Preliminary!

How Is Knowledge Being Transferred? –
Assessing the Indirect Effects of Basic Research

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I. Introduction

Schumpeter, in his theory of innovation and entrepreneurship, provides the conceptual foundation for much of the modern writing on innovation and technical change. As regards the source of innovation, the heroic individual entrepreneur of his early writings (Schumpeter: 1934) is later argued to become obsolete - as the process of innovation itself becomes routinised in large commercial R&D departments (Schumpeter: 1942). Whereas his theory clearly offers the fundamentals for a more comprehensive analysis of innovation and technical change, the question as to where new knowledge ("inventions") itself comes from receives only marginal attention. In fact, it has been argued that the picture emerging is pretty much one where the innovators just draw upon available technical and scientific knowledge - in other words, inventions remain exogenous. To be sure, Schumpeter did recognize the powerful role played by science, but he did not elaborate on the complex intertwining between science and technology or explain how science can contribute to the innovative activities of commercial R&D work (see Nelson: 1990, p195).

From the point of view of the modern theoretical literature on innovation, basic research in particular becomes an issue in the context of the emergence of new technologies. Identifying the activities in academic or science-oriented institutions with what he calls "exploring", Lundvall for example argues that "exploring will sometimes result in breaks in cumulative paths and create the basis for new technological paradigms." (Lundvall: 1992, p71). In this sense, here and in many other writings there seems to be an implicit notion of basic research as the source of inputs to what Schumpeter calls 'radical' innovations. In Freeman's and Perez' work the equivalent would be the new 'generic' technology underlying a new techno-economic paradigm (Freeman: 1992). Adopting a life-cycle perspective to the analysis of technological development, this raises issues such as whether the science-base of technology is indeed more intensive during the early stages of its development. Questions along such lines have recently led to renewed interest in basic research as a factor shaping economic performance as witnessed by the quote from Niosi et al (Niosi et.al: 1993, p114):

"The outcome of basic research is likely to be codified and to resemble a latent public good. The institutions responsible for the generation of this type of knowledge are amongst

> the most important in determining the performance of a country as an innovator, and constitute a necessary addition to the basic Schumpeterian model of economic development."

It seems fair to argue that there is a broad consensus in the modern literature on innovation and technical change that accounting for basic research is rather important for the study of innovation. The works just mentioned suggest that this may be all the more true when it comes to explaining long-term changes in the stock of scientific and technological knowledge. So far, the predominant approach of accounting for basic research as an economic activity has been to view organisations such as universities or some government laboratories as the providers of a certain type of knowledge inputs to innovative processes in private firms. To an extent there is a presumption that for basic research knowledge to be transferred out of the institutional boundaries, it must be codified. Consequently, the primary carriers of such knowledge are scientific publications. This is how the results become accessible not only to scientists in other institutions, but also to potential user of those results in applied research and development in the public and in the industrial sector, at times motivating a conceptualisation of scientific knowledge as a public good.

The project of integrating basic research activities has particularly been promoted in the literature on national systems of innovation (NSI) (see for example, Edquist & McKelvey, 2000), as witnessed by the passage quoted above. As a rather recent strand of thinking, this literature explicitly views innovative processes from a systemic perspective, being primarily concerned with questions of differential performance among national systems. Central to this approach is the question as to how the generation and transmission of knowledge is affected by the structural features of the system. As regards basic research, it has so far mainly been accounted for by adding basic research institutions to the set of organisational actors in the system and studying the relationships linking it to the others. The links via which basic research contributes to the innovative processes co-ordinated by private firms are of course manifold.

The probably best-developed approach in this field is what is usually summarised under the broad term "scientometrics", assessing the contribution of basic research institutions by studying in how far patents make citations to papers originating in that institution. Via such a technique, technologies may be classified and ranked according to how extensively they make use of the scientific literature. For Germany, work along these lines has mainly been carried out at the ISI Karlsruhe (Grupp und Schmoch: 1992) and for the US by Narin et al (Narin et al: 1997). Similarly, the degree to which knowledge spills over among different technological sectors may be studied by analysing cross-citations in patents. The main contribution of such studies are insights provided on the technological areas where science serves to inform technological problem solving.

