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An Indicator-Based Determination of Commercialization Potential of Research Institutions

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Abstract

This paper develops a practical knowledge management decision support tool for research institutions. We build on the most established indicators inventions, publications and third-party funds. With the help of the Simple Multi-Attribute Rating Technique (SMART-Method) we combine these different indicators to a single measure that represents the existing scientific knowledge within research institutions that potentially can be commercialized using traditional transfer channels. A case study of a typical German university illustrates the applicability and transferability of our approach. We present several fields for future research and discuss a range of practical applications.

Keywords: knowledge transfer, commercialization, decision support system

JEL Classification: I23, O31, D81

1. Introduction

Economists have long confirmed that R&D is the central determinant of GDP-growth and hence of employment as well (Solow, 1956; Swan, 1956; Romer, 1990; Grossman and Helpmann, 1990). Among politicians this is already a strong conviction. Innovations constitute the core element of the "EUROPE 2020"-Strategy to improve growth and employment stimuli (European Commission, 2011). Innovations are the result of R&D activities, are key to problem solving by creating technological, economical as well as social renovation and involve an economic commercialization (Damanpour and Wischnevsky, 2006). It is widely known that most R&D activities are carried out by a small number of large firms (Konzack et al., 2011). However, more than 99 percent of the European economy is characterized by SMEs. Normally these firms do not possess the necessary financial and personnel resources to accomplish high-risk R&D-investments (Saunila and Ukko, 2014). Regions which are mainly stamped by a small-sized structure in their economy (do) have a significant competitive disadvantage by fighting for economic growth and wealth. In the future, research institutions, especially universities, shall operate as regional drivers of innovation (Fransman, 2008; Rampersad et al., 2012). They possess the resources, in particular the required infrastructure and knowledge, to not only create distinct innovations but even more important to support R&D activities of the local economy (Philpott et al., 2011). At the bottom line this assignment can be translated into a context of decision-making. From the perspective of research institutions the task to maximize income steaming from commercializing existing knowledge by means of traditional transfer channels shall sufficiently support the economy (Kester et al., 2009). With this in mind knowledge commercialization is the identification of knowledge involving economic potential or the exploitation of ideas from the market point of view, respectively (Fiet et al., 2007). Developing this thought, we evaluate economic potential of institutions by focusing on their existing research knowledge, which can be commercialized by means of traditional transfer channels. Economy can create innovations by applying this knowledge (Saunila and Ukko, 2014).

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In Germany, the biggest industrial nation in the EU (Europe's strongest economy), all necessary requirements to implement this strategy are currently not met. An insufficiently developed culture of exploiting ideas within the German landscape of universities, which traditionally focus on research and teaching, is a major reason. Consequently, necessary structures and processes to transfer knowledge between science and economy are inadequately developed (Siegel et al., 2007; Gulbrandson and Audretsch, 2008). This explains why currently 90 percent of all transfer activities between research and economy are bypassing transfer units of universities or are non-observable, respectively (Meier and Krücken, 2011). In order to become regional drivers of innovation research institutions first of all have to be able to gather, locate and transparently process available knowledge with economic potential before traditional transfer chancels can be used (Huggins and Kitagawa, 2012). Such methods or tools are known as "knowledge management decision support systems" (Cooper, 2003), "performance measurement systems for research activities" (Chiesa et al., 2008) or "decision support systems" (Nosella et al. 2008). Nonetheless, the identification of innovation potential and the application of such tools is strictly limited to firms so far (Schoenecker and Swanson, 2002; Hagedoorn and Cloodt, 2003; Roper et al., 2008). All of these basic approaches are not offhand transferable to research institutions. There are few approaches in literature directly focusing on the commercialization potential of universities. In general they aim to provide insights on the basis of single output indicators such as inventions, patents and licenses (Arundel and Bordoy, 2008). Additionally, research financing differentiated with respect to funding sources is analyzed as input indicator (Langford et al., 2006). Rasmussen (2008) includes the number of start-ups as a further indicator. On the other hand, Matsumoto et al. (2010) explore the influence of scientific output (publications and patent applications) on the economic development of different industries with a four-phase model. The interleaving of both aspects derives the following research questions addressed by us in the current paper.

- Which indicators can reproduce the entirety of existing knowledge of research institutions?
- How can these indicators in terms of "knowledge management decision support systems" be gathered, aggregated and transparently processed for knowledge transfer?
- Is the application of this basic approach able to deliver practical solutions and implications for decision makers in the context of knowledge transfer?

Our main research contribution is the first-time development of a theoretical framework for a knowledge management decision support system for research institutions. On the basis of the acknowledged scientific output indicators *invention activities*, *third-party funds* and *research activities* a tool to support decision makers in the field of research accrues. By means of the SMART-method indicators are aggregated to one single measure which represents the current stock of knowledge of units within research institutions, which have potential to be commercialized via traditional transfer channels in the future. Furthermore, we disclose existing restrictions of our approach and derive the necessity of research in the fields of econometrics, tacit knowledge as well as the regional economic demand and its absorptive capacity. The case study of a typical German university has led to distinct results and shows the practicability of our decision support system. In the sequel, university decision makers are now able to improve knowledge transfer between science and economy. Therefore our approach meets the political mission of the EU to expand research transfer activities by approaching suitable monitoring as well as evaluation systems (European Commission, 2012). Our approach strengthens universities in medium structured economic regions to act as local drivers of innovation. The paper is structured as follows. Within chapter two we analyze different dimensions of scientific output proposed in various fields of literature. On this basis suitable indicators to evaluate the overall band width are conducted. At the end of chapter two the SMART-method and its set of instruments is introduced in order to aggregate the identified assessment measures. By means of a case study we verify the practical applicability and transferability of our derived approach in chapter three. Using the example of a technical university in Germany we illustrate the methodical proceeding. Moreover, gained results are presented and discussed. Concluding in chapter four we underline the increment value of our work concerning research, practical experience and politics and endorse by existing restrictions of the approach combined with a prospectus for further research.

2. Theoretical Approach

This section presents a theoretical approach to support the identification of the commercialization potential within existing research institutions. Chiesa et al. (2008) refer to the task of designing a "performance measurement system" as a decision support tool. Necessary therefore is the implementation of a systematic scouting and evaluation process with the goal to identify existing knowledge regarding new and superior technologies (Fiet et al., 2007; Nosella et al., 2008).

