Author´s Copy
Quote as: Proceedings, International Forum on Konwledge Asset Dynamics (IFKAD), 4 – 6 July 2018, Delft, Netherlands
ISBN 978-88-96687-11-6, ISSN 2280787X

Technology Transfer Impact Determination in the Public Sector by Quantitative and Survey-Based Indicators

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Structured Abstract

Purpose – "Third mission", namely the direct interaction with society and economy, next to the tasks of education and research is by now a requirement for any Higher Educational Institution (HEI) and Public Research Organization (PRO). But how to evaluate success remains an open question.

Design/methodology/approach – Innovation literature has distanced itself form a linear concept of technology transfer in the last decades, even though it may still be prevalent in the management of public research organisations (PRO), higher education institutions (HEI) and political communities. In the last decades innovation literature strongly supported the addition of the public value criteria beyond a pure economic approach, which often concentrated on patents and licensing.

Originality/value – We hereby introduce a spectrum of input, output, outcome, activity and key impact figures (KIF). PTB serves as an example of a PRO. Patents and licenses are the easiest definable KIFs, but quantitatively the least important ones. Emphasis is given to recommendations of proposals of the Scientific Advisory Board to the German government (Wissenschaftsrat) in the field of technology transfer and KIF development.

Practical implications – The paper proposes a variety of transfer paths, where PTB serves as a sample institution. While some KIF may be special to this PRO, the concept of looking at a broad variety of activities of interaction with the economy and society as a whole may be viewed as a universal approach.

Keywords – – Innovation system, technology transfer, public, standards, patents

Paper type –Practical Paper

1 Introduction

Even though knowledge and technology transfer (KTT) as a “Third Mission” of scientific institutions has been a common acronym for almost four decades in the US, more than two decades in the EU and becoming a highly relevant output criterion in China, clear definitions of the process and criteria for transcending from output to societal value generation are still under discussion. KTT as a multidimensional, complex and partially chaotic process has been recognized since the 1990s, e.g. with the ascent of the “Triple Helix Innovation” concept, referring to Industry - Scientific Institution - State as the three subjects of an innovation system. [Leyersdorf 1998]. It especially added the notion of an ecosystem with interdependent actors and was applied to the Brasilian metrology system by one of the authors [Souza 2009]. Incorporating aspects of transfer to civil society and additionally aspects of sustainable, environmentally sound production, the discussion extended to a “Quadruple” [Leyersdorf 2000] and “Quintuple” [Carayannis 2012] model, respectively.

This view is in stark contrast to a linear scheme, which originated from Post-World War II US industrial policy [Meissner 2017] and certainly had had its merits at the time. The highest scientific advisory board to the German government, henceforth named WR, distanced itself from the latter view [Wissenschaftsrat 2016-1], by stating

. *“a simple linear model of transfer (...) is in most cases unrealistic and short sighted. Unfortunately, (...) not a few managers within the scientific system seem to orient themselves according to this oversimplified model up to today” [translation by authors; full quote in ref. section].*

This paper draws generalizable conclusions by analysing public data and literature and by evaluating proprietary data from conducted surveys in a particular sector of engineering and physics: the science of measurement, named metrology. The industrial sector of measurement instruments ranks in the 4th highest position for Germany in the G01 category of the international patent classification (IPC) scheme. According to data provided by the United Nations Conference on Trade and Development (UNCAD) in the past five years the Group 874 of the Standard International Trade Classifcation (SITC)[1] “measuring, checking, analysing and controlling instruments and apparatuses”, was responsible for 1 % of total

[1] The SITC is a product classification of the United Nations (UN) used for external trade statistics, allowing for international comparisons of commodities and manufactured goods (ec.europa.eu/eurostat/statistics-xplained/index.php/Glossary: Standard international trade classification (SITC)), [23.3.2016].

world exports, reaching about 400 billion US $ trade volume in 2014 [Unctad 2015]. Therefore, metrology with a high degree of clearly defined legal tasks and a high relevance for industry may be viewed as a model system for a broad variety of technology transfer processes.

