Barriers to the Industrial Usage of Megascience Facilities - The Case of the Synchrotron Radiation Source HASYLAB

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Abstract: *Private firms may benefit from public megascience facilities because they may directly conduct research at these laboratories or they may use results of scientific research. In this paper we argue that "supply-" as well as "demand"-sided barriers may hinder the direct industrial usage of megascience facilities. We present the results of a case study that is a based on a questionnaire of the scientific and industrial users of the German synchrotron radiation source HASYLAB (Hamburg Synchrotron Radiation Laboratory). Results suggest that on the demand side the lack of the firms' absorptive capacity and financial constraints are the main reasons for the moderate, direct industrial usage of synchrotron radiation sources. Small and medium size firms, which are mostly not able to conduct own research in these laboratories need scientific intermediaries to make scientific results of megascience facilities useful for firm's innovations.*

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JEL Classification: H50, H70, O31, O38

1. Introduction

Public megascience facilities are primarily designed to "produce" basic scientific knowledge. However, the construction and the maintenance of these facilities are very costly and their benefits to society may accrue – if there are any – in the far future. During the last years, politicians have become increasingly interested in the industrial utilisation of these expensive research laboratories because tax burdens and budget deficits have become a major reason for public discern. Therefore, expensive megascience facilities are in competition for public financial support with other research projects in more applied areas of science[1] and with other kinds of public expenditures too.

How may private firms benefit from megascience facilities? First, firms may *directly* use scientific instruments at megascience facilities that their in-house labs could never afford (Langford and Langford, 2000). The access to specialized technical equipment is an important advantage to usage of public laboratories (Audretsch et al., 2002). Secondly, firms may benefit from the scientific research done at megascience facilities. This second way includes cooperation projects between firms and the laboratory as well as the diffusion of scientific knowledge into the business sector by human and research capital in the long run. What politicians may have in mind when talking about industrial utilisation of public research is not the latter, but that the direct industrial usage of megascience facilities or industry-science research cooperations may have higher economic effects outside the labs.

In this paper, we discuss barriers that may hamper the *direct* industrial usage of megascience facilities. Such barriers might explain why only a few private firms directly use research instruments and methods at megascience facilities. We argue that not only *supply-sided* barriers, such as access conditions or research assistance in the laboratories, are relevant

[1] See Economist (2000) for a discussion with respect to CERN.

to explain this fact but *demand-sided* barriers, e.g. the lack of scientific knowledge within private firms[2], may play an important role, too.

We present the case study of the **Ha**mburger **Sy**nchrotron **Lab**oratory (HASYLAB) in Germany which can be viewed as a typical example for a megascience facility that has been founded as a publicly financed institution for basic research some decades ago and that recently has started to open its facilities for industrial usage. But despite a high number of possible industrial applications of synchrotron radiation research for industrial purposes, like materials science, medical science and biological sciences, as well as a high effort of HASYLAB to offer attractive research conditions and research assistance to private firms, the number of firms using this facility is still moderate. Our results suggest that "*supply- as well as demand-side barriers*" do indeed hamper the industrial usage of HASYLAB. We suspect that this is not specific to HASYLAB, but concerns other megascience facilities too.

The remainder of this paper is organized as follows. Section 2 explains the theoretical relationships between megascience facilities and the industrial innovation process. We identify theoretical demand- and supply-sided barriers for a wider private usage of megascience facilities. In section 3 we investigate these theoretical thoughts by the results of our case study at HASYLAB. Numerous interviews with scientists at HASYLAB and with responsible R&D staff of private firms using this laboratory showed reasons for the low industrial usage of this laboratory. A conclusion for the policy debate around megascience facilities and their industrial usage follows.

[2] Schartinger et al. (2001) provide empirical evidence that lack of information on university research has a negative impact on the probability to interact with university departments.