For decision (- making) processes Cooper (2003) highlights the systematic data analysis as basic characteristic of "knowledge management decision support systems". According to Cooper, this is a tool to acquire and gain access to valuable knowledge. The resulting transparency reduces the R&D costs of scientific institutions (Pacharn and Zhang, 2006).Such systems are fundamental preconditions for firms to optimally exploit R&D activities with the goal to secure competitive advantages and improve (their) market position. However, for research institutions an evaluation system has to consider differing output formats. In many decision-making contexts past performance is a suitable approximate for potential (in terms of future performance). Research institutions with well-established transfer structures and a clear focus on the commercialization of knowledge could base their optimal comparison of structural units, e.g., institutes or chairs, solely on past annual revenues generated by transfer efforts. Since most universities in Europe, especially in Germany, do not have the necessary commercialization culture and history, alternative methods for measuring existing knowledge for transfer have to be sought. In the transfer literature of research institutions there are only few attempts to measure the existing knowledge for commercialization (Langford et al., 2006; Arundel and Bordoy, 2008; Rasmussen, 2008). Existing analyses are primarily output-comparisons of different universities. For instance in Germany, Pohlmann (2010) investigates the transfer potential of identical departments of Hessian universities with the efficiency based Data Envelopment Analysis method. These papers normally focus on some but do not cover the full scope of available indicators of the commercialization potential through the exploitation of existing knowledge and do not justify their choice. We build our approach on the transfer literature of research institutions and add a discussion of the relevance of different research output indicators for firm innovations. Additionally, we contribute by integrating all transfer relevant indicators to a single measure. To develop an approach for a knowledge management decision support system for research institutions in the context of technology transfer and to derive policy implications we need to take the following pivotal steps: first, a literature based identification and discussion of possible indicators to measure transfer-relevant knowledge and second, the aggregation of chosen indicators using a legitimated value function.

2.1 Indicators

Although literature features a multitude of operating figures, so far no scientific approach for measuring the potential of innovations has gained full acceptance among researchers (Hagedoorn and Cloodt, 2003). Innovations are based on existing knowledge. In research institutions such knowledge is created as output of scientific activity in different forms. With respect to the transfer of the relevant economic impact of output formats significantly vary between research fields (Martinelli et al., 2008). Single operating figures having advantages and disadvantages can only explain a certain part of the commercialization potential. To our knowledge there is no approach to combine different output criteria to a single measure that represents the total knowledge of a structural unit and hence could be the basis for strategic decision-making (processes). Therefore, a combination of the most accepted indicators (a multiple indicator approach) can deliver a more comprehensive evaluation of the innovation or commercialization potential based on (the) existing knowledge (Hollenstein, 1996; Hagedoorn and Cloodt, 2003). In general, quantitative criteria are preferred to measure output as they are characterized by a simple data collection, direct evaluation and a higher level of objectivity (Chiesa et al., 2008). Qualitative assessments of commercialization or innovation potential usually originate from expert interviews. Personal preferences of participants may distort these results, and hence their comparability is limited. Moreover, the collection of a multitude of expert opinions comes at a great expense. Business and market innovation, for example, is indicators for corporate assessment with a qualitative character (Acs et al., 2002; Kleinknecht et al., 2002). Internal decision makers are responsible for evaluating whether an invention is classified as a market innovation or only as new to the company. In case of additional insights or missing information a combination of quantitative and qualitative indicators is possible (Chiesa et al., 2008). In this sub-section we enrich the set of possible indicators discussed in the literature and reveal their positive features and shortcomings. In Figure 1 we structure all proposed indicators into three categories of indicators: *invention activities*, *research activities* and *third-party funds*.

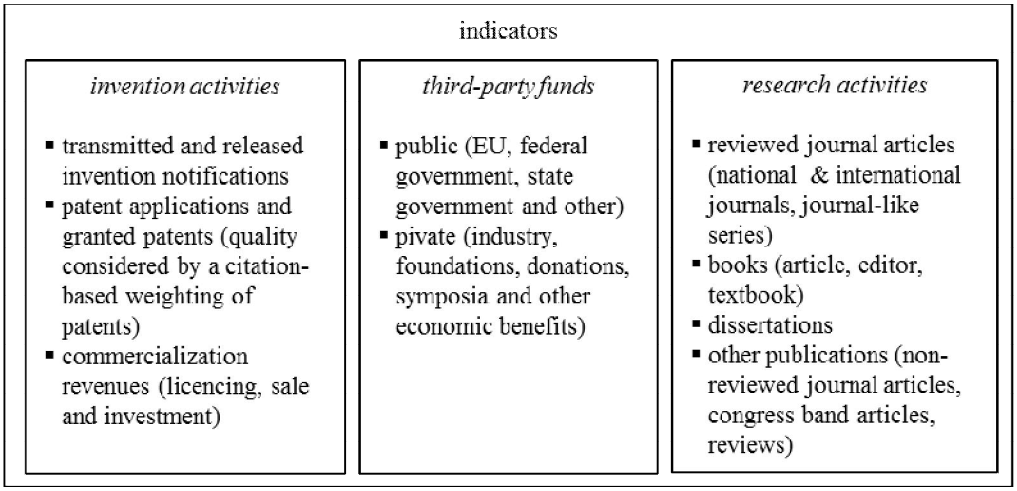


Fig. 1: Indicators for the Commercialization Potential

The relevance of these three dimensions for the innovation and commercialization potential of research institutions is confirmed in theoretical and empirical literature (van Raan, 2006; Langford et al., 2006; Matsumoto et al., 2010). *Research activities*, which is the most indirect category as a check for marketability, are usually missing. Nevertheless, it measures new knowledge at an early stage which is not covered by the other two. On the other hand, an indicator is listed in the category *invention activities,* if first steps towards an invention or a commercialization of research results are initiated, e.g., the protection of proprietary rights. Most indicators in literature belong to this category. However, it does not characterize the commercialization potential from direct cooperation with industries. Often this research must not be published and the industry partner receives all proprietary rights. Direct knowledge transfer to cooperation partners can be captured by the category *third-party funds*. The higher the amount of these external funds, the higher the expected economic value of the transferred knowledge. Subsequently, we discuss the measurement of possible indicators in greater detail.