The empirical approach to assessing the economic contribution of basic research suggested here is methodologically different, focusing not only on the transfer of results, but also of potential and capacity. A range of qualitative studies has presented evidence for a variety of economic effects going beyond those derived from scientific publications. Their results provide the major motivation for an alternative approach to the study of knowledge transfers, and will briefly be summarised in Section II. In Section III, some of the general problems of measuring knowledge will be discussed, motivating the outline of an encompassing approach of assessing the effects (Section IV) summarised before. Subsequently the crucial issue of data sources as the main constraint on empirical work will briefly be considered. Section V will discuss the general scope of the approach, its potential contribution to the literature on NSI and its relationships to existing work.

II. The Indirect Economic Effects of Basic Research

Scientometric studies capture one very specific aspect of knowledge transfer - namely published research output - not accounting for tacit knowledge nor for knowledge which has not yet been codified. To be sure, the intention here is not to criticize this work for disregarding something which more or less by definition is outside its scope, but rather to take it as a starting point. In terms of the argument pursued here, the implication is that it is not clear in how far studies using output-based indicators can be taken to give a representative indication for the overall interaction of basic research institutions with other actors. The studies to be reviewed here serve to illustrate that the interaction between basic research institutions and other actors in the system may be much deeper and partly unrelated to the direct output of research activity.

Illustrating this point, a survey undertaken at Yale University (for a more extensive discussion of results see Nelson: 1988) tried to identify the main input to industrial research from the point of view of 650 R&D managers spread over 130 industries. They were asked to rate on a scale from 1-7 the relevance of different basic and applied fields of science for their industry. Distinguishing between a) general relevance of the scientific field and b) the relevance of the academic knowledge produced in this field, it turns out that in many cases ratings on the two scales differ significantly. For example, forty-five industries rated the relevance of physics at five or greater, but only four gave a high score to university research in physics. Similarly, chemistry is rated important by seventy-five industries, while only nineteen industries rated university research in chemistry that highly (Nelson: 1988, p320). Notably, the measure on the two scales differ less for those fields of activity where scientometric studies predict science and industrial applications to be "close", as currently is the case in biology and biochemistry. What this suggests is a general underrating of the relevance of science by considering only "academic knowledge", as opposed to "general relevance". What is left open though is *how* different scientific fields are relevant to industry if not via the direct knowledge output produced.

This question has been addressed in a range of sectoral and case studies, pointing out the many different dimensions along which basic research contributes to technological advance. One of the most quoted example in this area is Gibbons and Johnston (1974), who have studied how scientists in industry solve technological problems and what sources of knowledge are utilized towards this end. Distinguishing between on average 30 units of knowledge per innovation studied, they then classify the sources of this knowledge, which can be personal (developed mainly through experience and education of the problem-solver) or "outside" knowledge.

Overall, they find that more than one-third of the knowledge which contributed to the development of an innovation and which was obtained from outside the company had its origins in basic research. Of all knowledge obtained by problem-solvers, approximately one fifth could be similarly classified. Their fundamental result with respect to the human capital aspect is that "the techniques and test procedures which are of considerable importance in most natural sciences do not find their way into application via the scientific literature". Similar points have been made by Faulkner and Senker, arguing that formal knowledge transfers often only represent the tip of the iceberg (1995, p.204). Underlying are complex structures of informal interaction and exchange at the science-technology interface feeding into a range of problem-solving activities.

Studies emphasising the complexity of the science - technology interface are naturally more limited in scope compared to large-scale scientometric investigations, but they serve to illustrate some very important aspects of scientific (as well as technological) knowledge. With regard to the economic contribution of basic research, they indicate that in fact codified results may not even be the most important input basic research can offer as an input to other activities. As emphasised by Pavitt (1991), science has an impact not just through direct knowledge transfers, but also through access to skills, methods and instruments. A similar conclusion is reached by Salter and Martin (1999), summarising the economic effects of basic research. The common dimension to these aspects is of course that strictly they are enabling factors for the production of codified research output. For the study of the economic effects of basic research, this analytical distinction should be maintained.

This theme of course directly leads to the question of how generally applicable scientific skills, techniques, methods etc are across organisational contexts other than those where they were initially developed. In other words, it is important to assess the degree of application specificity not only of new codified research output, but also of those aspects of scientific knowledge which have enabled its codification. To date, there are no systematic attempts to investigate the applicability of research skills across different organisational contexts. In view of this, a conceptualisation of knowledge transfer based on a strict demarcation of organisations into basic and applied - while relying on a narrowly specified transfer concept - may fail to capture an important economic dimension of basic research. Strictly speaking, it is the produced knowledge output which is basic or applied, as defined by its potential value as an input to other activity. Much less is known in this respect about the skills and methods underlying the research process.

