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The role of research infrastructures in cooperation between business and academic sectors in Hungary

PhD. thesis

Enterprise Theory and Practice Doctoral School

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„The possibilities of research performed in cooperation should be studied more in-depth than before, because till now these form the only visible hope for the renewal of science, when it grew too big for a sole person."

Jenő Wigner, Nobel laureate physicist

1 Scope of the research and rationale of the research topic

Research development and innovation (RDI) is in a similar situation as the "strategy" in Mintzberg's "Strategic Safari" (Mintzberg 2005) – as in the case of the elephant, everyone seems to know what RDI is. This is partly because the term "innovation" is not defined exactly, although great efforts are made to tackle this issue – see for instance the Oslo Manual of OECD (Oslo 2006) – and in many instances it is regarded as a marketing tool. As a researcher studying the "research infrastructures" which are closely connected to innovation I have faced with the fact that even this seemingly more specific term is not adequately defined nor studied in-depth.

I've been involved in many governmental RDI initiatives since 2011, such as the formation of the RDI Observatory which aimed at the harmonization and single point access of all RDI data relevant for Hungary. Another main task was the establishment and update of a single database of Hungarian research infrastructures. In finding solutions to the questions arising in connection with these activities I faced many challenges caused by the inadequate performance of the RDI system while trying to get an accurate picture of Hungarian RDI.

One of the main problems is the lack of cooperation in RDI. This is not a Hungarian issue, for this problem the "Triple Helix" (Etzkowitz 1999) concept is trying to provide a solution, which considers business-academia-government cooperation as the key for the development of the National Innovation System. While acknowledging, that this approach indeed can boost innovation performance, we must note, that a major tool for boosting cooperation – a common platform – is still not in the scope of decision makers when thinking about tools to achieve this goal. These are the research infrastructures, which are not really studied although "research facilities contribute significantly to long-term scientific developments in research and stimulate the competitiveness of the European economy." (Science Europe 2016 p. 11)

Not only in Hungary, but also abroad, discussions have started just recently on what research infrastructures can be used for (besides research of course), how can they integrate to the National Innovation System, what are the possible socio-economic impacts of them – and what is exactly meant by "research infrastructure" per definition. Unsurprisingly, the quantitative measurements of the former issues are in a very early stage as well.

The main questions of my research are finding the possible connection between enterprises and research infrastructures and also the identification of the infrastructures' characteristics. How are the research infrastructures used by the enterprises? What factors play a role for the enterprises in using the infrastructures? Is it important how and where they can access the infrastructure (either from location or from regulation side)? Is there a perspective to promote the usage of research infrastructures by enterprises at all?

Although the amount Hungary spends on research infrastructures adds up to almost 6 billion HUF[1] and their yearly upkeep costs are around 3 billion HUF for the academic research institutes alone, they were not studied in-depth in Hungary either. Although it is without doubt, that the main function of science is to do basic research, it is still a policy requirement to somehow measure the rate of return on expenditures. Also, the research infrastructures' involvement in economic development is a must, however this goal shall not jeopardize basic research. This involvement can be, and in many case is, realized in the forms of applied research and experimental development. The examination of how to broaden the scope of

[1] Data of 2016.

potential partners in cooperative research infrastructures is aimed at RDI activities based on join/shared use of research infrastructure by enterprises and academic research institutions, and is a key question of the dissertation.

In my dissertation – going beyond the widely available statistics – I aim to measure the exact level of cooperation between the enterprises and the most important basic research organization, the Hungarian Academy of Sciences' research institutions through the usage of research infrastructures. Research infrastructure usage is a good indicator, since we can assume that any cooperation that involves research infrastructures has some R&D connection, therefore they can provide basis for a long-term cooperation. Beyond this, I will denote these cooperation not only by a binary variable (yes/no), but define the exact value of cooperation intensity.

This dissertation was made with the aim of raising attention – besides being a dissertation. I hope that its contents will contribute to better knowing and understanding RDI in Hungary and will start a process similar to Hungary's accession to some international research infrastructures. For many years, there was no progress in this area, however, together with the scientific community, a realistic and sustainable portfolio of memberships could be formed that supports basic research while is also beneficial for the economy. Tackling the issues discussed in the dissertations requires similar joint efforts - though at a larger scale.

2 The research process

The research was carried out by making use of both secondary and primary results through a top-down approach. The dissertation gradually narrows from the macro data and relevant literature to the research-specific data and thus results in showing the research infrastructures' importance not only by themselves but placing them (and showing their importance) in the context of the National Innovation System as well. By using this approach I aim to present the research topic in a broader context, making it applicable in practice.

In my dissertation I use four main sources for my hypotheses:

1. Relevant literature
2. Analysis of statistical data
3. Questionnaire data analysis
4. Qualitative interviews

At the very beginning of my research I already faced the problem that literature on research infrastructures is quite limited. Indeed, this subject is not widely studied by scholars, while from the policy side it is, at least to a certain extent, this fact in itself shows that there is some demand for related research, therefore this "less-researched topic" status is likely to improve. Policy materials (e.g. G7, 2015; ESFRI, 2016; Griniece et al. 2015; Science Europe 2016) mostly deal with major, international research infrastructures and their surveys and findings are applicable accordingly. Moreover, looking at their publishing dates, we can see that research infrastructures are only studied recently. Therefore one of my primary tasks was to put the fragmented literature on research infrastructure together and make a coherent description of the research infrastructures that was not available yet. Situation concerning secondary data was similar, as they do not provide adequately deep information on research infrastructures, only indirect data on them are available. From among these indirect statistical data I chose the ones indicating some of the research infrastructures' characteristics: for instance the R&D investments or the number of researchers.

These secondary data combined with the available literature proved sufficient for making the first conclusions and defining the directions of the further research. Also, these data make it possible to place research infrastructures in the National Innovation System. However, I had to reinforce or deny my hypothesis by primary data as well, the best method of it being by using a questionnaire. The questionnaire, which is detailed in the fifth chapter of the discussion, can be considered one that includes almost all research infrastructures (313 research infrastructures) in Hungary, thus being unique not only for the research field but also for researches in general. The results made it possible to make certain conclusions.

Besides the above-mentioned methods I used the qualitative interview method as it is very effective at low sample level. I made nine interviews which cover most of the examined infrastructures' stakeholders. The results of these provide important explanation for the phenomenon observed in the questionnaire, since many of these could be explained only through the interviews.

The applied methods made it possible to provide a full and coherent picture on the situation of research infrastructures and their possibilities to cooperate with enterprises. My conclusions and suggestions are made based on this solid basis in the last chapter of my dissertation.