2.1.1Invention Activities

Most indicators are intended to offer insights to the input-output process in the context of firm innovations, on which basis performance comparisons of innovations are conducted. Input indicators such as R&D-expenditures (Fritsch and Franke, 2004; Lööf and Heshmati, 2006) and R&D-personnel (Brouwer and Kleinknecht, 1999; Frascati, 2002) are often applied since they can be determined with low effort and without ambiguity. Nevertheless, these ratios do not consider efficiency and cannot easily be transferred to the context of research institutions. Instead, we concentrate on the following output indictors for invention activities: transmitted and released invention notifications (Arundel and Bordoy, 2008), patent applications (Edler and Schmoch, 2001; Roper et al., 2008), granted patents (Acs and Audretsch, 1988), patent citations (Hall et al., 2005), return from past knowledge transfer (Langford et al., 2006), and number of spin-offs (Rasmussen, 2008). Since the German privilege for scientific staff to commercialize their own findings was repealed in 2002 (ArbEG §42), a German university now possesses all intellectual property rights that originate within the university. All employees have to register research outcomes that can be commercialized.

Usually this obligation to report inventions already in an early stage should lead to a reliable indicator for the commercialization potential. This indicator has a high predictive value, but only if the research institution has a sufficient incentive structure to report inventions. In practice, however, there is often a low awareness towards this obligation due to insufficient communication. Moreover, the incentive structure is not optimal and a penalty mechanism is missing. Hence, there is no reliable data on registered inventions available. For example, since a patent information center conducts an intensive patent examination before an invention is officially notified, the overall number of registered inventions is considerably lower. As an alternative, we use the three often available indicators that represent the output of the transfer process: transmission of inventions to external research partners, release to inventors, and property rights intended to be realized by the university. A second class of indicators discussed in literature is related to patents. Granted patents are suitable indicators for new knowledge that can be commercialized (Hülsbeck, 2011) because the patenting process follows a standardized and transparent procedure (Pohlmann, 2010). Thereby a significant progress in the development of an invention is guaranteed. On the other hand, proprietary rights cannot be acquired for all inventions so that part of the existing potential is neglected.

The propensity to patent also differs considerably between industries and faculties (Brouwer and Kleinknecht, 1999). Moreover, a head start is sometimes more important to realize value creation, and a patenting process is avoided to keep information closed. Additionally, patent test procedures are time consuming (Roper et al., 2008, Hülsbeck, 2011) and indicate commercialization potential with a large time lag. Using patent applications instead avoids this problem, but, again, inventions are considered at the beginning of the process. A third disadvantage is the considerable difference in the quality of granted patents, respectively the likelihood to successfully commercialize them. For this reason Trajtenberg (1990) argues that the pure count of patents is an insufficient predictor for the value of innovations and proposes a combination of indicators. This paper uses the number of patents weighted by patent citations and finds evidence for a higher informational value. Thus, patent citations measure the quality of patents as they reveal being state of the art or influencing a broad field of knowledge (Harhoff et al., 1999; Hall et al., 2005). To sufficiently estimate the market relevance of inventions, literature discusses different measures of the return flow from the commercialization of patents, in particular revenues from licensing and sale. These reflect most directly the market demand and confirm a patent's applicability. However, as the commercialization process typically takes years, this indicator reveals past activities but does not show the current potential for future transfer. Moreover, transfer payments are not a suitable indicator for universities with a poor commercialization culture. Generated revenues do not necessarily represent the real economic value and the required data are missing. We observe this problem in any research institutions in Germany (Fritsch, 2009; Astor et al., 2010). The choice among the set of possible indicators depends on the available information infrastructure at a research institution. We conclude that a combination of different indicators could improve the measure of invention activities.

2.1.2 Third-Party Funds

Third-party funds have a growing importance as indicator for the scientific productivity of research institutions (Zißler, 2011). There is a direct relation between the success to acquire third-party funds and the research performance (Hornborstel, 2001; Schmoch and Schubert, 2009). Due to the simple determination and unambiguousness, this operating figure is widely accepted in science as a performance measure (Pohlmann, 2010). Over the last decades, declining federal funding increased the importance of external funds. As a result, universities more frequently used these funds as internal performance measure and based the allocation of additional financial means on that indicator. Therefore, a high competition for limited third-party fundscan be noted. In general third-party funds are seen as input for future research efforts independent of the funding source. However, we follow the output-oriented approach of Jansen et al. (2007) which accounts granted third-party funds as the output of a peer review process, where international reviewers evaluate the innovation potential and the quality of a project proposal (Garcia and Sanz-Menéndez, 2005). With respect to the source of funds, we distinguish between private and public third-party funds. This structural separation is applied in different countries (Geuna and Martin, 2003; Langford et al., 2006). Public funds are intended to reward research quality and are often used to increase fundamental research capacity. In contrast, private third-party funds are mainly provided by the industry and rather characterize direct knowledge transfer assignments. Therefore, industry funds are a direct measure for the transfer orientation of a research institution, since firms mostly commission to solve clearly defined problems. This contract research constitutes the most direct form of transferring concrete and applicable scientific research results.

Typically, the channels of the traditional transfer model like consultancy, contract and cooperation research as well as qualification fall into that category (Debackere and Veugelers, 2005; Chiesa et al., 2008, Geuna and Muscio, 2009; Perkmann et al., 2013). Thereby, research areas and industries prefer different knowledge transfer channels (Bekkers and Boda-Freitas, 2008). Additionally, the commercialization potential differs among the various transfer forms and demands different support mechanisms in research institutions (Wright et al., 2008). So far this traditional transfer model is insufficiently applied by science and economy. First, it is not clear where in an institution transfer-affine knowledge can be found and of what size. Second, the necessary structures to transfer knowledge are insufficiently established. In this context we focus on the evaluation of existing knowledge as a necessary but not sufficient condition for the application of the traditional transfer model. An empirical analysis calls for the distinction between public and private third-party funds, allowing to test the hypothesis that private third-party funds stronger stimulate research output which can be commercialized. Literature even postulates that within these two classes different funding sources have different quality in signalizing performance potential (Schmoch and Schubert 2009).