Closely related to this is the second conclusion which may be drawn from this work, namely that skills, the mastery of certain methods and techniques underlying the research process are largely embodied in the individuals employed by an organisation. The strong tacit dimension stemming from the procedural aspects of the knowledge dealt with here implies that successful transfer across organisational boundaries will be more difficult than for codified knowledge. This point has for example been made by Pavitt (1991), arguing that knowledge transfers are mainly person-embodied, involving personal contacts, movements, and participation in national and international networks. Knowledge is not, therefore, only embodied in individuals, but also in social networks formed by groups of scientists. Consequently, there is another vital distinction to be made here, namely between the value of the knowledge possessed by the single individual and the value of knowledge stemming from the interaction and collaboration of more than one individual carrying different kinds of knowledge. In research as well as innovation, knowledge may not always be exploitable in isolation, but only jointly via the contribution of others.

Explicitly viewing knowledge transfer as embodied in individuals has a range of analytical implications. Most importantly, it makes knowledge transfer contingent on individual behaviour. Despite the role attributed to the individual scientist in the studies mentioned above, this fact has not been systematically exploited. Rather, the individual predominantly seems to play a role as a carrier of non-codifiable knowledge inputs to innovative projects, and in attributing these inputs to various organisational settings. The essential feature of the approach to be outlined below is the attempt to systematically exploit the fact that knowledge transfers are contingent on individual behaviour. In making decisions about whether and how to become involved with a project or work for an organisation, individuals respond to a set of incentives, being at the same time constrained in many different ways. As basic as this may seem, it is rather central for studying knowledge transfers, and in particular if the research question is related to the contingency of knowledge transfers on institutional features of the system.

Most studies focus on knowledge transfers which have been realised or innovations which were successful, analysing them in terms of the institutional actors involved. Rather less is usually said about why individuals actually engage in transferring knowledge. Ultimately, this decision is the precondition for the project to be successful. Moreover, individual constraints and the way they are perceived will to a large extent be rooted in the institutional structure. Given the strong orientation towards the structural determinants of knowledge transfers especially in the NSI literature, this fact has remained somewhat underexploited. In particular, it will be suggested that data on scientists' career trajectories can reveal useful information in this respect. The economic value of scientific knowledge can only be realised via the individual embodying it, being linked to other individuals within a complex social network. A systematic analysis of individual career trajectories can potentially be a useful device in imposing structure on the complexity of the science-technology interface.

III. Measuring the Economic Value of Knowledge

When dealing with the issue of knowledge transfer, what is often kept implicit is that what is really meant is an effective transfer. In other words, there is an interest in knowledge transfer because it is being assumed that under certain conditions that knowledge may be of some economic value. Furthermore, for this to be the case, there needs to be someone initiating the transfer. This transfer could be viewed from many different perspectives, for example the one of the innovating firm trying to coordinate knowledge inputs in the pursuit of profit; it could be viewed with the eyes of the individual seeking to appropriate the value of his or her embodied knowledge; yet another alternative could be to shift focus on the originating research institution.

Many qualitative studies of knowledge transfer approach the problem by taking a successful innovation at the level of the firm as their object of study. For example, Gibbons and Johnston (1974) organize their inquiry around one specific project, trying to trace the different contributing knowledge inputs. As already indicated, the main contribution of such work is to point out that a variety of potentially very heterogeneous knowledge inputs play a role. Using this approach however to attribute percentages reflecting relative importance of sources of knowledge pushes the approach to its conceptual limits, as such an exercise requires a common unit of measurement[1]. For example, Gibbons and Johnston (1974) suggest that of the knowledge obtained outside the company, 36 percent had its origin in basic research. As knowledge is a multidimensional concept characterized by indivisibilities and complementarities, it appears problematic to attribute specific elements of ones knowledge to various sources.

To illustrate, does attributing 36 percent of knowledge to basic research activity mean that this knowledge can be attached a value of 36 percent of the incremental turnover or cost reduction the firm is faced with after carrying out the innovative project? Certainly not. The value of all the knowledge contained in the innovation can clearly only be realized as a very specific constellation of knowledge inputs interconnected through complementarities. Furthermore, an approach based on separating out single bits of knowledge would be difficult to extend to systematically capture the economic benefit of basic research. What is suggested therefore is to start from a single research organisation and analyse the way its output is being diffused through the system. As far as direct effects, ie the publication of research output, is concerned, this is clearly within the scope of scientometric studies. There is, however another, more indirect effect involved here which is strongly related to the skills, scientific methods, etc identified above as further economic benefits of basic research.

