Impact Studies of Regional Effects of Research Infrastructures: Economically Concentrated or Multidimensional – Approach of a Holistic Evaluation Model

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SUMMARY

This article shows the current focus of impact studies of regional effects of research infrastructures in German. A literature review clarifies whether these studies concentrate on economic effects or assume a multi-dimensional perspective. Furthermore, it will determine where there is still a need for research in the evaluation of infrastructures and which effects are still of interest to the regional impact of a research institute. Based on this analysis, a first approach to the multidimensional evaluation of research infrastructures is presented. The evaluation investigates not only economic effects of research infrastructures, but also new knowledge effects (e.g. project innovation type), political effects (regionality of projects), and cultural effects (e.g. anchoring in the cultural memory). The general objective is to highlight the positive impact of a research infrastructure on the region (the associated federal state) and to expand the examined aspects of previous studies.

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INTRODUCTION

Research occupies an important position in a future-oriented society. The rising research expenditures express the importance. The German government´s goal of investing three percent of Gross Domestic Product (GDP) in research and development (R&D) was achieved for the first time in 2015 (BMBF 2017, p. 8). With an increase of 9.5% (to 62.4 billion euros), in 2015 German companies invested more than ever in their own research and development (BMBF 2016).

Within Germany, regional research expenditure and the share of GDP expenditure are very different, suggesting a significant difference in the economic and industrial structure of the regions (BMBF 2017, pp. 13–14).

The economic structure in Germany is divided into the manufacturing sector (including the construction industry) and the service sector (Statistische Ämter der Länder 2017a, p. 3). These two account for almost 100% of the economic structure in the federal states. The areas of agriculture, forestry and fisheries can explain a possible difference (in total a maximum of 1%). On a nationwide average, the distribution is 30% for the manufacturing sector and 69% for the service sector (Statistische Ämter der Länder 2017a, p. 3).

Further indicators describing a difference in the economic and industrial structure among the federal states are e.g. the investment ratio as well as the economic performance and growth (Statistische Ämter der Länder 2017b, pp. 24–25). Economic performance and economic growth are directly related. The economic growth also increases if the economic performance in Germany is better. However, the economy in the federal states is growing to varying extents. In 2016, Germany's total economic output amounted to EUR 3,133 billion, an increase of 1.9% over the previous year (Statistische Ämter der Länder 2017a, p. 7).

Small and medium-sized enterprises (SMEs), in addition to large companies and corporations, are particularly responsible for performance and growth. Out

of more than 2.4 million businesses [sections B to N (except K) and S95 of the WZ 2008 (classification of industry)] in Germany, 99.3% are in the SME category, 60.7% of the total workforce is employed (or more than 15.5 million) by SMEs, account for 33.3% of the overall turnover of Germany (Destatis 2018; Söllner 2014). The share of SMEs in the federal states is similar to the national average. The same applies to the shares of micro, small and medium-sized enterprises in all SMEs in the respective countries. However, the absolute number of large companies in the federal states differs considerably (GENESIS-Online Datenbank).

The evaluation of investments in a small economic structure with low R&D expenditures is particularly important. Research infrastructures occupy an important position in the innovation system. The Wissenschaftsrat defines research infrastructures as follows: *"Research infrastructures are understood to be those which are in part public or private, specifically built for scientific purposes, medium to long-term, and for their proper construction, operation, and use, specific scientific or interdisciplinary (Method) competencies are required. Its function is to facilitate or facilitate research, teaching and the promotion of young researchers. They are locally fixed, distributed over several locations or are only provided virtually without a defined physical contact point. They are not used exclusively by individuals or groups, but are in principle open to an international professional community or several professional associations. A research infrastructure always includes specially qualified personnel that facilitate or facilitate the use of researchers, teachers and, in some cases, students. Likewise, there are always general infrastructures such as buildings, power supply networks, operating software and the like."* (Wissenschaftsrat 2011, p. 17, translated by author)

The following literature review shows which objects and which effects are of interest in the previous studies.

IMPACT STUDIES OF REGIONAL EFFECTS OF RESEARCH INFRASTRUCTURES

This evaluation of studies on regional impacts of research infrastructures is limited to the German-speaking area and includes literature from the year 2000 onwards. The limitation of literature to the German-speaking world is mainly because the German research landscape is unique with its R&D activities in industry, public research (universities, research organizations, academies, etc.) and intermediate research (German Research Foundation and other foundations). In addition, due to the public funding of many research infrastructures, there is great interest in assessing the impact of these facilities.