This might apply to scientific research performance in general, but not for the measurement of commercialization potential. While professional peer reviews may be an indicator for a higher quality of research, they are not necessarily a superior measure for the marketability of research. For this reason we compare research units or scientists on the basis of the unweighted sum of funds, i.e., we propose to independently evaluate the two classes of funding sources but not to discriminate within.

2.1.3 Research Activities

In general, publications are the most important indicator to measure research performance, yet research results only indirectly characterize the innovation and research potential of a structural unit. A higher quantity of research output tends to result in a higher expected return from research transfer. Publications keep record of the latest research results and determine among others the market price for external research contracts via related reputations of scientists in the academic community (van Raan, 2005: Zißler, 2011). In general, research areas considerably differ in their way to publish research output, e.g., they vary significantly in the average number of coauthors, citation culture, size of community and preferred type of publication. Therefore, academic productivity and simultaneously the reputation of researchers need to be measured by bibliometric procedures with quantitative (the amount of publications) and qualitative indicators (peer review and citation analysis). The pure number of publications is no suitable indicator for the evaluation of researchers as it does not control for significant differences in several dimensions. Literature has provided fractional numbers of publications as solution, accounting for the number of authors and the length of research papers (Skolnik, 2000). The measurement of research quality, on the other hand, is extremely controversial (Moed et al., 1985; Narin et al., 1994; Seglen, 1998). Traditionally, a double blind peer review of at least two experts is used by journals to evaluate quality but often proves to be subjective and is sometimes compared with a lottery (Rinia et al., 1998). Alternatively, citation analysis uses the number of citations to estimate the relevance of research for the scientific community (Osareh, 1996). Like other approaches citation analysis also has significant shortcomings. It is necessary to control, among other aspects, for self-citations and the number of coauthors (Costas and Bordons, 2007). Moreover, this quality measure still depends on subjective evaluations and has a significant time lag. To compare publications in different journals raises the additional problem of measuring the quality of journals. Literature offers several methods to determine the reputation of journals, e.g., the journal impact factor as most prominent measure. Nevertheless, there is substantial criticism of their explanatory power (van Raan, 2006; Garfield, 2006). Additionally, it is difficult to measure and compare the scientific performance of different disciplines due to their specific characteristics (Pohlmann, 2010).

Although not free of criticism, a combination of quantitative and qualitative procedures currently represents the best available basis for an evaluation of scientific results. Modern rankings for researchers, like e.g., the German ranking of the newspaper Handelsblatt for economists, also consider qualitative aspects and have a considerable informational value at least within certain disciplines. Nevertheless, we found no evidence in literature that the quality of research positively correlates with the transfer orientation of research institutions (Edler and Schmoch, 2001). For a complete evaluation of research achievements we need to consider books, dissertations, miscellanies, reviews and editorial scripts as well (Münch, 2006). This necessity can be attributed to the diverse publication preferences of different disciplines. We acknowledge this aspect and, hence, propose to approximate the publication performance by the unweighted sum of all publications, if possible adjusted for the number of authors and the length of publications. We abstain from a qualitative weighting to avoid interdisciplinary distortions, e.g., often medical and economics faculties focus on peer-reviewed journal articles, whereas in mechanical engineering many researchers publish monographs.

2.2 Aggregation of Proposed Indicator Categories

So far, literature has a limited explanatory power, as existing approaches only contrast some of the available indicators. As a multi-criteria comparison is often ambiguous, results are interpreted carefully. Our goal is to aggregate the full set of indicators to a single measure of the commercialization potential of research institutions. In decision making the employment of different indicators describes the setting of a multi-criteria decision problem. To compare alternatives (here: structural units of a university) we have to aggregate different information with a value function. So far, a value function has not been used in literature to determine the commercialization potential of research institutions. With the approved SMART-method (Simple Multi-Attribute Rating Technique) we can form a single operating measure which combines different influence factors (Goodwin and Wright, 1998). This method allows us to interpret performance differences of alternatives and is typically used to determine the best available alternative.

On the other hand, the funding allocation among several alternatives should be based on their marginal productivity but can hardly be determined in practice. If we want to use the resulting ranking to directly conclude on the allocation of special transfer funds among structural units we need a further assumption. The SMART-based ranking is a good approximate to allocate a fixed budget to a fixed number of structural units to be supplied, e.g., a university wants to financially support the best 20 departments. Therefore, the proportion of the given budget allocated to each of these departments is determined by the relation of their performance value to the sum of the top 20 performance values. In order to apply the SMART-method, the critical assumptions need to be examined. Particularly, the indicators used to approximate commercialization potential must be additive and separable. This basically requires that all indicators can be evaluated independently. Otherwise it could lead to distortions from over- or underweighting. In that case we need statistical procedures that control for autocorrelation of explanatory variables. We normalize the performance value per-capita to account for the different dimensions of all indicators. In this scoring approach the structural unit with the best performance for an indicator receives 100, the worst 0 points. All other performance values have to be scored accordingly within this range. The weights w_i of the value function are based on expert opinions. We propose to ask field and transfer experts for swing weights (Goodwin and Wright, 1998), because they express the relative importance of an indicator as well as the magnitude within indicators. For small differences between all structural units an indicator will receive a lower weight and hence will have a lower influence on the overall value. The received swing weights are normalized and, therefore, add up to one.

$$v(SU_j) = \sum_{i=1}^{4} w_i \cdot v(x_j^i) \quad \text{with} \quad \sum_{i=1}^{4} w_i = 1$$

The overall value v (SU_j) of structural unit j (j=1…n) is the sum of all per-capita performance values $v_i(x_i^j)$ for the relevant indicators x_i^j weighted individually with w_i. Our four independent indicators (*invention activities, research activities, private third-party funds and public third-party funds*[3]) provide different evidence for a high potential of commercialization of knowledge per structural unit. With the above provided additive and separable value function we can compare all structural units on the basis of a single effectiveness measure v (SU_j). The per-capita commercialization potential of each structural unit is accordingly valued within a range of 0 to 100 points. Multiplied, respectively, with the number of full-time equivalent employees, we receive the overall commercialization potential per unit as a second decision basis. The next section presents an empirical test of our methodology and discusses different models to determine the weights for our indicator bundles.

3. Methodology

To practically test our theoretical approach we have chosen to call in a case study. Hereafter, the area of analysis - the university structure - is delineated, before the selection (data basis) and the loading of indicators (interviews of experts and models) is described in detail. Finally, we present the results of our case study and provide a discussion of the implications.