I will note for each research hypothesis which chapter is the most closely connected to it. I also note for each which methods I used both from qualitative and quantitative side. It is important to note, that the primary and secondary research are not sharply distinguished in the dissertation. The main reason for this is that secondary data in many cases provides an explanation of the phenomenon observed through the secondary research and vice versa. Some of these topics are to be found in chapters 2.1 and 4.2 which present the research infrastructures' situation and characteristics in general. The contents of these (and others as well) chapters are gap-filling, as mentioned above, because source literature on research infrastructures are limited.

3 Research hypothesis and thesis

The hypothesis is structured in a way trying to take into account all quantitate actors that influence the usage of research infrastructures by enterprises. Therefore in my hypothesis the research infrastructures' physical location, role in R&D, scientific characteristics and financing are examined in the context of their impact on entrepreneurial usage. I set up some financial hypothesis putting future measurability as a goal. A general hypothesis was also made that examined the research institutions' performance and thereby the possibility of making them more effective in cooperation through organizational development.

The hypothesis and thesis form three groups:

3.1 Factors determining the possibilities for enterprise-research infrastructure cooperation

These factors mostly depend on the enterprises. The research infrastructures' owner has some influence on them, but only partially (researcher attitude) or indirectly (enterprises open to cooperation). As with regard to cooperation, enterprises are influenced by far more factors than those listed here (for instance R&D strategy, product development strategy, HR policies), but the examination of these go beyond the scope of this dissertation. For this purpose I

examined the factors influencing cooperation at the macro level and besides them the entrepreneurial possibilities of research institutions.

H1a. The number of enterprises which potentially require research infrastructure for R&D or innovation is limited in Hungary.

The basis of the hypothesis is provided by R&D statistics and the interview results. This hypothesis is general with regard to all the other ones as through the data on research infrastructures we can make a conclusion on the general possibility of cooperation in the field of RDI. Its primary backgrounds in literature are summed up in the dissertation's 2.1 and 2.2 chapter.

The hypothesis examines if there is a scope for research infrastructure and enterprise cooperation at all and if yes, how big it is. Is there a demand for research infrastructure services?

Several issues can be identified in general in the Hungarian RDI system when taking a look at the relevant data (detailed in the dissertation):

- low number of R&D enterprises
- low reputation of the Hungarian Academy of Sciences (HAS) among enterprises
- there is no quality R&D at the enterprises
- diverting effect of tenders
- large companies use their own infrastructure for R&D activities
- large enterprises conduct most of their R&D activities outside Hungary

The above problems are closely interlinked and their solution has to be made in a similarly interlinked way. The low R&D activity of the enterprises and the low demand for R&D of large companies could be improved by making the supply side working closer together, thus, higher education and academic research institutions should form a common R&D portfolio and provide easier access.

The hypothesis is supported by secondary data and literature as well – the new aspect lies in its approach from the research infrastructure side.

T1a: The number of enterprises which potentially require research infrastructure for R&D or innovation is limited in Hungary.

H1b. Cooperation involving enterprises and HAS research institutions mostly involve basic and applied research for long-term.

This hypothesis is supported mostly by qualitative results (interviews), from quantitative side I used the data as at H1a. supplemented by some other data as well. The theoretical background is detailed in chapter 2.3 of the dissertation.

The results of the secondary research (see 2.3 chapter of the dissertation) suggest that the number of research institutions and enterprises cooperation is very low. I examined if these few cooperation are in-depth cooperation or not. The results of the interviews confirm that among the current very few R&D cooperation, there are even less in-depth cooperation

making long-term cooperation possible; these are much more of an exception. In the field of experimental development we find relatively high activity, though the level of these are not very convincing, either. By summing the numbers of enterprises mentioned in the interviews it seems correct to suggest that the number of enterprises using the research infrastructures of HAS is around 150 to 200. (This number is supported by the CIS numbers as well, where the share of enterprises cooperating with public research organizations is only 2.8% for 2014.) This figure is around 5-10% of the R&D enterprises however it might be higher if we include the higher education institutions' research infrastructures as well. There are 30 cooperating research infrastructures at HAS and 100 in higher education. Considering these figures including higher education some 400-500 enterprises can be seen as possible cooperative partners – which could be partners for the HAS research infrastructures as well. However, the results of the interviews show that there are practically no such projects where academic research institutes cooperate with higher education institutions in terms of providing research infrastructure related services to the enterprises. The possible synergies of such cooperation are not exploited, either.

The situation is worsened by the fact that the scope of this very moderate demand from enterprises is also very limited: enterprises mostly wish to have measurements done, in some rare cases they require advisory services. In general it can be concluded that cooperative enterprises want to have solutions quickly to their emerging problems without any strategic scope. There are no long-term cooperation and the existing few ones are limited to one partner institution and no networks are involved. The scope of large companies appearing as cooperative partners is limited: in the interviews less than 10 companies were mentioned. The potential number of these companies is limited: they make up only 7.5% (119) of the R&D companies (KSH 2014).

T1b: Cooperation between enterprises and HAS institutions mostly involve applied research and experimental development and have a project character.

H2a. The ratio of research infrastructure usage by enterprises is defined by the location of the research infrastructure (HAS or higher education institution).

The theoretical backgrounds for this hypothesis are in the 2.2 and 2.3 subchapters of the thesis. I also used quantitative (NEKIFUT statistics) and qualitative (interviews) data as well. Studies suggest that cooperation level will be lower in the HAS institutes and this implies that the location of a research infrastructure determines its cooperation level with enterprises as well. To identify this I had to determine the ratio of research infrastructures cooperating with enterprises.

Table 1. Research infrastructures of HAS and higher education by their cooperation type with enterprises

Utilization by enterprises	Cooperating infrastructure	Non-cooperating infrastructure	Total	Cooperation ratio
HAS institutes	30	49	79	37,97%
Higher Education	102	132	234	43,59%
Total	132	181	313	

Source: Own calculation, based on NEKIFUT database

Data show that research infrastructures located at HAS institutes cooperate less than the ones in higher education, which supports the findings in the relevant literature. However, if we examine if there is a connection between the location of the research infrastructure and its cooperation activity, we find that these two factors do not influence each other (this is supported by a chi-square test as well). This result means, that the underlying cause of higher education research infrastructures tending to cooperate more intensively with enterprises is not that an infrastructure is at a higher education institution and not at a HAS institute. Cooperation, contrary to the expectations, happens not on the basis of institutional background. It is not characteristic for HAS institution research infrastructures to cooperate less or higher education infrastructures to cooperate more. As it can be seen, the cooperation ratio does not provide adequate answer to the nature of cooperation, therefore we will have to introduce the data on cooperation intensity in another hypothesis.

We have to make a new thesis based on the result before examining the matter from the cooperation intensity side.