Regional effects are effects attributable to a specific spatial category (city, municipality, economic region of the federal state). These effects can be direct, immediate, indirect or induced. Direct effects occur in a company. Immediate effects arise through supplier relations of a company. Indirect effects arise from suppliers' supplier relationships. Induced effects are multiplier effects (definition according to Schasse et al. (2016, p. 20)).

Following the example of Emrich et al. (2013) and Stoetzer and Krähmer (2007) and own supplements, it was possible to provide an overview of the literature on the evaluation of regional effects. Due to the lack of space, discussion here is limited to four important sources.

The Economic Importance of the University of Kassel for the Region of Northern Hessen

This empirical analysis of Beckenbach et al. (2011) is based on the impact studies of Blume and Fromm (2000a), Blume et al. (2001) and surveys of Daskalakis and Kauffeld-Monz (2007), and Daskalakis et al. (2008). The investigation of the effects takes place here in the categories of input and output analysis. Direct regional effects of the input are determined with regard to personnel, material and construction expenditure as well as consumption expenditure. With an input-output analysis and a developed coefficient matrix, the indirect effects of the expenditure are determined. The output effects of a university are well-trained graduates, the generation of knowledge as well as the transfer of knowledge and the spin-offs from the university. Finally, Beckenbach et al. analyze the relevance of the research facility to regional companies. Under relevance here assessed the perception of the university by companies in the region, compared the innovation-specific specifics of the companies and the appreciation of the university, and examined the innovation-relevant characteristics of the spin-offs.

The study shows that a university makes a significant contribution to shaping the region. The economic effect on the output side (with regard to the spin-offs) is the largest.

Regional Economic Impact of Public Research Institutions in the Region of Basel and Northwestern Switzerland

The work of Haisch (2008) analyses the income, employment and tax effects as well as the effects of the transfer of knowledge of a university and a technical college in Switzerland. The systematization of Engelbrech et al. (1978) is applied and the two research institutions are examined with regard to the provision of services and the output.

The performance is determined using a (Keynesian) multiplier analysis to assess the impact of a single organization on an entity (a region). In addition, expenses of a research institution are direct effects and the effects of demand on suppliers are indirect effects. Making knowledge available to a wide public and innovations that optimize products and processes are the output of a

research institution. Theoretical considerations and the interviews of research groups of both institutions make the transfer contribution of a university clear.

The results show large economic importance and strong influence on the innovative ability of regional enterprises by the university. The indicators of regional anchoring offer good starting points for further work.

Universities as a Regional Economic Factor

This study of Schubert and Kroll (2013) examines the activities of higher education institutions in terms of their economic impact. The main impacts are "GDP per capita, unemployment rate, available per capita income and regional per capita patent revenue" (Schubert and Kroll 2013, p. 4). Effects that, above all, have an economic background and do not take into account comparative perspectives such as non-investment or alternative investments.

The methodology relies in particular on regression procedures to convey regional outputs through the local activities of higher education institutions and so-called fixed-effects panel data models. The calculations are made on the basis of absolute numbers and not on data with a specific reference to a particular university. By summarizing all higher education institutions in the federal state, the determined effect in a region is given as a derivative and aggregated value. The definition of region types makes structural differences of the regions / federal states clear.

This survey finds either a positive effect or a non-negative contribution to all the above aspects, e.g. an increase in GDP, a reduction in unemployment and an increase in patents, as along with non-significant change in the disposable income in all federal states. With the help of this analysis, the basis of legitimacy of universities is extended and substantial implications (for East Germany and university investment decisions) can be made.

The Contribution of the Fraunhofer Gesellschaft to the German Innovation System

This study by Frietsch et al. (2016) introduces the Fraunhofer Gesellschaft (in the further course Fraunhofer) with another approach to measuring the contribution of a research institution. The systemic perspective assesses the impact on the German innovation system.

This analysis examines the levels of innovation, microeconomics and macroeconomics, highlighting the often difficult-to-see effects of Fraunhofer. The participation of Fraunhofer in the development of technology (lines) takes place in the innovation-economic perspective with the help of expert interviews. Above all, the microeconomic perspective deals with the effect of cooperation and sets the matched-pair approach, which uses a "statistical twin" and certain control variables to compare success between cooperating companies and non-cooperating companies (Frietsch et al. 2016, p. 49). In the course of the macroeconomic observation level, the economic contribution of Fraunhofer is measured and identified on the basis of merged data from internal sources as well as from the Federal Statistical Office (DESTATIS) and subsequent application of panel data econometrics.