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[1] I am grateful to Laurent Bach for turning my attention to this point.

Probably one of the most interesting results of the Gibbons and Johnston study is that in their category of personal knowledge, an element of knowledge often could not be attributed to anything more specific than education and experience (comp. p228). So instead of trying to determine the value of the knowledge in terms of contribution to the innovative project, one may rather use as an indicator for its value the benefit derived by the individual from transferring that knowledge. This amounts to a fundamental methodological reorientation, but appears to be flexible tool to the study of how knowledge diffuses through a system. It must be made clear though that this is suggested as an attempt to capture the indirect effects of basic research, namely those in addition to published research output.

If individuals engaged in basic research activity are hypothesized to be carriers of valuable knowledge, the question of how this value is determined arises. If this knowledge cannot effectively be codified, its value at a given point in time will certainly be a function of the number of individuals available who possess that knowledge. One the other hand, as this knowledge diffuses through training and at the same time is gradually being replaced by other techniques, it becomes outdated and loses value. In view of the evidence on the significance of the indirect effects of basic research, it appears important to devise a general and encompassing approach in order to study how knowledge diffuses through the system. The following section will outline such an approach in more detail, showing why focus should be on the individual.

IV. The Indirect Effects of Basic Research: An Encompassing Approach

The empirical question to be addressed below is in how far the entity of scientific knowledge generated and developed in one specific organisational context - with all its diverse aspects - can potentially be transferred and adapted towards other settings, which may follow a different logic and be governed by different motivations. Rather than focusing on actually realized transfers, the concern is therefore more with the potential reach of specialist knowledge in terms of its applicability. Furthermore, if knowledge is transferred via the movements of individuals, the question arising immediately afterwards is on what basis this will happen. In the context of basic research institutions, it is clearly the published results of research what has received most attention. Point of departure here is the observation that an exclusive reliance on output-based indicators in assessing the economic contribution of basic research is limited and needs to be extended by including less tangible and more indirect aspects of the scientific process like skills, mastery of techniques and access to networks. It may then well be the case that the transfer of knowledge is primarily motivated by the applicability of this latter kind of know-how to other contexts, rather than the actual knowledge which could be transferred via publications. Of course a range of further distinctions could be made, such as into skills which are specific to the scientific field where they are first developed, such as certain gene-identification techniques, and such which are of a more general nature, like advanced IT-skills.

The main fact to be exploited here is the assumption that if scientists perceive some economic value to the knowledge they embody in contexts other than basic research institutions, this will have a systematic impact on their behaviour. In particular, reference is made to the kind of behaviour governing career patterns of scientists, and how they go about appropriating the knowledge they accumulated while engaged in basic research activity. To start with, one may define a population of scientists with a similar career history in a basic research institution and study what these people do after leaving. What this comes down to is to study turnover rates to different destinations, such as the academic sector, industrial firms, or service-related activities in the economy. One can then determine how large a percentage of those scientists with a certain qualification like for example a PhD ends up in different industries. If for example it turns out that x percent of a defined cohort work as industrial scientists in the semiconductor industry, one could then go on to investigate the relationship between the knowledge accumulated during a PhD in experimental physics and professional success in this industry. Similar investigations could follow the observation that the financial sector steadily appears to increase its importance as a prospective employer for PhD physicists.

Along such lines it should be possible to obtain a pattern of the potential applications of basic research knowledge on the basis of a systematic analysis of people's destinations. In a way, the entire approach is based on the idea that individuals who have accumulated knowledge will in their career aspirations be driven by the desire to appropriate the knowledge they embody. The case is or course most straightforward for scientists who leave research establishements in order to start up their own company and exploit the commercial value of their knowledge. For scientists to undertake such a venture quite a specific constellation of favourable factors appears to be required as precondition, including the nature of the knowledge in question. This aspect of knowledge transfer has been analysed at length in the literature, whereas a second, conceptually closely related instance of knowledge transfer has been relatively neglected.