We largely follow the "Contingent Technology Transfer Effectiveness Model" (CTTM) [Bozeman 2000 / 2014], which separates KTT-processes into the aspects: who is transferring what, how and to whom. This systematic enables the quantification of output and impact parameters and their subsequent interpretation of trends and success. Activity KIFs are included. Effectiveness is contingent on the underlying mission.

Section two presents a brief introduction into the particularities of metrology and its merits of detecting and measuring KTT activity for society. Section three describes the CTTM and categorizes the merits of different forms of parameters. Section four describes available data directly from own data bases, through performed surveys and compares it with the literature. Sections five and six conclude the paper and present an outlook.

The paper is an attempt to describe the size, the order of magnitude and scope of KTT activities in terms of parameters, which can be generated at low internal costs, also named coordination costs. It is to be considered as an intermediate step to look primarily at those processes of a public research organization (PRO), which create most value for the economy and society as a whole.

2 Metrology – a brief introduction

National Metrology Institutes (NMI), such as PTB, safeguard the precision and uniformity of the physical measurement system, commonly known as the SI-system (second, meter, ampere etc.). In Germany a unified system of units is a requirement embodied in the Constitution. Subsequent laws define the task of an NMI in mainly three sectors:

- Legal metrology, related to all physical quantities that transfer directly into an economic value, such as electricity consumption, weighing of volume goods, gasoline or social tasks like traffic speed control devices. This is a pure regulatory task with respect to the economy and society.
- Calibration services to industry, that trickle down via a hierarchy of calibration labs to app. 12 million calibrated measurement devices in the German industry.

- Fundamental research to improve the definition of the physical units; this is the realm of time definition via atomic clocks, quantum physics and nanotechnology, to name a few.

PTB devotes about 40 % of its activities to the upper two subjects and 60 % to fundamental and applied Research and Development (R&D), but both are intrinsically intertwined. Before debating KTT to industry, economy and society , a short quantitative flash light on the mere scope of the regulatory merits of an NMI should be set by data from legal metrology: Sales tax (V.A.T.) and gasoline tax at the gas station result in 59 billion Euros in tax returns in Germany [Blickpunkt 2018]. An inaccuracy of 0,01 % in the volume measurement of these carbohydrate liquids results in a positive or negative gain or loss in tax income of 5,9 million Euro, an inaccuracy of 0,1 % makes this 59 million Euro.[1] The merits of other PRO in other fields of science may not be measured as easily, as in the case of a regulatory body.

The rest of the paper will only discuss the KTT processes in the above listed points two and three, where PRO-industry interaction is done on a purely voluntary basis.

3 Towards Technology Transfer Parameters

3.1 The contingent technology transfer model

Bozeman [Bozeman 2000, 2014] compiled a synopsis of 187 papers on technology transfer and developed in the earlier work a “contingent technology transfer model” (CTTM). The term “contingent” is key: Without prior knowledge or policy setting all subsequent key indicator figures (KIF) will be at best misguiding. The concept is explained in figure 1, which reproduces the original design with our additions of further aspects in the otherwise unchanged boxed domains. The effectiveness measure “public value” is explicitly the single addition in the 2014 paper. To measure technology transfer by one of the criteria of row 3 is contingent on the originating institution of row 1, for example its mission statement and the attributed resources. It is contingent to its interaction with the demand world. And it is contingent to the activity expertise of the transfer recipient in the

[1] The data are meant to be a vivid example how standard errors in measurement transform into a monetary value, if large volume goods have to be measured. Legal error margin (“Eichfehlergrenze”) at the gas station is actually 1.5 % in Germany.

second row as a vital intermediate to row three, the world of judging technology transfer effectiveness.