The result of this study shows the significant support of Fraunhofer within the German Innovation System. In addition to application-oriented research, Fraunhofer Institutes make direct and indirect contributions to strengthening the system. Essential here are the economic factors identified here, which detect a positive difference between monetary effects and investments in Fraunhofer. In addition, Fraunhofer helps to implement political goals and the internationally oriented training of young scientists.

Summary of the Studies

There are a large number of scientific papers in German-language literature dealing with the significance, charisma and contribution of public research institutions, especially universities and colleges. At first glance, the existing methods focus on assessing the regional economic contribution. That other aspects such as the infrastructural, cultural or social impact of institutions are more likely to be left out (Haisch 2008, p. 18; Beckenbach et al. 2011, p. 6).

Few sources of literature deal with a single research institute and its regional impact. "The empirical research on the demand effects of scientific institutions has so far been characterized by a large number of case studies on individual German universities [...] Publicly funded research institutes have rarely been included in such studies." (Franz et al. 2002, p. 15) The studies are primarily concerned with the economic impact of research infrastructure and thus confirm the first impression.

In most cases, economic effects include not only the effects of service provision (input), but also the effects of output and thus knowledge transfer as an economic parameter (Blume and Fromm 2000a, Pavel 2008, Schubert et al. 2012). Knowledge as an essential competence of research infrastructure is often an economic factor. This approach does not only understand knowledge as an economic aspect and has therefore added this category to Table 1, which gives the impact categories and effects of research infrastructures.

Table 1
Effects of research infrastructures

Category	**Effects**
Economics	Influence on regional income, labor market, economic structure, labor mobility, location decisions
Knowledge	Effects on knowledge networks, knowledge transfer, dissemination of knowledge, integration into networks
Politics	Changes in the political structure, increased public participation, better organization of political processes
Demography	Effects on population size, structure and mobility
Infrastructure	Effects on the housing market, traffic, medical care, volume and density of shopping
Culture	Greater supply and demand for cultural assets, impact on cultural climate
Education	Impact on educational participation and quality of (higher) education
Social	Effects on the quality of life, influence of students, influence on regional identity, image
Ecology	Influence on the consumption of land and of other natural resources, use of the environment, influencing the handling of nature

Source: Haisch 2008, p. 18 and own additions

This table shows that there are other effects of research infrastructures in addition to the frequently examined economic effects. Typically, they do not appear directly, not in the first round of action, and certain effects only set in after a longer period. In the further course of own research activities, we therefore try to develop a procedure model and concepts for the evaluation of most effects. The status will be shown in the next section based on the literature review and my preliminary evaluations.

REGIONAL EFFECTS OF RESEARCH INFRASTRUCTURES

A region is a "cohesive geographical area of mostly medium order between aggregated economy and disaggregated spatial points (localities) as marking a particular scale of spatial analysis" (Haas and Neumair 2017).

Contiguous areas may evolve depending on cultural (e.g., language), economic (e.g., currency), or agricultural attachment. At the political level, federal states divide regions. They are places of living, work, leisure and can change quickly in terms of time and space (Sposito and Faggian 2013). The systemic link between a region and a research institution is diverse. In addition to their primary role, the research organization assumes responsibility on many levels and influences it in different ways (Haisch 2008, p. 17).

Economic Effects

Regional demand effects of personnel expenditure

The personnel expenses of a research institution change over time and depend on the number of employees. As a result, the direct demand impact of staff spending over the years evolves. The regionally effective demand results from the previously calculated consumption expenditure and the regional consumption quota. The place of residence of the employees mainly determines the regional consumption rate. There is a direct correlation between regional demand and place of residence, as the greatest demand for goods and services arises at home. So, the higher the proportion of employees residing in the region, the higher the regional consumption and demand.

Another place of consumption is the workplace. The regional consumption rate increases if the workplace is in the same settlement. The outputs outside a region, e.g. while on vacation, are comparatively low, but must not be

neglected (see for example Haisch 2008,Beckenbach et al. 2011, Schubert and Kroll 2013).

Regional demand effects of property and construction expenditure

In contrast to the demand effect of the personnel expenditure, the material and construction expenditures become directly inquiry-demand and can be found out over the addresses of the suppliers/service provider (see for example Haisch 2008, Beckenbach et al. 2011, Schubert and Kroll 2013).