2. Industrial Usage of Megascience Facilities

2.1 Megascience facilities and the innovation process

According to the traditional understanding of the innovation process, new scientific results form the basis for the development of new technologies, which diffuse across the economy (Schumpeter, 1942). Within this sequential model – often called "linear model" – megascience facilities provide highly specialised instrumentation and experimental techniques. The scientific knowledge that is generated by the research of scientists using (and improving) these instruments and techniques may diffuse ('trickle down') into the industry where it allows or facilitates industrial innovations. Possible channels of diffusion are articles in scientific journals and congresses, for instance. According to this model, innovation is a one directional process where scientific research may influence and improve industrial research but not the other way around. However, the shortcomings of the linear model have been criticised by several authors. Kline and Rosenberg (1986), for example, have presented the "chain-linked model" which takes into account that interdependecies and feedback effects between different stages of the innovation process exist.

Another important point has been made by de Solla Price (1984). He states that advances in instrumentation and experimental techniques are of major importance for radical advances in science as well as in practical application since both use the same instrumentalities.[3] Here, it is the *common* usage of instrumentation and experimental techniques that creates a link between scientific and industrial research. De Solla Price argues that the Galilean telescope is the most prominent historical case for this link. The telescope formed the basis for radical theoretical advances in fundamental science and its success induced a number of industrial innovations (optical instruments). Viewed through the lens of de Solla Price's approach, megascience facilities, like synchrotron radiation sources, are instrumentalities which may be used by scientific as well as industrial researchers.

We want to describe the role of megascience facilities in the (industrial) innovation process in a very simplistic framework where only two different relationships between megascience facilities and industry exist (see figure 1).[4]

First, firms may use megascience facilities *indirectly*. They may place out R&D contracts to scientific users of megascience facilities and/or they may cooperate with such scientific users. In contrast to the linear model, scientific researchers that cooperate with industrial firms carry out at least some of their research with practical goals because the aims of cooperative research are specified by the firms that we call *indirect industrial users*.

Secondly, firms can *directly* use instrumentation and experimental techniques provided by megascience facilities. Here, the influence of megascience facilities on the firms' innovation process does not necessarily depend on the research of scientific users.[5] Instead, the connection between industrial and scientific research is due to the fact that industrial researchers and scientists make use of the same instruments.

In practice, however, the number of firms that are directly engaged in research at megasciene facilities is quite small. This may be due to the fact that intruments and experimental techniques are designed to fit the needs of basic scientific research rather than the needs of industrial research. Another explanation may be that direct industrial usage of megascience facilities is hindered by a number of barriers. This is visualized by the dashed line in figure 1.

[3] De Solla Price (1984) calls instrumentation and experimental techniques instrumentalities.
[4] Knowledge diffusion is not considered here.