T2a. The ratio of research infrastructure usage by enterprises is not defined by the location of the research infrastructure (HAS or higher education institution).

H2b. The intensity of research infrastructure usage is different at HAS institutes and higher education institutes.

This hypothesis is in close relation with H2a, as the data used for its testing and its theoretical background are both similar. The method for calculating cooperation intensity was formed prior to sending out the questionnaire. The value of cooperation intensity consists of the percentage of total usage of the research infrastructure and of the percentage of enterprise usage. These two figures result in the cooperation intensity value.

The intensity values differ significantly for the two entities. The intensity value was higher for the HAS research institutions than for higher education research infrastructures. This means that if a cooperation is actually formed, it is more intensive, though in general the cooperation ratio is lower for HAS research infrastructures. This result suggests that cooperation of HAS and enterprises through research infrastructures involve complex research activities which require more time and commitment – for instance, in the field of basic research. We will examine if this assumption is true in a later hypothesis.

The high cooperation ratio suggests that the cooperation intensity should be similarly high in the higher education sector. The lower value of cooperation intensity comes from the fact, that while cooperation happens more easily between higher education institutions and enterprises, they are usually not research infrastructure intensive. Therefore, thought these two sectors often interact with each other, no long-term commitment is made by the enterprises for joint research. The explanation of this phenomenon comes from the interviews. The enterprises wishing to get good results fast, cannot rely on higher education institutions, because these have limited capacities for research. In higher education institutions emphasis is on education , and research is only of secondary importance. In the academic research institutions research is in first place and education comes second. Consequently, enterprises that need results fast will approach the HAS intuitions – though as we will see this does not necessarily mean in-

depth research cooperation. We will also examine some of the methods usually offered to widen higher education-enterprises cooperation: the spin-offs and the technology transfer.

T2b. The intensity of research infrastructure usage is different at HAS institutes and higher education institutions.

H2c. The cooperation ratio of research infrastructures and the cooperation intensity do not correlate with each other.

We saw, that cooperation intensity and cooperation ratio takes different values for higher education and HAS institutions. As data on cooperation ratio is somewhat easier to gather (by simply asking the stakeholders if there is cooperation or not), it would be good if the value would indicate the intensity of cooperation.

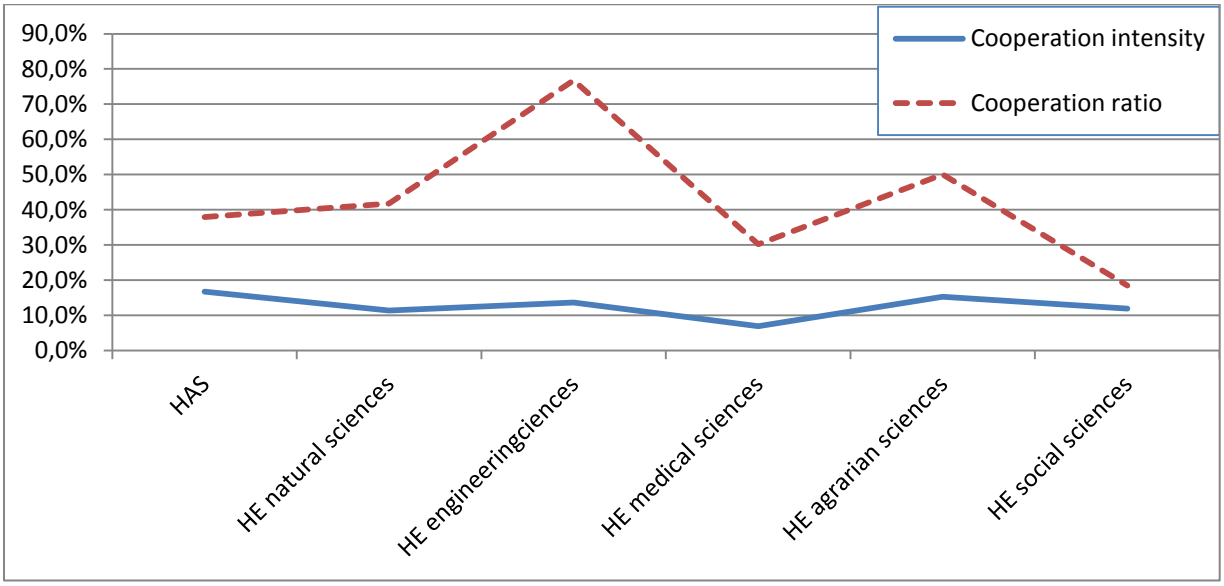

Fig. 1. Research infrastructures by cooperation intensity and ratio

Source: Own calculation, based on NEKIFUT database

When examining the two values for each scientific field (Fig. 1.), we find that the values differ from each other significantly; there is no correlation between the two types of data. This also suggests that the data on cooperation intensity provides more exact results than the cooperation ratio, therefore the usage of intensity data is proposed for further research – the cooperation ratio data does not have much use.

The difference between ratio and intensity means that the fact that cooperation is formed (represented by the ratio) does not necessarily mean that there is actually intensive cooperation (intensity). The high cooperation ratio is very likely to be the result of closer personal relations and greater visibility of the higher education institutions. The personal relations form the basis of trust between the higher education and enterprise partners which results in cooperation between the two sectors. In the case of intensity, however, actual R&D capacities (both from human and infrastructure side) play a key role, therefore HAS research institutions with their higher availability (which does not necessarily mean higher quality) have an advantage. This theory is supported by the interviews as well, though it must be

noted, that in the case of HAS institutions the personal relationships play a key role as well – but their amount is more limited than that in higher education.

T2c. The cooperation ratio of research infrastructures and the cooperation intensity do not correlate with each other.

H3. There is an optimal cooperation level between enterprises and research infrastructures that makes it possible to carry out the desired research activities by researchers and for enterprises to carry out their researches at the same time.

The basic idea of the thesis is in subsection 5.7.2. We have seen that it is possible to determine the extent of the current level of cooperation between research infrastructures and businesses. The question is whether this cooperation has an optimal level, that besides high level of scientific operations, allows the utilization of research infrastructures for economic purposes. To test the hypothesis I primarily used in-depth interviews, taking into account the results of subsection 5.7.2.

The definition of an optimal level of cooperation is also essential in the light of the changes in the environment of the research infrastructures is essential. The funding of infrastructures under the "old model" is not sustainable for several reasons (e.g. communication, policy), while the other end of the spectrum, where requirement of business use of research infrastructures is extended to basic research infrastructures as well, can cause more harm than good. When In determining the optimal level of cooperation the main scientific discipline where the research infrastructure is utilized must always be taken into account. Today's decision-makers take into account mainly the construction or maintenance costs of the infrastructure, and expect a faster economic return from it which can impose unrealistic demands.