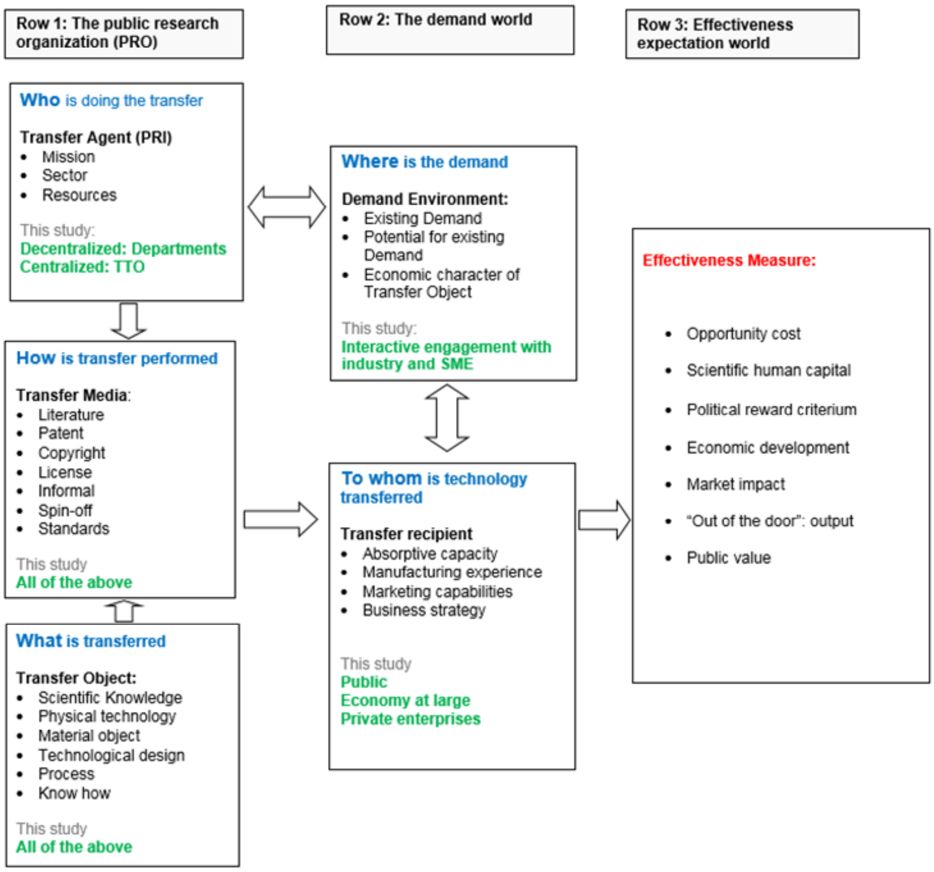

Figure 1: Contingent technology transfer model. The term "contingent" refers to method and goal of transfer activity. "Real" impact can only be measured via a transfer agent. Coloured typing are additions to the original graphic in this paper.

Being a review paper, the CTTM-list of effectiveness measuring possibilities is a summary of the proposals in the literature and discussed for their pros and cons. But from the diagram already several observations can be made. If true effectiveness is the aim - not glossy marketing brochures on "tech trans" activity - measuring a KIF is strongly dependent on the transfer recipient, whose abilities are beyond the scope of the PRO. If row 2 is bypassed, this leads to pure "out of the door" criteria, leaving the question unanswered, if public or private value is generated through the transfer. This will be picked up in the next paragraph.

Figure 2 represents a partial subsection of figure 1 in a more graphical description. Starting from the left, “input”- parameters, can be viewed as part of a cycle stemming from societal demand. If you like, this is the cut-out of a “triple-helix” innovation cycle.