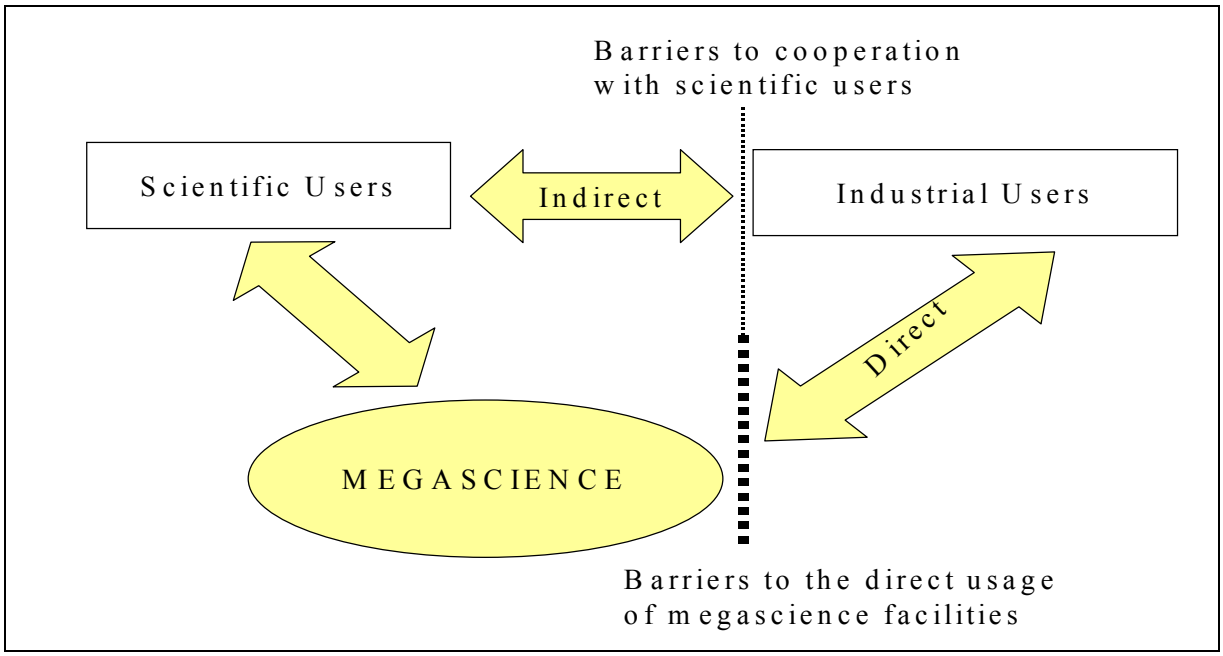

Figure 1: Megascience facilities, industrial innovation process and barriers to industrial usage

2.2 Barriers to the industrial usage of megascience facilities

In general, barriers to the industrial usage of megascience facilities can be divided into supply-sided and demand-sided barriers. In Table 1 main barriers are listed:

Supply-sided barriers	**Demand-sided barriers**
no/scarce access to megascience facilities	*lack of knowledge about possible applications*
- preferential treatment of scientific users	- no in-house scientific research
- inflexible schedules	- low technology firm
unpleasant contract conditions	*financial restrictions*
- confused price systems	- internal: high risks of new research methods
- confidentiality not guranteed	- external: credit rationing (small firms)
no/scarecely service to industrial users	*problems of communication inside the firm*
- no assistance to running experiments	- conflict between researchers and management
- no assistance to analysing results	- long vs. short run perspective

Table 1: Main supply- and demand-sided barriers to the industrial usage of megascience facilities

[5] However, researcher at megascience facilities may assist the industrial users or the management of such facilities offers special services to industrial.

Supply-sided barriers: Langford and Langford (2000) state that after the Second World War, *access rules* which focused solely on scientific quality of experiments emerged.[6] Of course, such rules discriminate against direct (and indirect) industrial usage of the labs and are indeed a relevant supply-sided barrier. Moreover, inflexible access to research instruments does not fit with the needs of firms because this may slow down firms' development of new or better products. The *contract conditions* for industrial users regarding user prices or confidentiality may pose another barrier to industrial usage. Confused user price systems may deter firms from using megascience facilities. Confidentiality is important for industrial firms since they fear the leakage of their knowledge to their rivals. A third main barrier on the supply side might be a *lack of service to industrial users*. Since firms mostly do not have detailed knowledge about the highly specialized experimental equipment and the methods, they may need assistance in explaining usage of the laboratories, preparing and doing experiments and interpreting results.

Demand side barriers: The knowledge about possible applications is a prerequisite for the industrial usage of megascience facilities. The successful implementation of scientific knowledge and the direct industrial usage of newly developed research instruments strongly depend on the firms' ability to make use of them. Cohen and Levinthal (1989) argue that firms have to build up an "absorptive capacity" in order to assimilate and exploit knowledge from outside organisations and that this capacity depends positively on the firm's own R&D efforts. The study of Gambardella (1992) supports this hypothesis. He provides evidence that in-house scientific research of large U.S. pharmaceutical firms raises their ability to make use of outside knowledge (public science). Thus, one would expect that the firms' absorptive capacity determines the quality and the quantity of the relationship between industry and megascience facilities.

