universities, R&D Institutes and Corporate Science in the previous chapters. All of them are a part of the National Innovation System and they are united by the main function - knowledge production. In this chapter we will describe the interaction between these components in the context of industry-science relations (ISR).

2 Components

In accordance with OECD documentation [3] we extract the components of the NIS related to knowledge production and divide them into tree major groups: Higher Education Institutions (HEIs), Public Research Institutes (PRIs) and Industry. Each of them performs its own functions and activities related to the role in knowledge production processes and such functions and activities are defined taxonomy.

HEIs functions and activities are education and research. Education, i.e. knowledge transmission from an adviser and professors to young students was the original function of Universities and Institutes. In the early 20th century the Humboldt model of University was developed and implemented. Since that time universities have become the place for research. The Humboldt model of University presupposes that lecturers and professors of Universities are scientists, i.e. should be involved in knowledge production activities.

Functions and activities of Public Research Institutes are research and development. Historically, PRIs have been involved in mega-scientific projects like Nuclear Energy/bomb development or Space/Cosmos missions. Moreover, state scientific research institutes as the form of organization of R&D in aircraft construction, shipbuilding, etc. were popular in the Soviet Union. In general, PRIs can carry out a wide range of R&D activities - from basic research to applied development. The third part of our taxonomy is Industry. The main activity of companies is making a profit. For this purpose some companies require development (and sometimes research), i.e. application of existing knowledge to the creation of new products.

3 Linkages

There are many different linkages that bound HEIs, PRIs and Industry directly and indirectly. All of them are based on sharing information: phenomenon of knowledge transfer by means of communication. Communica-

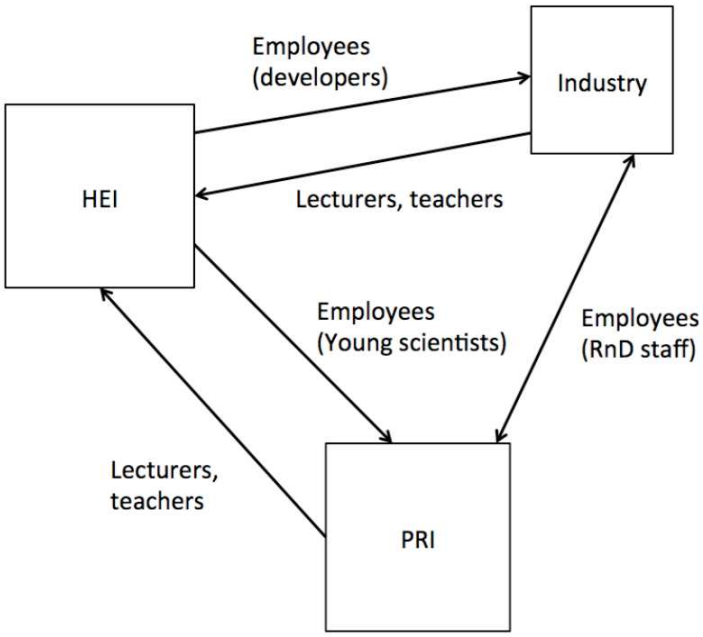

Figure 1:Education and mobility of personnel

tion occurs in multiple forms and for multiple reasons and we divide it into several groups.

3.1 Education and mobility of personnel

Education is the primary function of HEIs. Yong professionals upon graduation start career in Industry or PRIs. Mobility of personnel is the major driver for knowledge transfer in education: people obtain knowledge at one place (University) and apply it at another place within the framework of their professional activities [4].

At the same time there is a reverse flow of professionals from Industry/PRIs to HEIs. The reverse flow of personnel mobility is presented by mobility of professionals. Skilled professionals can become teachers, professors, advisers etc. at HEIs, because they have unique and superior knowledge obtained from personal experience in industry projects.

One can divide the education system into tree different classes: worker education, engineering education and science education. Each of these classes has its own forms of education-industry linkages. For example, in case with the worker education, the education- industry linkage can be institutionalized in the form of *dual education*. The dual education system combines the

education process and on-the-job training. Usually students spend half of their education time in class and the other half of their education time - at companies.

In the case with the Engineering, education-industry linkages can be presented in the same way as the worker education: final year students can take internship in Industry (or at PRIs) and make graduate projects based on internship. Engineering professions require theoretical and practical knowledge, and practical knowledge can be obtained only in actual practical projects in Industry. But new standards of education in engineering, for example, CDIO (Conceive, Design, Implement, Operate), presuppose involvement of students in practical engineering projects within the process of educations. That leads to moving engineering education competence from industry to education institution.