3.1 Area of Analysis and University Structure

The case study we executed at the Otto-von-Guericke University of Magdeburg (subsequently OvGU), is a middle sized university in the German federal state of Saxony-Anhalt. R&D-activities of economy and science of this region can be accounted for being representative for numerous states in Germany (Bühnemann, 2012) and for several regions within the EU as well (Bocken et al., 2014). On this account an OECD case study examined the economic region in order to gain insights into the existing structure and the related processes (Proto et al., 2012). The economic structure can be characterized by more than 98 percent of small and medium-sized businesses (subsequently SMEs), in many cases with annual turnover of less than two million Euros. Moreover, these firms operate most of the time on local and regional markets with marginal export rates. With on average 1.15 percent of the GDP, R&D-activities of these SMEs are exceedingly small and in addition intensively government-funded (65 percent of the expenses). Cooperation between science and economy is rarely established.

3 To analyze the influence of the sources of external funds on commercialization potential, we suggest separating them and, hence, consider four different sets of indicators. This split does not distort results insofar as the weighting process of indicators takes into consideration their similar character.

We identified several reasons for this lack of cooperation: research foci of academics do not largely correspond to companies` R&D-demand and the cooperation potential is not sufficiently identified. Exemplarily, the OvGU's technology transfer center aiming to promote transfer between economy and science is not perceived adequately. Based on these findings federal politians invite universities, e.g. the OvGU, to promote innovation and to support regional economic growth. Necessary structures and processes for an intensive transfer between science and economy have to be developed and implemented immediately (Becker et al., 2013). Just like many other universities within Germany the OvGUhas notyet established structures of commercialization. In order to structure a market-oriented unit focusing on the commercialization of research-based knowledge considerable investments are necessary (Genua and Muscio, 2009). Following these arguments the OvGU is supporting the conducted case study by giving access to information which are unique in scope (data basis) and quality (interviews with experts) in the analyzed field. Objective is the transparent identification of structural units (institutes as well as chairs) with a high level of economically usable research-based knowledge as a fundament for decisions concerning future activities in the area of transfer. Additionally, our analysis is the prerequisite to develop the monitoring and evaluation system for transfer structures postulated by the EU (European Commission, 2012). Our data collection and analysis follows the organizational structure of the OvGU, graphically shown in figure 2. All faculties are assigned to the university's three foci: mint, medicine and social sciences. In parentheses the number of institutes per faculty is given. Therefore, in total 113 structural units have been included in our analysis.

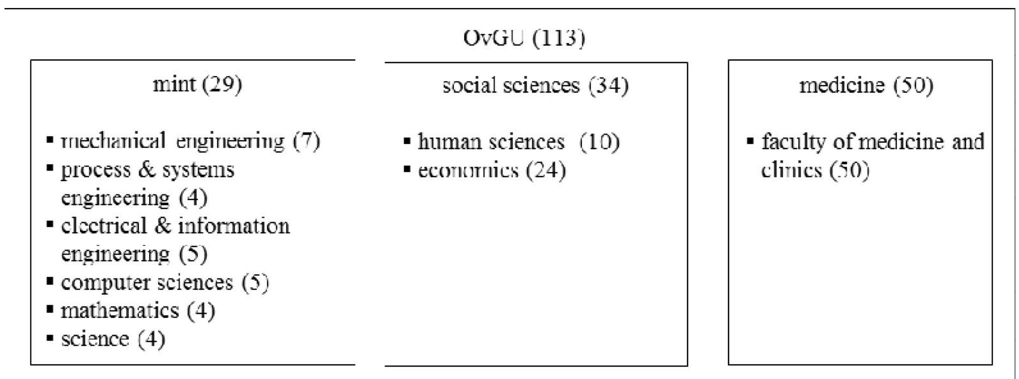


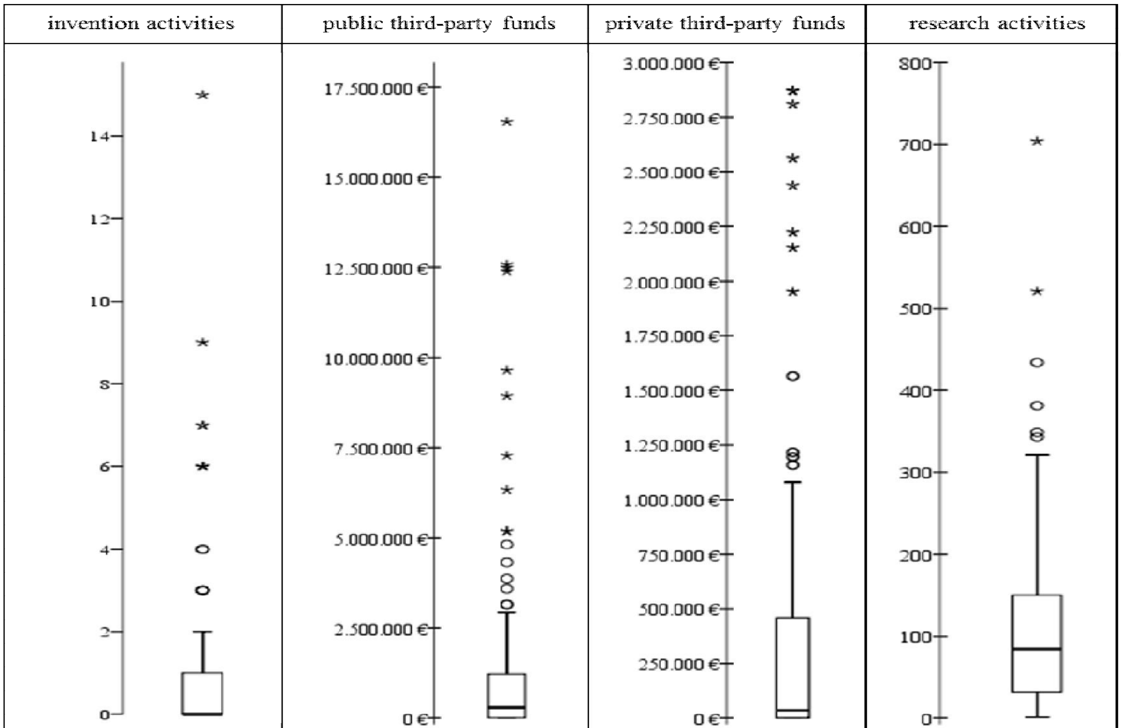
Fig. 2: Organizational Structure of the OvGU[4]