[6] They also postualate that rules of access to megascience facilities are an important indicator of the relationship

Moreover, communication problems within a firm may be a barrier too. Researchers and managers may evaluate the usage of megascience facilities in different ways. While researchers may recognise the advantages of the usage of newly developed instruments and methods in the public lab in the long run, managers may build their decision more on short-term cost-benefit-analysis. From a business point of view the usage of new methods may seem to be too risky and uncertain compared with relatively certain results of traditional techniques. In this sense, new research methods compete with traditional and well-known methods.

3. The Case of the Synchrotron Radiation Source DESY/HASYLAB

3.1. The Survey

We have identified 13 firms that have been current and former direct industrial users of HASYLAB and 11 of these firms have been willing to give an interview.[7] We carried out structured interviews on the phone with 8 of these companies and more in depth personal interviews with 3 companies. Our contact persons for both types of interviews have been R&D managers in the surveyed firms.

Moreover, a sample of 150 scientific users of HASYLAB has been surveyed in order to identify *in*direct industrial users of HASYLAB. In a first step, we have sent a questionnaire to 150 different direct scientific users[8] of HASYLAB by mail and e-mail. Amongst these, 72 institutes answered the questionnaire, which corresponds to a response rate of almost 50%. This questionnaire contains a question concerning the industrial cooperation partners of the scientific users. We have explicitly asked for those cooperations that deal with the usage of synchrotron radiation. Among the responding scientific users, 19 percent have reported that they have such cooperations and these scientific users provided us with the names and

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of the three partners in megascience: university, government and industry.

addresses of 17 indirect industrial users. In a second step, we have sent by mail another type of questionnaire to 13 firms that have been identified as (pure) indirect industrial users of HASYLAB.[9] We have received questionnaires filled in by 6 of the 13 companies.

3.2. Supply-side barriers at HASYLAB

HASYLAB opened its doors for direct industrial users in 1995 after a general agreement between the German Federal Government and the directory of HASYLAB concerning the industrial usage of HASYLAB was signed. An information campaign has been started in form of brochures sent to firms, events with the Chamber of Commerce and private firms. Special websites have been created to inform about research possibilities and research conditions in the laboratory. HASYLAB has offered beamtime, service and special contract conditions to industrial users. We have explored how these measures are judged by industrial users of HASYLAB.

In our questionnaire, direct (current and former) industrial users of HASYLAB have assessed the *relevance* of different aspects of cooperation with HASYLAB, i.e. service, availability of beamtime, user costs and contract conditions. Four answers were possible (from very important to unimportant). Morever, firms have evaluated the *performance* of HASYLAB with respect to these aspects. Here, five answers were possible (from very good to very bad). For better comparability of these subjective judgements we have converted the semantic responses into numerical responses. Figure 2 reports the arithmetic means - rescaled between 0 and 1 - for each of the aspects.[10] In the following we will discuss our findings.

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[7] Besides these firms there are also two industrial research institutes which have conducted direct industrial research at HASYLAB.
[8] Scientific institutes in universities and public research institutions
[9] These are industrial users which are not also direct industrial users of HASYLAB. Four firms have been identified as direct as well as indirect industrial users.
[10] Note, that there are a few missings for a few items.