The alternative option open to scientists is of course to seek employment in an incumbent firm at a certain point of the career, expecting to be more fully compensated for the economic value of their knowledge (Dasgupta & David, 1994). On the level of the entire population, in many scientific fields there may be a significant impact in terms of economic value added by those scientists having migrated into incumbent firms.

The approach of course crucially hinges on the definition of what is considered a to be a successful transfer and what is simply a case of occupational mismatch in the sense that someone gets employed by a firm, but not primarily on the basis of previously accumulated knowledge. Studying the transfer of knowledge from a life-cycle perspective of individual scientists requires to build upon success indicators which can be analysed following a specified time horizon following the career transition, linking "success" to the career path of the individual spent in basic research.

The most straightforward indicator to the economic value attributed to this knowledge is of course the wage an individual would receive from a potential employer. For example, the wage first received by a PhD chemist when moving to the German chemical industry is about 20 percent higher than the wage received by someone with a four-year University degree[2]. This could in some way be interpreted as the economic value of the individuals embodied knowledge. However, going beyond the initial earnings differential, it would also be interesting to see in how far the subsequent career dynamics are different – not only in terms of earnings but also with respect to the tasks taken up later. A further issue for investigation is in how far the individual in question is actively engaged in diffusing its knowledge, for example by training colleagues or directing say, a project group within the firm's R&D department.

Of course, the general scope of each investigation is constrained by the availability of data. Recently, is has been argued that a data source which has generally remained underexploited in economics is curriculum vita data (Dietz et. al 2000). Despite being relatively free available, it demands a lot of effort in terms of coding for statistical analysis. There is a broad range of insights which can be gained from people's CVs, particularly as they can be interpreted as a trace through the different organisations people have been affiliated with over the course of their career. However, if one is interested in the precise nature of the knowledge transfer taking place and what aspects of knowledge are involved, further methods of investigation like questionnaires or personal interviews must be applied. At this point however data protection issues are

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[2] (http://www.gdch.de/arbeitsv/berufka.htm#m1100)

likely to get a grip as for the study of a previously defined population of people address data is needed to contact them. Some of these practical issues receive further attention in the project outline contained in the Appendix.

V. General Scope and Relation to Other Work

The approach sketched here differs in some fundamental respects from a) the way basic research has so far mainly been conceptualised in the NSI framework and b) empirical studies attempting to quantify knowledge flows between basic research organisations and technological applications. The paper departed from the observation that basic research is seen to have an impact on innovative performance mainly over the longer term, and that studies of its contribution have often focused on research output as contained in scientific publications. Evidence for further and more indirect economic effects of basic research has been established by a range of smaller scale case or sectoral studies which are generally more qualitative in nature. However, it was argued that these studies have not been conducted within a homogenous conceptual framework.

By trying to argue that in general knowledge transfers should be studied from the perspective of the individual embodying that knowledge, it is submitted that such an approach can give a fuller and richer account for indirect economic effects of basic research activity. By taking the individual as the unit of analysis, valuation of the embodied knowledge must proceed through the use of indirect indicators which in general must convincingly be able to connect career success with the previous knowledge accumulation while engaged in basic research activity. Such indicators could be wage differentials, but also responsibility for budgets as well as responsibility for other employees.

The distinguishing feature of this approach that it explicitly links transfer activities to the behaviour of individuals, foremost to the decisions about career transitions. The fundamental assumption is that in making such decisions individuals are by and large guided by a desire to appropriate the value of their knowledge. Of course, this is not to imply that appropriation issues are the only influence on people's careers. Rather, people face a range of constraints, not least because life cycles are interconnected in many different ways. However, at the level of a population with similar qualifications, it should be possible to observe statistical regularities.

Furthermore, incorporating individual constraints can actually be seen as an advantage of this approach, since it opens the avenue to study how the institutional structure of the system impacts upon knowledge transfer. If for example it can be identified in this way what the features are which induce individuals to leave a research organisation and take up employment in the private sector, crucial features of the system might be targeted in order to improve such knowledge transfer. Also, differences in the effectiveness of different ways of transferring knowledge across scientific disciplines may be studied. In this sense, such an encompassing approach may be a valuable tool in studying some of the main questions raised in the literature on NSI by allowing to gain further insights on the systemic features which determine differential performance in generating and diffusing new scientific and technological knowledge in NSI.