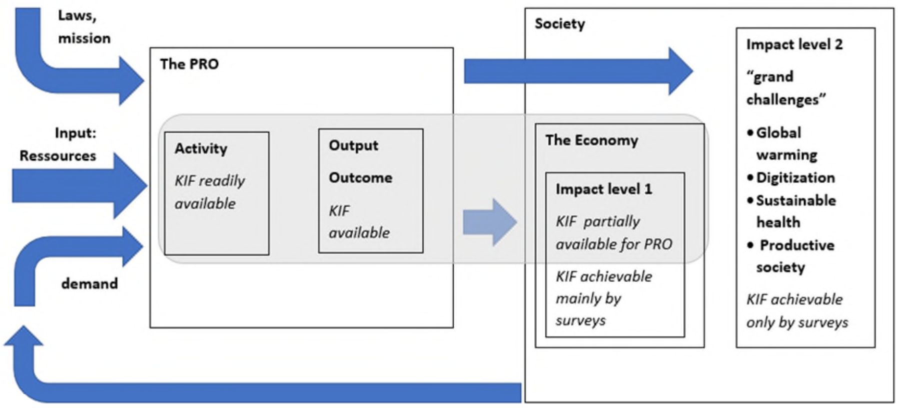

Figure 2: Subsection of the CTTM. Grey area shows subject of this paper. The recurring arrow from right to left indicates a non-linear scheme, stemming from to different types of input from economy and society to the PRO.

Before narrowing it down to a hand able portion, it should be pointed out, that “impact level 2” is not economical. It relates to a final outcome that can be found in terms of the EU branding of “grand challenges” of the 21st century: transforming energy generation under the threat of global climate change, evolving a high quality medical system within aging societies, creating productive societies under the influence of rapidly increasing digitization etc.

Upstream “impact level 1” portrays the economic sphere, where job creation, international competitiveness and innovative products and services are the main goals and intermediaries. The PRO as an actor in this flow has at its despense indicators, which are of an output, activity and economic character. Economic indicators are not necessarily identical to “impact”. Passing through a transfer stage, as shown in figure 1, the real impact is beyond the scope of a PRO. It is partially described here by a public survey on SME and an exploratory survey of PTB, the extension of it is symbolized by the grey shaded area in figure 2. It is the “merry” situation of metrology, that many data are available on the public tasks of the institution, that are hard to quantify in other fields of science, e.g. the humanities.

This study tries to be focussed on the “real” impact in the main fields of research activity for society and industry as a contingent effectiveness criterium. Real impact is at the centre of the target agreement of PTB under the authority of the Ministry of Economics and Energy (BMWi). However, other effectiveness criteria are prior on the list of the CTTM in figure 1 and will be discussed briefly.

Opportunity costs refer to a balancing of resources within the institution of the many goals that it is obliged to perform in general and in the narrower field of technology transfer. The underlying question is: what are the costs and gains, if one follows this managerial path, and not another one is taken. It is the very practical question, where larger achievements can be obtained by increasing or reducing a certain transfer path. Does one engage more scientists in applied or fundamental research, or does one increase or reduce technology transfer staff? - to name just two options. Opportunity costs, directly related to budget restrains, are an important criterium which effects all output parameters. If synergies between different public tasks exist, it can turn out as a win-win situation, but it also can be otherwise.

The effectiveness criteria of poltical reward refers to the overall esteem of the institution. This is the realm of “science marketing”, success stories and glossy flyers. While they are indispensable to inform the general public how tax payer´s money is spent, the public reward criterium is not a viable one, if real impact is to be monitored. Patent number sometimes falls within this effectiveness criterium, if patents are held primarily as a pure numerical entity and not because of their intrinsic value. In a recent study on another large PRO Blind et al. [Blind 2014] found “increase reputation” of the institution or the researcher as the top motives for patenting. In a previous study, we have shown, how a balanced approach via a Balanced Score Card (BSC) helps, not to overestimate the public reward criterium [Smandek 2011]. In Bozeman´s words: “technology transfer activities are often seen as a way (...) to enhance political support rather than as a mean providing significant economic or social benefits. In this sense it is a means, not an end.” [Bozeman 2014]

Number of patents can also be viewed as a small part of the “scientific value“ effectiveness criterium, as they are helpful for the institution to apply for industry oriented grants and for the individual scientist as part of the personal CV.