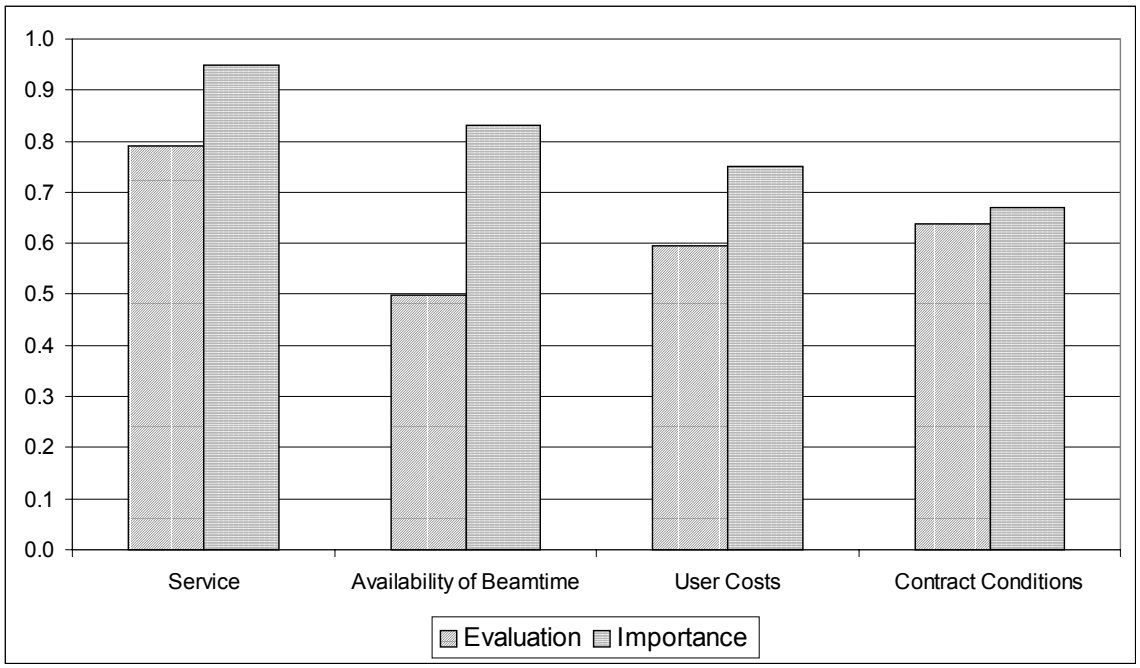

Figure 2: Importance and Evaluation of different aspects of cooperation with HASYLAB

Service: HASYLAB set up a special service group of scientists who are experts in the different types of SR usage in order to support firms' experiments and their evaluation. Depending on the needs of a firm and its kind of contract with HASYLAB, this support starts with help in preparing the experiment and ends with help in evaluating the results. It may also be focused on special parts of the research process. A *full-service,* in the sense that companies can simply describe their research goals and HASYLAB carries out the whole research project, is not available.

As can be seen from figure 2, no other aspect is assessed as important as service. Companies use it mostly in all stages of their research at HASYLAB. Firms explained that without assistance of the laboratory successful industrial R&D activities with synchrotron radiation are almost impossible. According to the results presented in figure 2, most of the

industrial users are relativley satisfied with the service of HASYLAB. This result would imply that there is no fundamental lack of service from the point of view of most industrial users. However, results of our in depth interviews show that industrial users wished better assistance in preparing experiments and even more in evaluating the results. One has to keep in mind that we have surveyed firms that are current or former users of HASYLAB. Thus, these firms have at least partly overcome the barriers. One would expect that potential users, which are less sophisticated, are even more dependent on the service from scientists. Given the importance of the service for industrial users the missing of *full-service* may be an important supply-side barrier.

Availability of research time: HAYSLAB changed it's organisational structures in order to offers a specific part of all research (beam) time to industry. Table 2 makes clear that the availability of beamtime is very important from the point of view of direct industrial users. The firms' evaluation of the availability of beamtime at HASYLAB (0.50) suggests that availability is a serious problem. At first glance, this result is somewhat surprising because reserved beamtime is not fully used by industrial users[11]. One explanation may be that industrial researchers need a lot of flexibility and want to do the research without planning research time in advance.

Contract conditions and user costs: Since 1995, HASYLAB has been offering different kinds of cooperation and usage contracts with different conditions for research time, research assistance, prizes, etc. Combined with the different kinds of contracts are different conditions for publication of results. It is possible to delay publication for 3 years or in exceptional cases to suppress it at all.

[11] Information of the HASYLAB directory.