Influence on regional economic performance

By combining internal company data with regional economic data, the research organization's influence on regional economic performance can be determined. Thus, among other things, it is possible to calculate the tax multipliers of the financial volume or the public financing of a research infrastructure (see for example Frietsch et al. 2016).

Knowledge Effects

Knowledge transfer

The three central functions of research infrastructures according to Assenmacher et al. (2004) are:
(1) the generation of new knowledge,
(2) the processing of global knowledge on regional use, and
(3) the selection or pre-selection of relevant information.

The generation of knowledge and transfer to (regional) companies represents the primary task of a research institution. With the second function, often referred to as antenna function, a research institute comes to the task of knowledge transfer. It tries to optimize the benefit for companies from the information, because the companies have little effort to obtain this information. The national and international networks of the research institute also play a crucial role in this, as they provide access to the latest trends and challenges in the region. On the one hand, the third function seeks to avoid a lack of information, but on the other hand also to avoid an over-abundance of information. This is mainly about the differentiation of relevant and irrelevant information for (regional) companies. The implementation of knowledge and technology transfer between research institutions and companies varies widely (see Table 2). A distinction can be made between hard and soft transfer forms (Assenmacher et al. 2004).

In summary, knowledge effects regarding research infrastructures can have the following regional effects: promotion of innovation and growth, regional development with the formation of regional networks, increase in competitiveness of companies and regions, initialization of regional research topics (in companies and politics) (Assenmacher et al. 2004, pp. 133–147)

Table 2
Transfer forms of knowledge

Transfer form	**Type of transfer**	**Example**
Soft transfer form	information transfer	Identification of problems with a literature analysis
	Consultant and reviewer activity	Evaluation of information and alternatives
Hard transfer form	Research cooperation	Student theses on behalf of companies
	Staff exchanges	Staff exchanges between companies and research institutes
	Scientific training	Participation in meetings, workshops and conferences

Source: according to Assenmacher et al. 2004, pp. 146–148

Project innovation type

In short, "a project that is essentially characterized by the uniqueness of the conditions as a whole" (DIN 69901-1 2009). A general classification of projects is possible in investment, research and development as well as in organizational projects. It is possible to supplement this distinction by the project size (small, medium, large) and project complexity.

Projects usually have a (narrow) time frame (fixed beginning in time, defined end in time); are subject to financial and personnel requirements; have one or more predefined project goals at which the project's success can be measured at the end and appropriate measures for achieving the goals can be derived. Characteristic of projects is the implementation in teams and high uncertainty or the high risk.

A classification of the projects of a research institute is relatively clear. The research and development project type is authoritative, but not sufficient for further evaluation. Therefore, other categories are useful for these projects. Categories such as e.g. the innovation of projects. According to Stummer et al. innovations can be subdivided into product, process, market and social/organizational innovation (Stummer et al. 2010, pp. 10–16).

A product innovation is a renewal or improvement of a company's manufactured products and services. Renewed or improved products can substitute existing products for a higher, additional benefit or a better price / performance ratio (substitutive innovation). The renewal will also open up expanded business potential and markets (value added innovation) and satisfy previously low-level needs (application innovation) (Stummer et al. 2010, p. 14). A project example for product innovation is the development of a technology for a specific application.

Process innovation focuses on the more efficient production of products and services. Optimization of key production factors such as time, resources used, output, and therefore costs due to innovation in the manufacturing process is achieved (Stummer et al. 2010, p. 15). Among other things, the use of automation technology represents a project example for a process innovation.

Market innovation represents an "absolute innovation". Associated with this is the first time offering of this product or service on the market. An innovation of this kind often opens up a new market or shifts competitive positions in the existing market. To minimize the risk, the target group and their consumption behaviour are analyzed in advance (Stummer et al. 2010, p. 16). Such projects are rare. Therefore, only a few projects in this category represent such an innovation. A market innovation, for example, are products such as smartphones or smartwatches.

The fourth and final innovation of this categorization is social/organizational innovation. It refers above all to the employees in the company and the corporate structure. Other aspects are the legal area and occupational safety. Often there is a direct link between this innovation type and others. Projects to mention here are those that promote the use of assistance systems in production and thus optimize the processes in the company. At the same time, they change the process organization and increase the output quality. This probably leads also to an increase in employee satisfaction, which is difficult to measure (Stummer et al. 2010, p. 16).

The categorization of innovations according to Stummer et al. (2010) is almost congruent with the classification according to Bullinger and Schlick (2002). Here, the division into product and process innovations (technically oriented innovations) as well as structural and social innovations (human oriented innovations) takes place.