3.2 Indicators and Data Base

On the basis of the available information infrastructure we detail how to determine and to aggregate the sub-indicators for each category as discussed before. *Invention activities* are approximated by the sum of patent applications, released inventions, and transmitted property rights. Two types of distortions are possible: First, inventions that cannot be patented and are commercialized by the university are not considered by the approximation. Second, an overlap of these three categories could happen, e.g., an invention is patented and later the right to commercialize is returned to the inventor. This double count is expected to have a low distortive impact, because a scoring takes place before the different indicators are summarized in a value function. Therefore, the absolute number is always between 0 and 1.As the OvGU is currently preparing a commercialization infrastructure and, therefore, has no sufficient commercialization history, we do not consider the return from commercialization of inventions. For the category *research activities* we equally weight all types of publications and, hence, use the sum of all as indicator for interdisciplinary comparisons. For reason of simplicity we do not control for differences in length, number of authors, etc. and are aware of some minor structural distortions that may result. In particular, we observe a tendency of medi-cal faculties to list more authors on relatively short papers compared to other disciplines, and we account for this and other influences in our interpretation. With respect to *third-party funds* we follow the résumé of section 2.1.2 and abstain from a discrimination of the sources of financial support. Hence, we take the unweighted sum of all funds classified according to their origin in public and private external funds measured in Euro.

[4]At the faculty of economics the institutional level does not exist. In some cases chairs were included in our analysis in place of the institutional level.

In order to test our approach we collected data with respect to the four proposed indicators from 2007 up to 2011 for all structural units predominantly from the university information system (HIS) and the annual publication report provided by the Technology-Transfer-Office (TTO). HIS contains data about third-party funds and the number of employees per structural unit. Not until the number of employees is considered is it possible to receive a significant comparison of all structural units. The annual publication report of Saxony-Anhalt additionally lists all scientific publications, invention notifications, released inventions and patent applications. An explorative data analysis of all indicators provides an overview of OvGU-performance measures aggregated over the five year survey period. The boxplot in figure 4 summarizes this information and highlights outlying as well as extreme values for all variables (Johnson et al., 2002). Descriptive statistics offer further details to the indicators.



n:	113	n:	113	n:	113	n:	113
mean:	1	mean:	1.458.358 €	mean:	384.359 €	mean:	112
median:	0	median:	295.095 €	median:	35.532 €	median:	84
standard deviation:	2	standard deviation:	2.946.273 €	standard deviation:	682.042 €	standard deviation:	114
min:	0	min:	0 €	min:	0 €	min:	1
max:	15	max:	16.539.826 €	max:	2.871.662 €	max:	704
perc. 0,25:	0	perc. 0,25:	5.531 €	perc. 0,25:	218 €	perc. 0,25:	31
perc. 0,75:	1	perc. 0,75:	1.233.950 €	perc. 0,75:	473.186 €	perc. 0,75:	152

Fig. 3: Boxplots and Descriptive Statistics of the Four Indicators

In order to apply the value function introduced in section 2.2 we need to control for possible dependencies between indicators. Naturally, a large structural unit is expected to create more inventions, collect more third-party funds and have a greater number of papers published. The resulting high correlation between indicators can be eliminated by comparing the indicators on a per-capita basis. Thus, all indicators are set in relation to the amount of full-time equivalent positions in our value function. A correlation analysis of all per-capita indicators can confirm their independency. For the OvGU we determined the annual per-capita indicators as average over the period 2007 - 2011. Table 1 summarizes the results of the correlation analysis. The correlation matrix confirms only a moderate positive correlation between private and public third-party funds per-capita on a one percent level of significance. Nevertheless, the scatter plot reveals no systematic dependency between both indicators.

Tab. 1: Correlation Coefficients between all per-Capita Indicators

correlation matrix of the average standardized indicators (2007-2011, cases n=565)		researchactivities/st	inventionactivities/st	public third-party funds/st	private third-party funds/st
researchactivities/st	correlation (Pearson)	1			
	significance (double sided)				
inventionactivities/st	correlation (Pearson)	.020	1		
	significance (double sided)	.641			
public third-party funds/st	correlation (Pearson)	.013	.045	1	
	significance (double sided)	.758	.288		
private third-party funds/st	correlation (Pearson)	.012	.079	.137**	1
	significance (double sided)	.773	.060	.001	

**. The correlation is significant on the 0.01 level (double sided).st-staff

3.3 Indicator Weighting

We have identified 113 structural units of the OvGU, divided into medicine (50 units), social sciences (34 units) and mint (29 units). Nevertheless, depending on the available information, structural units on each level could be explored, i.e., even an analysis per person is possible. A comparison of all structural units on the basis of our four indicators reveals some basic insights, but does not allow a consistent ranking. In order to derive clear implications, all structural units should be represented by a single measure. The value function proposed in chapter 2.2 requires a weighting of the scored performances for the introduced indicators. So far, literature does not provide any accepted empirical attempt to establish weights for indicators of commercialization potential. In our case study we ascertain these weights on the basis of expert interviews with 18 transfer relevant decision makers of the OvGU. The selected individuals are all capable to answer our questionnaire since they possess the necessary expert knowledge and are acquainted with the universities's internal structures (Liker and Sindi, 1997). We have applied the CAPI method conducting face-to-face computerized interviews of roughly 30 minutes (Hamman and Erichson, 2000). To receive a broad range of information we have used four open questions to evaluate the present transfer activities, the status of transfer within the university and necessary future measures to restructure knowledge and technology transfer at the OvGU. A closed question concerning the relevance of our four indicators, motivated in section 2.1, followed in order to measure the commercialization potential of transfer relevant research results. The answers were mainly based on the experts' past experience. Experts were chosen according to an analysis of possible transfer key players at the OvGU (Häder, 2006). We have identified nine central transfer agents belonging to the organizational unit of the rectorate, the technology transfer center as well as pertinent research units. Additionally, we have included one transfer-affine expert from each faculty in our survey, most often the dean due to his/her representative position. Hence, this broad expert base delivers a unique qualitative cross-section. We have identified significant differences in weights between the involved experts. Table 2 summarizes the results and indicates different faculty attitudes towards technology transfer (Martinelli et al., 2008).