The starting basis for the hypothesis was the research result referred to below, namely that there should be a balance between research and the economic activity which results in "medium" level of cooperation, that is, "the industry is involved in some, but not all academic projects". I examined this optimal level of cooperation from the perspective of research institutions in question. Assuming that this optimal level is 50%[2] it is apparently rather high, since the cooperation levels showed (whether we look at the secondary or the primary data) that this is unrealistic, even for countries with well-developed national innovation systems. Taking into account the previously showed data on collaboration I roughly estimated to 20% the optimal level of cooperation with businesses. The basis of the estimate is supported by the results of CIS surveys and by the number of R&D research units, 20 percent of which is roughly 300 research units, that seems realistic on the basis of the data presented above.

Each interviewee was able to tell what would be, in their opinion, the optimal level of business cooperation; this value was in each case around 30% A value of 30% A value of 30% means roughly 450 potential business research units that should cooperate in the field of research infrastructures - this number is slightly more ambitious, but not unattainable. To achieve this target joint efforts are needed in the field of research infrastructures.

[2] Meaning that 50% of operation time is used for business purposes.

T3. There is an optimal cooperation level between enterprises and research infrastructures that makes it possible to carry out the desired research activities by researchers and for enterprises to carry out their researches at the same time.

3.2 Factors affecting the research infrastructures' cooperation possibilities

In the following hypotheses, I examine the research institutions' tools for cooperation and their environment, which may affect the use of research infrastructure. These can be: the main discipline of activity of the research infrastructure, higher education cooperation having a key role in the supply of young researchers and in building relations with businesses, the method of financing also showing the pattern of the existing co-operations, and finally the impact of the use of research infrastructures by businesses on turnover.

H4. Higher education research infrastructures can be used primarily for experimental development projects, while the HAS research institutes infrastructures can be used primarily for basic and applied research by enterprises.

The hypothesis H1b is similar, but it specifically examines research infrastructure cooperation, also taking into account the current possibilities for cooperation. The theoretical basis is provided in subsections 2.3, 4.8, 4.9 and 4.10 of this thesis. For testing purposes, the survey on research infrastructures and the interviews were used.

The extent of business relations is greatly determined by the quality and type of relationships. Existing data and literature suggest the assumption that at HAS research institutes, more basic research is taking place, while in higher education, experimental developments dominate. This likely determines the orientation of business research depending on which type of institute they contact to have done a particular type of research (basic research / experimental development). The first hypothesis thus served as an exploratory basis by examining whether the type of institution where the research infrastructure located at or is accessible plays a role in cooperation. To determine this, I compared research infrastructures that did not cooperate with businesses to those that cooperated with enterprises. The cooperation ratio of research infrastructures can be well determined from the result.

The distribution of research infrastructures by scientific fields from the higher education and academic research institutions provides a spectacular answer. The number of natural science-related (that is strongly linked to basic research) research infrastructures have an average of 8 per HAS research institutes. Also, almost 84% of research infrastructures found here are linked to science compared to 38% in the case of higher education (Fig. 2.).

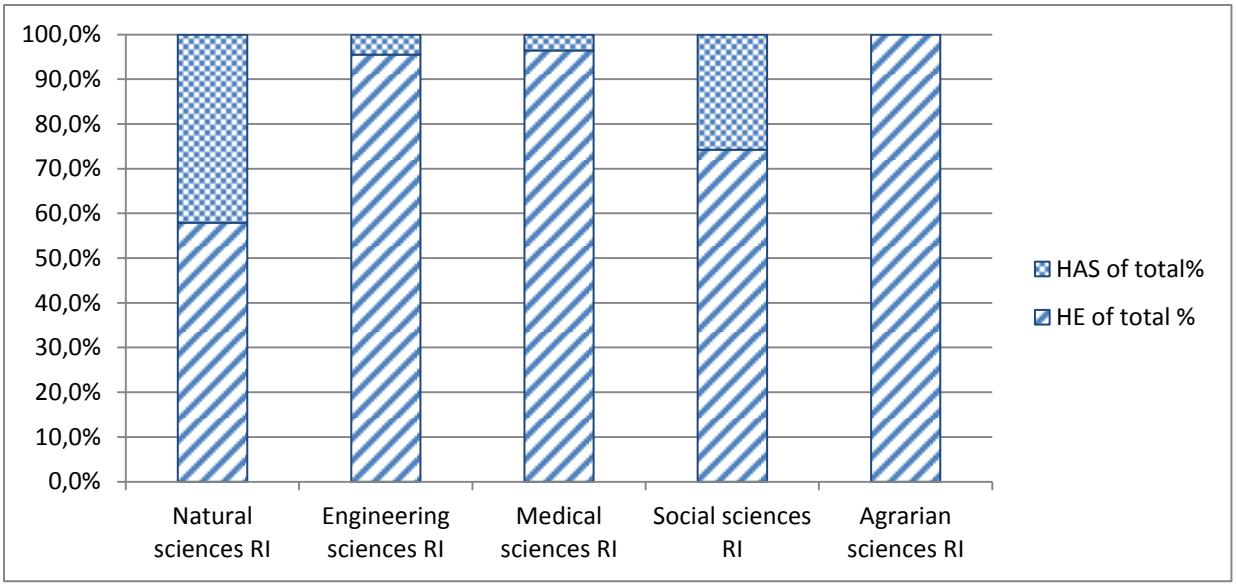

Fig. 2. Ratio of research infrastructures by fields of science and by institution type

Source: Own calculation, based on NEKIFUT database

We can conclude that the basic research related research infrastructures can be found predominantly in the HAS institutions (from among 79 HAS research infrastructures only 13 are not operating in the field of natural sciences), while in the higher education institutions research and experimental development related research infrastructures are present. Note that at the MTA research infrastructures, this high ratio is achieved by only 8 research institutes! In the case of other disciplines we must keep in mind the absolute values, as the number of research infrastructures differs significantly for each scientific field.

T4. Higher education research infrastructures can be used primarily for experimental development projects, while the HAS research institutes' infrastructures can be used primarily for basic and applied research.

H5. The research infrastructures' scientific field determines the cooperation possibilities with enterprises.

This hypothesis is slightly different from the others. I evidence through data the known assertion that research infrastructures have different characteristics according to their scientific fields and this effects their cooperation with businesses as well. Chapter 4.4 gives the theoretical basis of the thesis. This difference has not been studied yet through data. To confirm the hypothesis, quantitative methods based on the survey data are used, however, the use of qualitative methods, as the phenomenon is known in the literature, did not seem to be necessary.