Another way of categorizing innovation is the approach of Hutzschenreuter 2009 (see Figure 1). The dimensions of customer benefit and solution principles are the distinguishing features here. Feature values are "consisting" and "new". This in turn results in four types of innovation. These are incremental innovation, application innovation, technology innovation, and strategic innovation.

		Customer benefits (e.g. application)	
		consisting	new
Solution principle (e.g. technology)	consisting	incremental innovation	application innovation
	new	technology innovation	strategic innovation

Source: 2009, p. 395

Figure 1. Types of innovation according to Hutzschenreuter

One of the incremental innovations is the optimization of products and services. An existing customer benefit is therefore satisfied with an optimized existing technology (Hutzschenreuter 2009, p. 395). With regard to projects in a research institute, this includes, for example, optimization in the logistics chain.

Compared to incremental innovation, application innovation creates new customer value using an existing solution principle (Hutzschenreuter 2009, p. 396). The transfer of a method or methodology to a new area of application is a project that represents such an innovation.

A technology innovation fulfils an existing customer benefit with a novel technology. The way in which data gained plays an important role in projects with research institutions (Hutzschenreuter 2009, p. 396). Compared to

the past, where process data was taken by observing, recording the time or describing the process, process data are now collected automatically or through simulations.

The fourth and final innovation of this categorization is strategic innovation. It represents the greatest innovation. By using new solution principles, a new customer benefit is achieved at the same time (Hutzschenreuter 2009, p. 396). New business models characterize this type of innovation. This strategic change has a big impact on how technologies are used. Customer-specific data plays a decisive role now.

The review of innovation intensities is thus possible from several perspectives, on the one hand by the self-assessment of the companies and on the other hand by the classification of projects in one of these innovation categories. The innovation potential is measured by interviewing companies and “by the number of mentions of the various innovation-related activities" (Blume and Fromm 2000b, p. 111). The implementation of a potential assessment has not taken place to date.

Political Effects

Regionality of projects

For the regionality of the projects, it is necessary to analyze all projects of the research institute according to the clients, their country of residence and their postal code. This evaluation makes it easy to identify the share of regional projects in the total number of projects. Categorizations such as "projects within your own region", "projects with adjacent neighbors" or "projects within a radius X" can be very helpful for further evaluation.

Cultural Effects

Anchoring in the cultural memory

In theory, there are different forms of memory. The duration of remembering divides memory into social (short-term memory) and collective memory (long-term memory). When addressing the memory, the medium plays a major role. Conversations are the medium of social memory, while mental images are the medium of collective memory. Another form of memory is cultural memory. The cultural memory is characterized by "that we appropriate them [the signs: language, gestures, facial expressions, images, experiences, and so on], not to 'master' them or to use them for certain, but to deal with them and make them an element of our identity" (Assmann 2006, p. 4).

The anchoring of the research institution in the cultural memory is to be determined by means of a survey. In the process, images of the region, including the research infrastructure, are shown and, after that, the recognition of the individual locations is compared. The relation between the recognition and the total number of respondents gives the factor of anchoring in the cultural memory.

CONCLUSION AND FURTHER INVESTIGATIONS

The evaluation of German-language literature shows a concentration on the determination of economic effects. Economic effects also integrate knowledge effects due to the frequent classification in service production and output. Typically, investigated research infrastructures were universities and the study period was often limited to one year. This means that a development of regional effects over a period of several years has rarely been analyzed.

The in-depth studies consider the following:

(1) firstly, to evaluate the effects of knowledge on another level,
(2) secondly, to extend the analysis to the effects of other categories,
(3) and third, to increase the period of observation in order to compare individual annual results.

The first point aims to see knowledge not only as an economic factor. The focus is on the handling of knowledge, the preparation and transfer of knowledge as well as the frequency of a particular project innovation type. The second point clarifies the intention of a holistic valuation model. The last point is to avoid the vulnerability of a one-time evaluation. For example, it brings to light the resilience and strength of a research infrastructure. Research infrastructures can therefore be important stability factors for a region in a crisis.

This work presents a first approach to a holistic assessment of regional impacts of research infrastructures. Social, cultural and ecological effects are the focus of further actions. Extending the literature to the English-language sources is a goal despite the uniqueness of the German innovation system.

It has become clear that a research infrastructure has a positive effect on its region. An extension of the existing assessments is possible through further meaningful indicators that are not limited to economic effects. During the preparation of this text, therefore, ideas for other indicators emerged.

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