Tab. 2: Weighting of Indicators by Transfer Experts and Representatives of all Faculties

area	position	invention activities	public third-party funds	private third-party funds	research activities
transfer area					
patent information center	head	0,200	0,350	0,350	0,100
technology transfer center	patent respons.	0,300	0,200	0,200	0,300
rector's office	vice rector	0,600	0,150	0,200	0,050
technology transfer center	head	0,400	0,200	0,300	0,100
research department	head	0,050	0,375	0,375	0,200
data & knowledge engineering group	head	0,200	0,200	0,200	0,400
rector's office	rector	0,200	0,300	0,300	0,200
chair of entrepreneurship	head	0,400	0,200	0,100	0,300
chair of innovation management	head	0,000	0,100	0,900	0,000
faculty					
electrical & information engineering	vice dean	0,100	0,200	0,300	0,400
mechanical engineering	dean	0,100	0,400	0,300	0,200
science	dean	0,100	0,800	0,100	0,000
process & systems engineering	dean	0,100	0,300	0,300	0,300
mathematics	dean	0,100	0,300	0,200	0,400
computer science	vice dean	0,300	0,200	0,300	0,200
economics	dean	0,000	0,200	0,050	0,750
human science	dean	0,050	0,400	0,050	0,500
medicine	dean	0,050	0,350	0,250	0,350

There is no ultimate way to handle diversity in expert opinions. Various opinions exist, especially with respect to the competences of transfer and faculty experts. In general, with differing expert opinions diverse weighting philosophies can lead to significant variations in the ranking of structural units. The expected consequences are even more severe the smaller the transfer budget. If results critically depend on the chosen weighting model we expect a difficult discussion among decision makers. Our methodology could become a helpful guide in this process, since the enhanced transparency enables better matching of university targets and consequences of resulting measures. Nevertheless, our set of proposed weighting models is not closed and institution-specific adaptations are recommended. An ex-ante comparison of different weighting models could even serve as a mediator, stimulating a better alignment of transfer relevant structures. We present seven different concepts aggregating 18 collected expert opinions. The resulting weights for all models are summarized in table 3.

- The first model represents the average of the weights of all 18 experts against the background of an equal consideration of transfer agents and representatives of the faculties.
- For model 2 we assume that only transfer experts possess the relevant know-how and hence calculate the weights as arithmetic mean of the nine transfer agents.
- In contrast, model 3 exclusively indicates the view of the nine faculty representatives by calculating the weights as their arithmetic mean.
- Model 4 accounts for the differences between the faculties with respect to the importance of indicators. Here, the performance of all structural units is directly weighted with the particular faculty representatives'' rating while transfer experts are ignored.
- Model 5 is also only based on the faculty representative's weights, but concentrating on the average of the university's focus areas mint, medicine and social sciences.
- Model 6 is a combination of model 2 and 4 paripassu. Hence, we consider the experience of the transfer experts and the individual preferences of faculties at the same time.

- Finally, model 7 accounts for situations in which a single person within a university has the sole responsibility for knowledge transfer. This central decision maker nominates weights for the indicators based on a profound transfer expertise and allocates resources and takes other transfer measures on the basis of the resulting rankings.

Tab. 3: Different Weighting Models

indicator / model	invention activities	public third-party funds	private third-party funds	research activities
model 1 - university average	0,181	0,290	0,265	0,264
model 2 - transfer experts' average	0,261	0,231	0,325	0,183
model 3 - facultuies' average	0,100	0,350	0,206	0,344
model 4 - single faculties	data single faculties			
model 5 - mint/social siences/medicine	0.133/0.050/ 0.025	0.367/0.350/ 0.300	0.250/0.250/ 0.050	0.250/0.350/ 0.625
model 6 - combination model 2 and 4	equal weighting of model 2 and 4			
model 7 - central planner	0,200	0,300	0,300	0,200

3.4 Results

An application of all weighting models delivers seven different rankings of commercialization effectiveness and, hence, represents various philosophies. Table 4 shows the ten best structural units of the OvGU anonymized and arranged according to model 1 (the arithmetic mean of all opinions) in descending order. The rankings provide valuable information. As the commercialization of knowledge is gaining in importance, a university can use the rankings to decide which fields of commercialization can be addressed best. A comparison of the seven rankings reveals isolated strong deviations in the performance of some structural units, but we observe relatively robust ranking orders.

Tab. 4: TOP 10 Ranking - Knowledge Potential for Commercialization per unit and Employee

model / unit	m 1	m 2	m 3	m 4	m 5	m 6	m 7
mobile systems	44.93	49.54	40.35	46.24	43.98	47.77	47.54
medical psychology	39.27	41.92	36.56	36.63	36.63	41.62	38.39
micro & sensor systems	38.19	42.42	33.91	30.19	36.79	41.28	39.88
manufacturing	38.14	42.04	34.33	41.67	37.35	33.88	40.65
material engineering	36.93	40.76	33.13	35.99	34.66	36.66	38.21
mathematical optimization	36.43	29.02	43.92	40.15	43.73	28.95	36.17
electric energy systems	30.89	32.19	29.61	34.23	30.12	30.82	31.44
psychology II	29.47	23.65	35.35	55.28	34.19	18.52	28.62
thermodynamics	29.38	30.16	28.61	31.57	28.09	28.40	29.23
logistics	29.08	27.59	30.55	26.95	28.04	26.37	27.45

For the OvGU only structural units with extreme differences in the performance of the four indicators are prone to significant variations in the overall per-capita commercialization potential depending on the weighting model. Robust rankings have a crucial advantage: they facilitate a fast decision and foster the acceptance of resulting measures. If different priorities lead to similar results a discussion about the appropriateness of the involved philosophies is redundant which reduces costs and complexity of decision making. As the origin of aggregated weights might be controversial we suggest a transparent determination process with broad participation. A central decision maker could even initiate a general discussion and delegate the selection/design of a weighting model that meets a high level of acceptance.