The thesis provides empirical support that there are different possibilities of cooperation in the different fields of science. Of course, the data examined show the current cooperation levels. To examine the differences between scientific fields, we can take into account the data of the higher education research infrastructures, since, as we have seen, the HAS institutions research infrastructures are only involved in science. Fortunately, we can examine a significant number of data in total 234 research infrastructures. We have seen the importance

of scientific field in cooperation, now we examine if cooperation is determined by scientific field. Evidence shows that the scientific field determines the presence or lack of cooperation in the area of research infrastructures.

The chi-square test also confirms that there is a close relationship between the scientific field and the fact of cooperation with businesses. The analysis shows that the existence or non-existence of cooperation correlates with the scientific field, therefore the claim that there are different possibilities for cooperation by fields of science, can be regarded as justified. This conclusion is important for science policy: All research infrastructures have to be evaluated differently taking into account the scientific fields they belong to.

T5. The research infrastructures' scientific field determines the possibilities of cooperation with enterprises. The desired level of co-operation between research infrastructures and businesses must be determined and evaluated by taking into consideration their scientific field.

H6. Research infrastructure usage is an essential component of collaborations between higher education and HAS.

For the H6 hypothesis I examined the question of whether the actors - higher education and academic institutions - considered as one entity in the "Triple Helix" are working together in practice and if this cooperation is visible for businesses through a common research infrastructure use. Chapter 3 of the thesis serves as theoretical background of the question "How much can it be expected that higher education and academia acts together as one entity towards businesses?", is very important to be answered from the policy side. The question was examined through quantitative statistics (survey results) and qualitative interviews.

Table 2. Cooperation based on partner-type at HAS and HE institutions (number of mentions)

Source: Own calculation, based on NEKIFUT database

	Higher Education	HAS
Enterprises	162	24
Higher Education	118	**144**
HAS	**147**	70
No cooperation	63	18

Cooperation between higher education and research institutions of HAS appears to be very strong. Presumably, both parties benefit of using each other's research infrastructures to provide services for companies or carry out education.

Based on the data, research infrastructures located at higher education has a greater use by students, so the role of these research infrastructures is greater than those located at HAS. It is also true, however, that in terms of total utilization higher education institutions do not perform well. The difference between the infrastructure utilization of these two types of institutions is obviously due to the difference in availability of the infrastructures, but also

other factors play a role, such as incompetence or even the fear that the instruments will "break". The lack of students is another problem. Therefore the opportunity to reach students is a major motivation for cooperation for academic researchers.

In addition, the quality of research infrastructure is not clearly superior at the academic research institutions therefore the academy benefits mostly from the higher level of availability in terms of PhD education. However, research infrastructures don't help to countervail the small number of students and their relatively poor quality – in higher education, the new research infrastructures did not add much to the quality of students. Research infrastructures can have an impact only if teachers and instructors with professional and appropriate scientific knowledge are considered as part of these research infrastructures.

In higher education it is an issue that academic infrastructure is mainly used for doctoral studies, and at the same time there is the general lack of students – this leads to rivalry between the HAS and universities for "good" people. They often feel that the university educates the students and when they could be "used" for sophisticated research, colleagues from HAS siphon them off. However, if there is not enough researchers and PhD holders in higher education, there will not be an adequate level of higher education. It might be a solution to involve HAS researchers in other levels (BSc, MSc) of higher education.

Based on the above, we can conclude that the infrastructure related research collaborations are mixed between higher education and academic areas. On the one hand the competition for students in PhD courses appears, while on the other hand teacher researchers from the Academy focus on young researchers that can be attracted from universities (i.e. they prefer to teach in PhD courses). But sometimes even personal or professional conflicts play role as well. These have a major impact in particular scientific fields where there are already few students. The use of research infrastructures in the education would be a priority. The difference between "trained for research" and "trained through research" explains is exactly this: While in the first case research is not necessarily part of the education, in the latter one education is done through research, which means the use of research infrastructures in many area. As a result the infrastructure will be used in the future by the student who already used it during his/her studies – either as a business professional or as a researcher. The fundamentals of cooperation, despite these issues are strong: The level of higher education and HAS cooperation in connection with research infrastructures was roughly estimated at 30% of all research infrastructure cooperation.

T6. Research infrastructure usage is an essential component of higher education and academic collaborations.

H7. The cooperation intensity of research infrastructures is in connection with the operator institution's income from entrepreneurial activities. Higher research infrastructure usage intensity is reflected in the incomes as well.

The issue of financing research infrastructures motivates their operator institutions to receive external business revenues through a variety of cooperation. The theoretical basis of the thesis is included in chapters 4.6, 4.7, 4.8 and 4.9. When testing the hypothesis I was curious whether the research infrastructures' entrepreneurial activity results are visible in the incomes of their operator institutions. This hypothesis is tested for if it worth using the research infrastructures for entrepreneurial activities or not.

Based on the survey data we get an idea of what is the expected role of external (business) financing for research infrastructures. This data could show the types and distribution of cooperation in the areas examined (HAS research institutes and higher education).

A more accurate assessment of business turnover was made possible through the use of HAS research institutes' data. I received these data from HAS and for research purposes I treat them anonymously. The business turnover was in each case compared to the intensity of cooperation to examine that more intensive research infrastructure use correlate with business turnover. The former data includes non-research revenue as well (as I found that institutions don't always handle research and non-research incomes separately).

$$\text{Business income} = \frac{\text{research income} + \text{nonresearch income}}{\text{total income}}$$

The research infrastructure usage intensity for each research institute was calculated by taking the average of each institution's intensity.

Among the examined institutions (along with the principles described above) I didn't take into account those not participating in enterprise collaborations and those with no available research infrastructure intensity indicator. The result is shown in Fig. 4.