In the case with the scientific education, education-industry linkages can exist in the form of laboratories or institutes sponsored by Companies as the part of the education institution. This type of cooperation is important for both actors. From the point of view of Industry, as it was mentioned before, a dedicated laboratory is a channel for personnel recruitment. Secondly, a laboratory can be a source for state-of-the art technologies because most Universities are involved in research activities. Participation in research activities is another type of education- industry linkages.

In sum

Education is an important driver for science-industry linkages. Interaction of Industry and HEIs in education can be institutionalized in the form of:

- Dual education
- Internships
- Industry sponsored laboratories/institutes

Incentives for HEIs to cooperate with Industry are as follows:

- Teaching enhancement by employment of skilled professionals
- Transfer of Empirical knowledge
- Cooperation with companies gives an opportunity to employ graduates and have a positive impact on the reputation of HEIs

Incentives for Industry to cooperate with HEIs are as follows:

- Access to the state-of-the art technologies
- Source of employees
- Possibility to organize and participate in joint research projects

3.2 Research and collaborations

Research activities can be another driver for the education-industry interaction. Research is often expensive, requires special equipment, which is concentrated in institutions, specialized in scientific research. But scientific and applied research is a source for new technologies and technology-based innovations, and some companies can make donations, investments in research activities and sponsor them.

There are several different ways to invest in research. The institutionalized form of investment can be represented as payment of salary to a PhD student. Research tasks are divided into PhD-sized projects, and the company can give tasks and pay salary to PhD students that work on the research issue. HEIs are interested in scientific tasks, and thus, not any issue from Industry could be used for PhD project.

If a company is interested in various research topics, and it needs to invest in more then several PhD-sized projects, the company can establish a joint laboratory or an institute within the University. This structure can combine the education function of the University that was described in the previous section.

Interaction of PRIs and Industry lie in the area of business processes. Industry can outsource research activities to specialized PRIs. Outsourcing of research activities and organization of laboratories are direct communication of Industry with HEIs and PRIs. But there is an indirect communication. For the purposes of research HEIs and PRIs require equipment and this equipment is manufactured by Industry. The need of equipment with new features initiates interaction of HEIs or PRIs with Industry, creates a market for scientific equipment and initiates technology transfer.

Direct and Indirect linkages emerge in case of big scientific projects, "mega-science". It is a special type of a scientific project that involves multiple research groups in collaboration and development of specialized equipment like Large Hadron Collider or experimental reactors. Such kind of collaboration involves all participants of R&D activities.

Small collaboration can be established for inter-disciplinary research projects or as a mechanism for implementation of government policy in education and research. In this case, science-education linkages increase coherence of components of the National Innovation System.

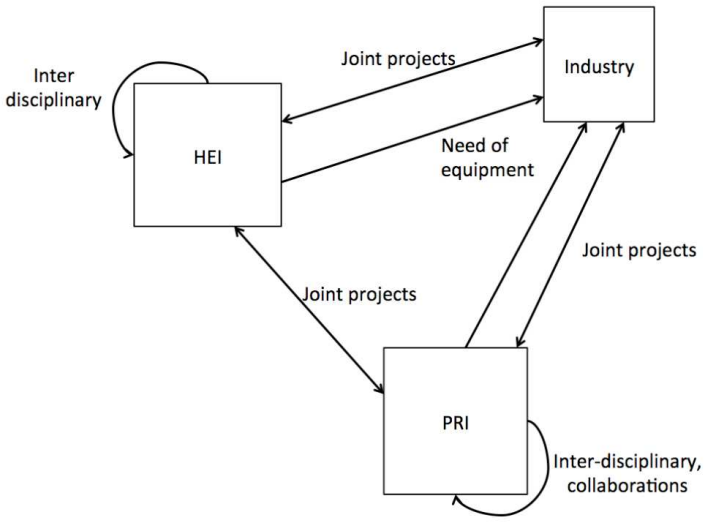

Figure 2:Research and collaborations

In sum

Research activities can be a driver for scientific-industry interaction. Depending on the possibilities and requirements of a Company in research activities, involvement of the company can be as follows:

- Funding of a PhD-sized project or a group of projects
- Creation of a research laboratory or institute at the University
- Outsourcing of research activities to PRIs

Reasons for involvement in research cooperation are as follows:

- Access to laboratory equipment
- Decreasing risks and costs of the basic research
- Implementation of a long-term research project
- Inter-disciplinary research

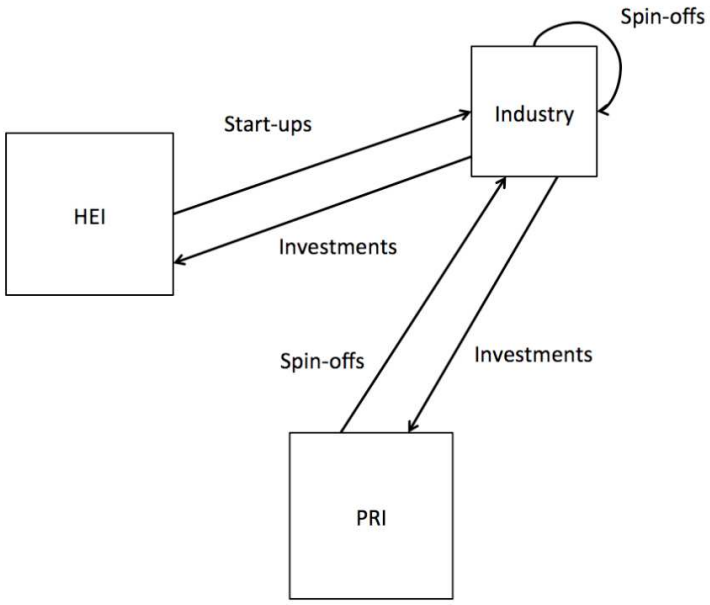

Figure 3:Commercialization

3.3 Commercialization

HEIs, PRIs and Industry are the components of the National Innovation System and can be a part of a long chain of commercialization of technology-based innovations. The developed NIS provides possibilities for turning scientific knowledge (technology) to a commercial product. Commercialization of scientific knowledge is another form of linkages [2].

Commercialization of scientific knowledge can be performed in multiple forms but in the context of industry-science relations one can distinguish two initial forms of a technology-based company. The first one is a university-based start-up and the second one is a spin-off start-up. One of the main similarities of this kind of enterprises is that both of them are based on the results of research activities. The initial point is technology or developments based on the previous R&D work. One of the main differences is the place (institution) where the original knowledge was obtained. In the case with the university-based start-ups, one assumes that the University is a place where the previous research activities were performed. In the case with the spin-offs, one assumes that PRIs or industry is the place where the previous research activities were performed.

In the process of creation of university-based start-ups and spin-off companies the Innovation System plays an important role. Creation of start-ups requires mechanisms of protection of intellectual property, venture capital

and market.

Intellectual property developed at HEIs or PRIs shall be protected. Venture capitalists place their investments at a greater risk if there is no protection of IP. Patents, trademarks and copyrights can protect IP. The IP protection system is another form of education-industry linkages, because protected and commercialized knowledge ensures return of investments to investors and HEIs/PRIs.

4 Support

Industry-science linkages cannot exist without an additional support of the National Innovation System. No legal framework for intellectual property results in the fact that Universities cannot establish enterprises and receive money from commercialization of research activities. Moreover, special mechanisms are required to initiate and support communication of HEIs, PRIs and Industry. Several mechanisms ensuring communication and linkages are presented in this section.

4.1 technology transfer offices

Technology transfer offices (TTO) are special structures within a HEI or PRI dedicated to detect research activities that are expected to be commercialized. These research activities can be "packetted" into a start-up, and in this case, usually, a TTO provides support to young enterprises in initiation of their business processes, provides services related to searching for investors, etc. Moreover, a TTO can facilitate implementation of joint R&D projects of HEIs and Industry/PRIs or strengthen international cooperation. A TTO can be the entrance point for Industry if any company needs technologies or special research [1].

4.2 Science/technology parks

A Science Park is an element of the Innovation infrastructure. It supports technology transfer and creation of high-technology enterprises. Science parks are the basis for technological innovation. The roles of science parks are as follows: strengthening of university-industry linkages and growing start-ups. A Science Park becomes an intermediate platform for university-based enterprises that are already big for university laboratories but too small for the real market. Depending on the level of maturity of a project, some science/technology parks can provide support in the form of incubators, i.e. the

place for growing young start-ups or accelerators, i.e. the place for increasing performance and production of the enterprise. A set of scientific parks can be united in an innovation cluster that can combine companies and HEIs specialized in related areas.

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