Although this will have little influence on the resulting strategic measures for robust rankings it signals democratic participation of lower management levels. The per-capita commercialization potential is interesting in the long-run since it has strategic implications for universities. However, this leads to the question which institute or faculty should be targeted first by the transfer unit? In the short-run it is more important to identify the existing overall potential of commercialization for each structural unit. We multiply the per-capita value of all alternatives with the number of full-time equivalent employees. The structural units with the highest overall commercialization potential within the OvGU are ranked in table 5 in descending order according to model 1. A comparison of all seven weighting models on the basis of overall commercialization potential reveals that the resulting rankings are quite robust as well. Although the overall performance of some structural units strongly depends on the weighting philosophy (e.g., structural unit 5 ranges between position 4 and 13), the rank order is stable all together.

Tab. 5: TOP 10 Ranking – total Knowledge Potential for Commercialization per unit

model / unit	m1	m2	m3	m4	m5	m6	m7
information systems	1	3	1	1	1	1	1
mobile systems	2	1	3	2	3	2	2
micro & sensor systems	3	2	4	9	4	3	3
process engineering	4	5	2	3	2	5	4
radiology & nuclear medicine	5	4	11	13	11	4	5
electric energy systems	6	7	6	4	6	6	6
machine design	7	6	9	6	8	9	7
manufacturing	8	8	10	7	9	10	8
neurology	9	12	5	5	5	12	10
electronic engineering	10	10	8	8	10	11	11

The comparison of the two presented rankings contains valuable information about the type, the source, and the composition of the commercialization potential of a research institution. We have identified a large discrepancy between table 4 and 5. Among the 30 best structural units in the per-capita commercialization potential, 1/3 of all institutes differs to the top 30 of overall commercialization potential, since many of the structural units with a high commercialization effectiveness are quite small in size. Overall, we found interesting patterns. As expected, the structural units belonging to the MINT-area perform clearly above average in both rankings independently of the considered weighting model. Almost 2/3 of all units in top 30 rankings are assigned to the MINT-area. Structural units belonging to the medical faculty account for 25 percent. Hardly any unit from the social sciences was able to enter any of the top rankings. Within the mint-area the mechanical engineering faculty performed extraordinarily well. All structural units from this faculty are among the top 30 rankings.

4. Contribution

Our investigation supports the public perception of universities as leading drivers of innovations, especially in economic areas characterized by small and medium enterprises. Thereby, we provide multiple implications for research, practice and politics. To our knowledge our approach is the first theoretical attempt to set up a "knowledge management decision support system" for research institutions. Our measure uses three generally accepted output indicators: *invention activities*, *third-party funds* and *research activities*. We apply the SMART-method to combine all indicators to a single measure for different research entities that represent the actual research knowledge asset for future commercialization using traditional transfer channels. The case study of a representative German university indicates the applicability of this approach. Using data from a rampant German information system of universities we guarantee the transferability of our approach. Nevertheless, our study has several limitations that simultaneously offer starting points for future research. First, subjective evaluations of experts within research institutions might lead toa strong distortion of the results (Ganzach et al., 2000).

This motivates the development of an econometric model with the income from knowledge commercialization as dependent and our indicators as independent variable. This should quantify the influence of each indicator on the knowledge commercialization income within different fields of research. Second, so far our approach assumes that existing knowledge can be transferred independent of scientists involved. However, it is proven that the responsible researcher is a main driver of knowledge transfer (Saunila and Ukko, 2014). This "tacit knowledge" is not simply transferable and deserves more attention in future research (Collins and Hitt, 2006). Within the above sketched econometric model a significant error term might indicate a strong influence of a/the researcher on the successful knowledge transfer of a unit. As a third research approach we propose to integrate this personalized factor as dummy variable in that model. As our study considers the average of all indicators over a period of five years we can directly derive a third research approach. We propose to analyze the variation of single structural units over time as "longitudinal approach". We are able to derive multiple insights, in particular, what drives the economic potential of academic knowledge (e.g. change in professorship or investment in infrastructure). Fourth, the range of suitable indicators needs further investigation. Empirical studies might approximate the real weights of indicators and prove the independence of proposed variables as precondition to apply the SMART-method. We suppose a basic level of dependence between *invention activities* und *research activities* as publications before patent application might circumvent the commercialization of research results. As fifth and last contribution our paper might be a basis to determine the transfer-affine research potential of institutions. Additionally, for a successful regional knowledge transfer it is necessary to take the perspective of regional firms and to determine their demand for academic knowledge. A question related to that is whether the regional economy is able to use academic knowledge (Zahra and George, 2002; Bishop et al., 2011; Mäkinen and Vilkko, 2014). Damanpour and Wischnevsky (2006) call that „absorptive capacity". The results of our investigation have some practical implications as well. Decision makers within research institutions might use the proposed systematic process to better manage the scouting of ideas and the evaluation of transfer relevant knowledge (Nosella et al., 2008). Our work guides the further development of so far insufficient commercialization structures at most German universities. A professional transfer unit is a necessary precondition for a successful cooperation of science and economy. At least all universities that use the data management system HIS can directly adapt our „decision support system".

Our first case study has already delivered several insights. Despite huge differences all structural units within research institutions can be compared with respect to the commercialization potential of their research results in total or per capita. This approach reduces searching costs (Pacharn and Zhang, 2006). Rewards on the basis of our proposed rankings as part of an incentive scheme might strengthen the perception of knowledge transfer within research institutions (Perkmann et al., 2013). A sustainable transfer system has to meet the following demands. First, our theoretical approach has to be tailored to the individual requirements like the existing data basis. Second, we recommend automatizing this process to continuously collect data. The horizon 2020-strategy of the European Union focuses a stronger cooperation of science and economy as key to increase total R&D-activities and generate economic growth. Our approach contributes to the development of an evaluation and monitoring system at research institutions. Applying such systems delivers transparent results. This is said to be the best instrument to stimulate the exchange between science and economy (Geuna and Muscio, 2009). The realization of that political target is compulsory for all countries within the European Union (European Commission, 2012). Political decision makers intend to strengthen the role of knowledge transfer as third main task of universities and improve the researchers' awareness (Becker et al., 2013). In Germany, universities are traditionally financed by federal states. The current need to economize forces universities to open up new financial resources. A professional commercialization of knowledge might replace decreasing federal funding. Our paper delivers an instrument for decision makers to locate knowledge with high commercialization potential. Additionally, we argue that further processes and structures need to be implemented to use traditional transfer channels.

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