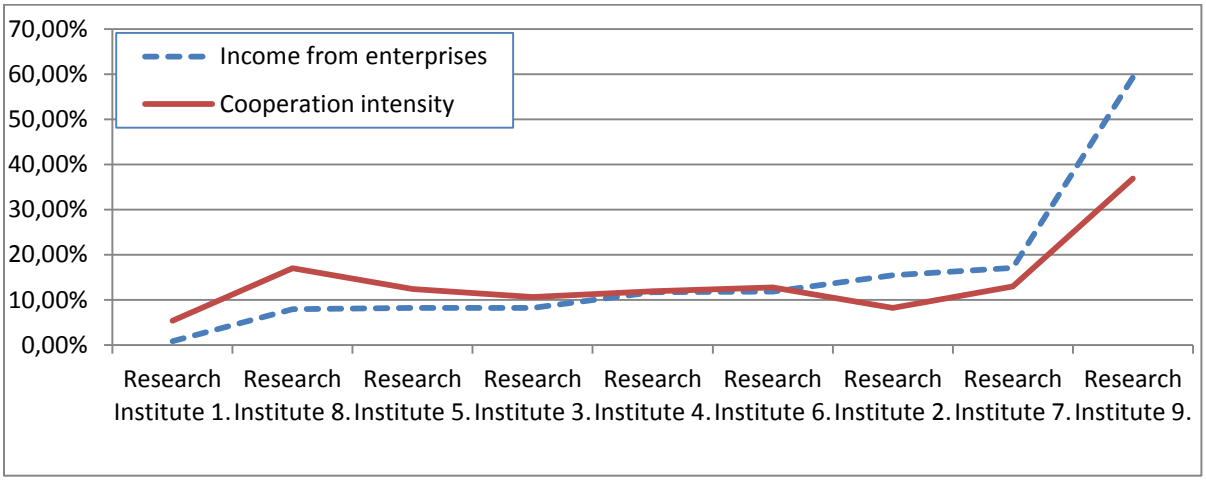

Fig. 3. Income of HAS institutes and their research infrastructures cooperation intensity

Source: Own calculation, based on NEKIFUT database

The chart clearly shows that the value of cooperation intensity correlates closely with the turnover. We can confirm this through a correlation calculation as well. There is a linear relationship, P = 0.930010595, between the income of the research institutions and their research infrastructures' cooperation intensity. The correlation does not in itself mean that a given phenomenon's *explanation* is found, but in this case it is not too bold to say that the cooperation intensity of research infrastructures has a correlation with incomes – it effects them in a positive way.

Knowledge of costs and revenues of research infrastructures in all the institutions would be essential. It would also result in greater cost efficiency and would shed light on savings opportunities - conscious management would provide better opportunities for all institutions. For the future assessment of research infrastructures (should it target either scientific or business performance assessment) it would be imperative to know this data.

T7. The cooperation intensity of research infrastructures is in connection with the operator institution's income from entrepreneurial activities. Higher research infrastructure usage intensity is reflected in the incomes as well.

3.3 The possible forms of research infrastructure cooperation and the factors influencing it

The previous hypothesises examined the nature of cooperation both from nosiness and from research institution's side. In the following ones I will examine the methods of cooperation through three key factors: the access to research infrastructures, spin-offs' and technology transfer researcher's attitude in business cooperation.

H8. Typically, business enterprises have an access to research infrastructures through the infrastructures' partial usage.

The national research infrastructures provide predominantly one-sited and local access. This in itself does not make it easier to use them, which would complicate the full/ partial /closed types of access. The question is under what conditions can business enterprises use the research infrastructure once cooperation is established. This hypothesis was tested through the survey responses received as a result of qualitative analysis, text analysis and interviews.

One of the direct indicators of cooperation with companies is the way of accessing the research infrastructures. There are three main types (full, partial, closed) of access, among which my a priori presumption was that the typical method of access to research infrastructures is partial access, that is, research institutions carry out research jointly with researchers from business. The assumption behind the idea is that the examined research infrastructures are in all cases "open", they provide controlled access for external users. This openness is a fundamental principle of the ESFRI and is a key element in the "Open Innovation" concept of knowledge transfer. If the partial openness is an existing cooperation form, it can form a real background to knowledge transfer and policy could strengthen this. Possibilities to access research infrastructures were assessed based on the NEKIFUT questionnaire.

Evidence shows that the possibility to use a research infrastructure virtually (i.e. remote access) is not widespread: This kind of accessibility, regardless of the type of the institute, is possible in 15-20% of the cases. Interestingly, access to research infrastructures does not depend on whether it is multiple sited or single sited, either. The above show the possible access to research infrastructures but the actual way of use can be seen from the interviews.

The results of the interviews show that collaborations are typically concentrated on measurements where there is no need for the business enterprises' researchers to carry them out. Although openness can be seen in certain areas, it is far from the level that would be necessary to build a meaningful knowledge transfer cooperation. This is not only the research institutes' fault. In many cases, business side lacks the knowledge to use the infrastructures or is not interested to make the necessary measurements. They are interested only in the result: yes or no. In this context, the question arises of whether the advantage often stressed in the

context of the socio-economic impacts that businesses have access to research data, is a real (or realized) benefit. Presumably, businesses are only interested in data which were produced specifically for them (their project).

T8: A typical way of access to a research infrastructure by businesses is the production of processed data by the research institutes.

H9a. In the cooperation of HAS institutions and business enterprises spin-offs play a marginal role and technology transfer is weak.

The theoretical background of this thesis can be found in Chapter 3 dealing with this issue in-depth. By testing the hypothesis I was curious if the generally proposed methods of cooperation namely technology transfer and spin-offs have any possibilities in research infrastructure cooperation. The question was not examined through quantitative data; from qualitative side, however, a comprehensive picture could becreated by means of the interviews.

An obvious form of cooperation would be the establishing of research institute spin-offs, through which researchers of the institutes use the research infrastructure, while at the same time they perform entrepreneurial activities as well. Through such activities they connect closer with RDI actors and make stronger technology transfer possible. Strong entrepreneurial activities in RDI ultimately allow more intense technology transfer. In the literature, however, it can be seen that this issue should be handled with care. If we look at what's going on regarding spin-offs and technology transfer among academic research institutions, unfortunately, we see that caution is not unfounded.

Creating spin-offs does not seem a good solution, mainly because researchers who wish to undertake already do this, therefore to generate a new wave of spin-offs would not result in a better use of research infrastructures by businesses. The researchers' attitudes should be changed regardless of this. It is also true that this issue is more manageable in an institutional framework, so technology transfer as solution is analysed in the interviews. According to literature, a technology transfer office could be the single point of contact on all institutional offers. In some institutions, this feature is partially successful. In other cases it is the opposite way, however, the need to create a strategic TTO arises. This activity, however, have to be performed on professional level. A prerequisite for this would be that the TTO has an overview on the research activities.

Based on the interviews, the assessment of technology transfer is at least mixed. On the one hand many interviewees reported successes, partial successes, while on the other hand technology transfer is often a complete failure. The viewpoint that the entire academic research network can emit a substantial volume of licences and services, which would facilitate the technology transfer, might be a good solution. We see, however, that the current organisation (public bodies) of HAS don’t make this possible, mainly due to lack of capacity. However, some form of technology transfer - despite its problems - is needed.

T9a. In the cooperation of HAS institutions and business enterprises spin-offs play a marginal role and technology transfer is weak.

H9b. The efficiency and possibilities of cooperation with business enterprises is greatly influenced by the researchers' attitude and the lack of management approach.