Figure 2 shows that the perceived importance of user costs (0.75) and contract conditions (0.67) is lower compared with the importance of service and the availability of beamtime. This suggests that user costs and contract conditions, like prices and publication duty, seem to a less relevant part of cooperation conditions. Evaluation of user costs and contract conditions at HASYLAB is higher compared with the evaluation of the availability of research time. Firms know that even if they have to pay money to the laboratory (in some corporation forms they need not to pay at all), the prices are much below real costs. Publication rules were not mentioned as a barrier for industrial research in this lab.

3.3. Demand-sided barriers reported by firms doing research at HASYLAB

Lack of knowledge about application of SR: Firms have been asked about their opinion on demand-side barriers inside their firm and in general. The *lack of technological knowledge of employees* was pointed out as the most important reason for the low usage of SR research; more than half of the firms mentioned this factor (see figure 3). First, firms need to have general knowledge about the application possibilities of synchrotron radiation and the possibility to use public laboratories. Secondly, they need to have specific knowledge about this research method that makes them able to carry out experiments and to interpret the results.

We asked scientific and industrial users for their opinion about the future development of application fields of SR for industrial purposes. Whereas the firms see in average no increase in application of SR research for applied purposes, the scientific users gave an amazing number of potential application fields of research with SR for the development of industrial innovation. From their point of view, SR could be used much stronger for industrial purposes especially in chemistry, metallic industry, electronics, and others. These different opinions may show information deficits on the side of the firms and can be the result of the long period of public scientific (basic) research without regular contacts to industry in the past. Mainly

scientists who came by their former education, training or job into direct contact with HASYLAB or another SR source have specific knowledge about experimental facilities and theoretical and/or practical application of SR. They can know about advantages of this technique compared with traditional methods of research[12]. The quality and the actuality of the knowledge of scientists are important for the firms' ability to realise advantages of SR research and to do this research successfully.

Interview partners also mentioned the importance of a ***"general technological understanding"*** inside the firms, which is strongly connected to the general goal of the firm with perspective to its market position. Most of the direct industrial users of HASYLAB see themselves as market leaders. As leaders they use experiments with SR to get strong advantages for the development of leading innovations. In their opinion, a firm that is not in the position of a leader and not in a situation of very strong competition will often decide for traditional, well-known research methods. Asked for alternative methods for doing the research, 40% of the companies answered that there is no existing alternative method, whereas 60% also could use traditional methods.

Financial restrictions: Research activities with rarely known methods like SR are strongly connected with risk-willingness on the one side and the availability of financial potential on the other side. The *lack of sufficient financial resources* was called the most important barrier for a wider usage of SR besides the lack of technological knowledge. There is a risk that the research does not bring out the expected results, and in the worst case, experiments do not bring any economically usable result. Additionally most experiments take some time, e.g.

12 This argument is supported by the fact, that the firms explained, most of their contacts with a SR source had developed because of personal contacts of employees, who in former times had worked as doctoral students or research assistants in the laboratory.

some months or years, until they bring out any result. So firms need certain financial reserves for doing this kind of research.

Communication difficulties inside the firm: Communication difficulties between research staff and management are in majority not mentioned as a barrier for more industrial usage of SR in special and megascience facilities in general.

Some of our results may be explained by the firm characteristics of direct industrial users. These are mainly big companies with more than 5,000 employees that have an own R&D department.[13] The high relevance of permanent R&D inside the firm and of sufficient financial resources to do R&D with SR may be the reason for this finding. Only large firms are able to spend time and money to recognise new research methods as applicable for their purposes and to use these methods in a public lab. It is likely that small and medium sized (SMEs) firms mostly do not have this potential.