Finally, a strength of the perspective on the individual submitted here should be that is can relatively easily be integrated with other approaches. For example, studying individual scientists may as well be done within a scientometric framework. Patents for example list the names of those involved in the generation of this new knowledge, together with their institutional affiliation. Along such lines, M. Gitterman (2000) has shown how the knowledge embodied in those individuals involved with the patent application can be traced to different institutions the person has patented with or published for earlier. The primary indicator of knowledge transfer is therefore no longer the citation pattern (to other patents or scientific publications), but rather the individual career paths across different institutions of the scientists involved. This type of approach however ultimately also must rely on people codifying knowledge. On the other hand, the fact that some knowledge is not codified should not be taken to mean that it will not have any economic implications.

Appendix: Project Outline

The specific project proposed aims to explore the incidence of embodied knowledge transfers at the Max-Planck-Society (MPS) in Germany. It consists of some 80 institutes, divided into a Chemistry-Physics-Technology Section (CPT); a Biology-Medicine Section (BM), and a Humanities Section. By far the largest share of resources is devoted to the natural sciences, that is, the first two sections, which are the focus of the project. The largely publicly funded Society is organised according to the so-called Harnack-Principle, meaning that individual institutes are largely designed towards the needs of specific individual scientists heading the institutes. That also implies that the overall structure is quite flexible, with new institutes being founded in promising areas and others closed after their research mission has been completed.

The overall orientation of the MPS is clearly towards basic research, contrasting with the Fraunhofer-Society, whose focus is largely on applied research. Within each Section, the research pursued by the Institutes is rather diverse. In the CPT, it ranges from the MPI for Materials Sciences or the MPI for Metallurgy over a large spectrum to Institutes like the MPI for Radioastronomy. In the BM, orientations of institutes are just as diverse. That shows how inquiries into questions of quite a diverse nature are grouped under the label of basic research. Only to a limited extent do formal knowledge transfers take place via the registration of patents, which are managed by an affiliated company called Garching Innovation GmbH. Generally, research results are published in scientific journals. There have also been 39 start-up firms, originating mainly in the BM of the MPS (comp. Frankfurter Allgemeine Zeitung 14th Aug 2000).

The employment structure of the MPS comprises doctoral students, post-doctoral fellows, scientists, visiting scientists, and scientific members of the MPS. Employment contracts are generally limited to time periods between one and five years. Naturally, for many people the subsequent career move is to take up employment in academic institutions in Germany as well as abroad, while anecdotal evidence suggests that quite a substantial proportion of former staff move to work in the commercial sector. Furthermore, such individuals appear to be quite successful in their new jobs. In the light of the argument of the paper, this lends itself to an in-depth study on how individual success during subsequent career sections may be based on the knowledge acquired while engaged in basic research.

The methodology adopted essentially consists of a two-step procedure, where during the first phase of the project a general estimate of the proportional turnover rate into industry must be obtained for each institute over a time span between five and ten years. Given the large number of institutes, with the largest ones employing several hundreds of people; a generally high turnover rate; and the non-existence of systematic information on people's destinations, this amounts to quite a complex task. In the second phase of the project, a sub-sample of people will be chosen for a more detailed study of their career paths, ambitions, and the way in which their current activities are based on or related to the knowledge and skills accumulated at MPS. After contacting individuals, this will be done on the basis of questionnaires coupled with semi-structured interviews if possible.

Preliminary research findings, which are mainly based on interviews and conversations with individuals heading institutes or research groups themselves suggest broad agreement with the validity of the hypothesis of the study. Particularly in the CPT there appear to be informally institutionalised links between institutes and industry, with many people moving into large firms - namely those with extensive R&D programs - after obtaining their PhD or finishing a post-doctoral fellowship[3]. Also, general trends in university enrolment rates seem to be reflected in the employment structure of the MPS.

Complications so far encountered and expected for the future are mainly related to data collection. Practices of storing information on the destinations of former employees vary widely across institutes and data are often only informally held. Thus centralized access is difficult. Moreover, it appears that in particular people who have just completed their PhD often do not immediately enter their preferred job, taking their time to compare options while bridging this time with lower quality jobs. This of course makes it more difficult to build on information obtained from their former institutes.

[3] According to Keck (in Nelson: 1993, p138), 46% of domestic industrial R&D capability (as measured by R&D
employees) in the German chemical industry are accounted for by Bayer, Hoechst, and BASF.

However, the hope is that such obstacles will be overcome and that the study will be capable of delivering new insights on embodied knowledge transfers.

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