The available literatures on the attitudes of researchers are examined mainly in subchapter 3.3. of the thesis, but the question runs through the whole Chapter 3. I believe that it is a good indicator on the issues of cooperation and trust, how opportunities for cooperation relate to the people involved in them. The examination was possible from quantitative side, so I studied on the basis of the interviews, if the findings in the relevant literature concerning cooperation are true to the cooperation involving research infrastructures as well.

The researchers' attitudes are a particular hypothesis, as it is of key importance - we have seen that these are decisive in the success or failure of cooperation. Under researchers' attitudes I understand the attitude towards businesses and openness. In other words: What is the supply side of R&D on the research institute side? The majority of interviewees represented the HAS research institutes and their views determine the possibilities on the future cooperation.

According to some of the interviewees, the researchers have no sense for any actual usage of research results and have no such motivation either. Overall, it appears that economic activities are more tolerated (endured) rather than supported activities. As long as there are possibilities to apply for grants, these are preferred (in accordance with the literature) over collaborations with business enterprises, that remain a side activity. From the researchers' side this is an understandable attitude, but it also seems that there will be no significant changes in the business cooperation. To tackle this issue it would be necessary to put together the rather fragmented landscape of technology transfer activities.

Examining the available literature on research infrastructures' operation (ESFRI 2016, ESF 2013, Technopolis 2015) it is a basic assumption that proper research infrastructure operation is not possible without a proper management. This means the presence of not necessarily scientific managers, who can deal with financing, legal and operational issues with a professional management approach. Currently in Hungary this is mostly the task of scientific colleagues.

However, setting up a proper management structure is not possible in the HAS institutions, since their operation is way too research-oriented. In spite of this it would be advisable to involve non-scientific experts in their activities. This issue reaches beyond the cooperation between business enterprises and research infrastructures but it is a key element of these as well.

T9b. The efficiency and possibilities of cooperation with business enterprises is greatly influenced by the researchers' attitude and the lack of management approach.

4 Results of the research, conclusions

By accepting the above theses we can identify the key factors influencing the usage of research infrastructures by business enterprises. These factors play a major role in the efficiency of the national innovation system as well.

I numerically underpinned that roughly known fact that there is a limited number of RDI companies in Hungary. In addition, I have also shown how large is the number of those that could possibly use the research infrastructures for their R&D. The market of research infrastructures "market" is not very significant: We have seen that we can speak up to 400 to 500 enterprises. We have also seen that in the field of R&D activities, major companies require only very limited use of research infrastructures and substantial increase in their number cannot really be expected. Even if a large company builds up its R&D centre, it is more than likely that it would not build its R&D activities on the more than 20 years old academic research infrastructures, but would bring its own research infrastructure. Regardless, such cooperation is possible, as there are some cutting-edge research infrastructures that would allow it, but a dramatic change in the magnitude and nature of the research infrastructures is not expected.

The nature of research carried out using research infrastructures is rather unanimous: The available research infrastructure regardless of its nature – should it be cutting-edge or an almost obsolete measuring instrument – are mostly used for experimental development and measurement. The joint R&D projects which would be carried out on longer terms in basic research are rather an exception than a rule. The landscape of R&D stakeholders and the lack of demand side for such activities do not make it possible to carry out in-depth cooperation. The concept that large companies will use research infrastructures for long-term basic and applied research does not seem viable. It is much more worth to ask the question: What motivates the businesses to use the research infrastructures? We saw that the ratio of infrastructures used is independent from its operating institutions' type, and also that in higher education there are more research infrastructures that could be used by business enterprises.

The quality (intensity) of usage shows sharp difference: While it is true that in higher education there are more infrastructures and thus more cooperation, where quick and quality results are needed, the usage of infrastructures in the academic research institutions becomes preferred. It seems that higher availability makes higher quality services for academic institutions' research infrastructures which also have the benefit of quickness. Here, in contrary with higher education, research takes time away from research that can be rescheduled and not from education that cannot be rescheduled.

The number of businesses using the services of the research infrastructures is unlikely to grow in the current structure. Moreover, we saw that their services towards already existing cooperation are fragmented as well, meaning that these cooperation are rarely formed on institutional or research infrastructure level; rather on an ad-hoc basis than some sort of a strategic approach. A change in this situation is quite possible, since the managers of different research institutions defined a rather high level of optimal cooperation, therefore from managerial side the openness to build cooperation between enterprises and research infrastructures exists.

It has to be taken into consideration that there are different possibilities for cooperation. We saw that research infrastructures have different characteristics according to their scientific fields, limiting their possible usage by business enterprises. There are more opportunities to cooperate where the scientific field is closer to applied research and experimental development. I managed to underpin this statement through the use of data as solid evidence, defining the current and expected levels of research infrastructure usage as well. In practice this means that in business cooperation those research infrastructures have to be taken into account which make it possible to have cooperation and for instance in the fields of social sciences there is no point to make great expectations from them in this sense. This does not

mean that they should not be called to account for their socio-economic impact! Here we also have to make a sharp distinction between the two components as their economic impact is in many cases limited and not obvious. It also has to be taken into account that also in the field of natural sciences many research infrastructures exist which are usable only for basic research . One such example is an experiment in CERN where according to our current knowledge no practical usage of the results is possible. However, the economic impact can be expected in this case as well, through licensing, operation, building etc.

To fully utilise research infrastructures it is needed to have the adequate supply of researchers and to have many students who are aware what research infrastructures are at disposal at higher education and academic research institutes. The importance of the supply of these two "factors" is obvious. However, it must be stressed that the long-term effects of the „trained through research" concept can appear in the business enterprises' RDI activities as well. It would be important to broaden the number of students participating in this kind of education (education through the use of research infrastructure), because this could help in the growing of research-infrastructure intense projects at business enterprises.

Data on financing underpin the same extent of cooperation with enterprises both at HAS research institutions and in higher education. Other than business sources are almost at the same level at both institution type, suggesting that the financial model of operation is very similar regardless of the type of its operator institute (research instite or higher education institution). It is remarkable, that the usage of research infrastructures pays off: There is strong correlation between research infrastructure usage intensity and incomes from business enterprises. This means research infrastructures have significant effect in incomes – to put it simple we can say it worth to use a research infrastructure in cooperation with business enterprises.

The way this cooperation happens is a common decision of businesses and research institutions. Obviously, when a company strives for a quick and superficial cooperation (e.g. to have a measurement done) it is enough for it to get the results only. This is the most effective solution for both parties in such cooperation. This access to research infrastructures does not generate noteworthy technology transfer even less knowledge transfer. Unfortunately the current usage of research infrastructures in most cases reaches the level of a vending machine: the input is given and the institutions provide the output. For longer term, in-depth R&D cooperation at least a partial access to the research infrastructure would be needed. (Full access in many cases takes too long or is financially inefficient.) This could provide the basis for knowledge transfer between research institutions and business enterprises. However, both parties need to collaborate: Researchers should be open to give knowledge, while business enterprises should be open to make use of this knowledge after implementing it.