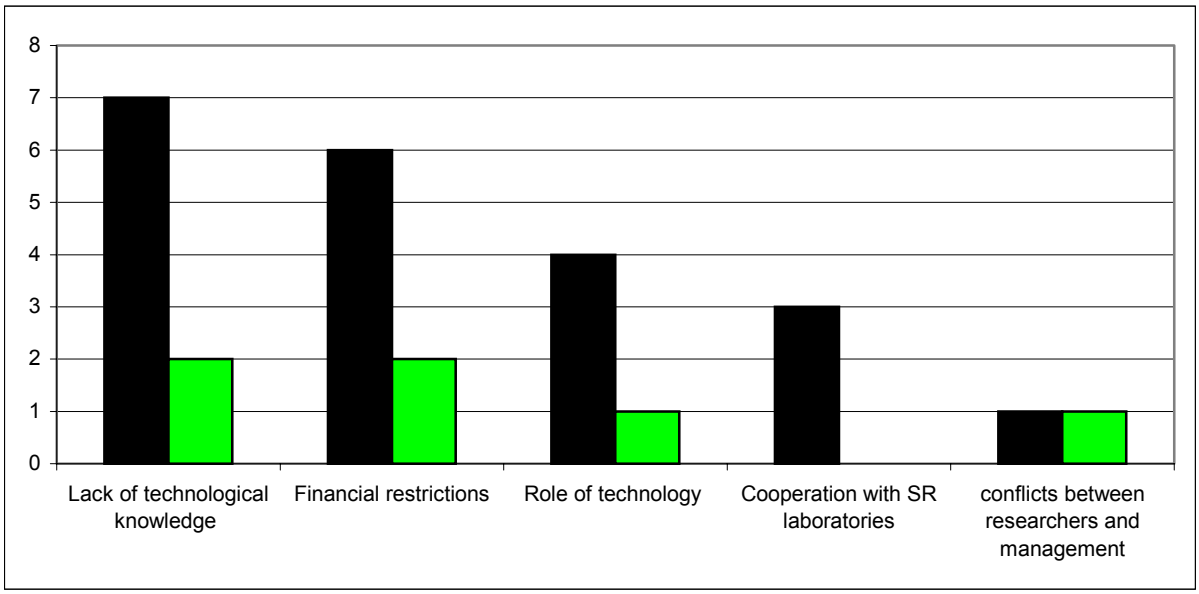

Figure 3: Number of direct and indirect industrial users of HASYLAB that evaluate certain barriers inside the firm as relevant, (based on answers of 11 direct and 6 indirect industrial users)

4. Conclusion

This paper discusses the barriers that may hamper the industrial usage of megasciene facilities. In contrast to the existing literature, we do not solely focus on supply-side barriers but take into account demand-side barriers too. We present the results of a case study dealing with the industrial usage of the synchrotron radiation source HASYLAB. Our results suggest that supply- as well as demand-side barriers are relevant.

In particular, we find evidence for supply-side barriers that may arise from the lack of full-service to industrial users and inflexible access to megascience facilities. Firms depend crucially on scientific assistance in running experiments and evaluating the results since they usually do not exhibit the relevant know-how. Moreover, inflexible schedules may be a problem, since advantages arising from fast product and process innovations may play an important role for firms' facing fierce competition.

The main demand-side barriers are the lack of technological knowledge and financial contraints. The knowledge about the application possibilities of synchrotron radiation is a prerequisite for industrial usage of SR sources. Moreover, firms seem to need in-house research (R&D departments) in order to make use of megascience facilities and/or they need (full-) service from scientists of megascience facilities. Financial constraints may be a special problem for small and medium size firms (SMEs) due to capital market imperfections. Large firms have the personal and financial recources to carry out very specific and risky research. The fact that mainly large firms belong to the direct industrial users of HASYLAB may be viewed as a hint on this.

We think that our results are not specific to HASYLAB or other synchrotron radiation sources but may also provide useful insights into the factors that may hamper industrial usage of megascience facilities in general. We conclude that until now demand-side barriers, like

[13] And some of them exhibit relatively high R&D intensities.

firms' lack of technological knowledge and financial constraints, may not have gained the interest they deserve.

From a policy point of view, it is interesting to note that direct industrial use of megascience facilities seems to be constrained to large firms. Given the importance of SMEs for innovations in industry, it should be discussed whether the main focus of policy concerning megascience facilities should be on direct industrial usage or whether *in*direct industrial usage via industry-science cooperations could be more promising with respect to firms' innovative activities.

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