Theoretically, spin-offs that are created for the use of research infrastructures could answer the question how research results should be channelled towards businesses. Also they would solve to have solid business partners that use the infrastructure on a long term providing floor for long-term cooperation as well. The experiences with spin-offs hardly support this theory. On the one hand they are efficient mostly abroad and where there is an innovation "core", on the other, their domestic experience either generally speaking or focusing on research infrastructures is quite depressing. One of the main reasons of this is the lack of the demand–side market, therefore a good product (which in many cases is the sole product of the spin-off) is not enough for success, as the revenues quickly fell – or did not begin to grow at all. In spite of this the institutions sometimes formed a spin-off for a good product, or, what happens most of the time, the researchers themselves carry out entrepreneurial activities. Therefore at

the research institutions the possibilities of technology transfer should arise as solutions for this matter. There are initiatives for this, but there would be plenty of space for making it more effective and to have bigger outreach.

We cannot abstract from the fact that a somewhat ambivalent motivation for cooperation on the supply side of research infrastructures is concerned. Researchers usually want to do research, this correlates with the goals of the research institutions and their infrastructures goals, and in many cases this forms a part of their Founding Documents. In the thesis I showed that the approach that research by itself is important cannot be defended anywhere in the world, neither in Hungary. This pushes research institutions to seek alternative financing sources stronger and stronger. One of these sources are the tenders, which, since usually one has to provide scientific results for an application to be successful, are more comfortable than cooperating with businesses. The diverting effect of tenders is in many cases tangible. This makes it possible that there are research infrastructures which could be used by businesses but they are not aware of the existence of these, as they cannot get access in either form. The other source could be the cooperation with business enterprises. Here in many cases the scope of cooperation is of little scientific value; the most often cooperation involves mere measurements which do not bear new research possibilities. The latter is in the first place for researchers and this – to „be able to conduct research in peace" - is the main reason why they do not attempt to make business use of the research results even if there would be a possibility of it. Researchers do not prefer cooperation, which results in the perception that they lock themselves in their „ivory towers".

5 Suggestions

To provide a solution on the above I suggest a new working model that involves various stakeholders which can activate and increase the R&D demand of the business enterprises and also the supply of higher education institutions and academic institutes.

An important part of my research is that I believe I found one of the key elements which could help the national innovation system to operate more efficiently. These are the research infrastructures, which through providing floor to cooperation for business enterprises and academic sector play a key role. To strengthen their role the current operating scheme of RDI should be altered, strengthening the project and management approach and also to grow the number of stakeholders potentially using research infrastructures. To this end the following should be considered:

a. A common research infrastructure service portfolio should be formed between the academic and higher education research institutions. This broad service portfolio would make it possible that businesses do not choose infrastructure but service. The quickest way to achieve this is to include the academic institutes' services in the higher education technology transfer offices' services. This way such scientific hubs could be formed where business enterprises had to approach only a single point of contact when seeking research services. It is important, that these hubs should be connected not to institutions but rather to economic fields (biotech, ICT, manufacturing etc.). It would be possible to have interlays between the hubs' portfolio to avoid unhealthy competition for higher valued fields. Also, the scientific hub would make the licences in its scope available in some traceable (registration) form. In optimal case these (when neither the researcher nor the institute wishes to utilize the license) - would be freely available for business enterprises. To rise the interest of the

researcher or the institute there are many possibilities: for example the researcher (or the institute) receives grant from such usage, or the license is free, but only to the extent that it requires the researcher to take part in the implementation. Providing the licenses for free is a key element, which is supported by the fact that we are speaking by state financed research results – business sector has a legit expectation not to pay for knowing the license.

b. To strengthen the demand from business side it is important to strengthen the potential number of users. This involves introducing research infrastructures to each student showing not only their scientific but economic benefits as well. To this where it is possible, the actual research infrastructure has to be used, and also researchers in research institutions should take more part in BsC. and MsC. education as well. It would be imperative that such teaching activity is financed somehow.

c. Research infrastructures could be operated more efficiently if in the research institutions there would form an organizational unit dealing solely with the operation, development and usage of research infrastructures. We saw the magnitude of costs for upkeep such infrastructures and also how less these costs are currently controlled. Such unit should be formed at each research infrastructure upkeep organization which could provide data for the government on their operation.

d. It would greatly help the research infrastructures' usage by business enterprises if in the forming higher education-business cooperation research infrastructures would appear in the role of open laboratories. It would also be important that this would not only involve measurements, but the forming of joint projects which make knowledge transfer possible between businesses and research institutes.

The results of the research have numerous other ways for practical use. One of these is the harmonisation and synergy building between research institutions and higher education activities. By itself it is likely that none of the involved parties will initiate this, therefore governmental measures should be taken to make this happen. It would be timely, though since in 2016 there were major resources allocated through applications to higher education-business enterprise cooperation. These would make it possible to form applied research institutions like the German Fraunhofer or Max Planck institutes. For this the portfolio of higher education institutes (as the primarily contact to businesses) should be strengthened and broadened, so that they could provide solutions on a wide basis. It would worth making a questionnaire among the businesses to seek answers to the above suggestions. How big would be the demand for free licenses? Under what conditions would businesses utilise these? What other help would they need to use these?

Full integration of research infrastructures to higher education would not be efficient, however, since we saw that research is separated from education. Through the integration the institutions' advantage that makes it possible for them to take part in more intensive cooperation, namely the higher service level would be lost. Moreover the two different culture's blending would pose a major challenge to any higher educational institute. It would be important to minimize the competition between the relevant research institutions and higher education institutes. To coordinate this activity goal it could be a good solution to set up a unit with proper management responsibility which strongly cooperates with the scientific fields – this could be the university chancellery as well.

Before any reorganization it has to be assessed what are the possibilities for research infrastructure-type cooperation, the service portfolio, utilization, business usage level and

intensity, costs and of course scientific utilization have to be examined. An element of these could be the presented intensity indicator or the inspection of business enterprise income. Also the soft elements, such as research infrastructure management organization should be assessed. On the scientific side it would worth to see what researches are carried out on the infrastructures – from policy side the assessment in a single framework and the evaluation of the results would be important.

Where it is possible, the socio-economic impacts of research infrastructures should be presented through conscious communication – this can help in raising interest for the scientific career, which is also important. Research infrastructures have to be considered as units that are organic parts of the domestic and European innovation system and serve as a net to the different stakeholders in the system should they be researchers, students or business enterprises. To exploit the possibilities of them is the common responsibility of the RDI sector's actors.

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