The other effectiveness criteria are discussed in subsequent sections.

This study is restricted to transfer activity to the economy (the grey shaded area in figure 2), i.e. to small and medium enterprises (SME). Spin-offs of PTB are tacitly treated as SME in this context, otherwise extending the paper considerably. Transfer of personal is not included. Pure knowledge transfer is included for completeness, it is however considered as a transfer pathway, if directly connected to technology transfer.

Even though defining pertinent technology transfer parameters remains a challenge, it is the purpose of this paper to look at those activities which are of predominant importance by “pointing the flash light into the right direction”.

3.2 Relevance of key indicator figures on technology transfer

To find a viable set of key indicators figures (KIF) on technology transfer is still an undertaking with open ends. A current approach by the German scientific advisory board (WR) to quantify output of HEI and PRO states:

> *“For other transfer achievements of the Sciences (e.g. science communication, consulting to politics, contribution in standardization) there is no clear cut definition standard, that can be put forward ”* [WR 2016-1]

Later in the paper it is clarified that key indicators are not intended to substitute for peer-to-peer review, but only to reduce an information gap. In an explicit tabulation it also states “undesirable and unintended usage” of the proposed KIF. It names explicitly as unintended usage ranking, to homogenize KIF across fields of science, as a decision variable on fund allocation, among others. To generate an example: If a public health institute generates warnings and actions against an upcoming epidemic, is the IP-portfolio of much relevance in this case? In the words of the latest OECD report on the matter it states

“while patenting remains important, it should not be the main focus of commercialization policies. For the majority of institutions, the amount of knowledge exchange with business (...) from collaborative (...) research is far more significant (..) “ and it asked for *“new indicators for measuring knowledge transfer, exploitation and commercialisation to (...) develop better policies.”* [OECD 2013]

KIF development has been going on for a very long time. Under the impact of knowledge commercialisation in the US, commonly attributed to the Bayhe-Dohle Act of 1982, a EU project came up with 12 categories and more than 65 proposed KIF in 2002. The main author [Mollas-Gallart, 2006] of this study reviewed this critically in a subsequent paper 2006 in similar wording as quoted above. In the examples of the UK and Spain it turned out to be difficult to summarise a variety of activities with different impetus even in the limited subset of technology transfer offices (TTO). However, the therein presented basic idea to monitor activity of an institution at low coordination cost is a valid one.

3.3 Categorizing key indicator figures

Semantic definitions of the KIF under consideration are presented in table 1. The parameter “input” is indispensable as material input, but also as an immaterial one in terms of objectives, laws etc. This sets the stage for what can realistically be expected.

	semantic definition	**example for PRO or HEI**
input	what is put into a system	ressources, budget, mission, objectives agreement
activity	Actions taken to create an output, intermediate with respect to countable output	Participation in a standard setting organization (SSO); cooperation project with industry
output	intended result of an activity; quantity produced	A standard; a project result being published or safeguarded as IP
outcome	Result of an activity beyond the scope of the underlying activity intention	A novel standard developed; usage of project results
impact	A marked effect or influence due to an activity	increase of production in a market segment due to novel versatile standard; decrease of production in a market segment due to overregulation

Table 1: Common definitions of KIF

4 Defining and evaluating key indicators of PTB as a sample PRO

4.1 Qualifying key indicators of PTB

The KTT activities of PTB are introduced in table 2 using the categories of the CTTM, as shown in figure 1. For initial clarity: none of the transfer activities in table 2 are obligatory or regulatory to industry. The regulatory “legal metrology” framework is excluded from this discussion.

	Transfer Object	Transfer Medium	Transfer Agent	Transfer Recipient	Economic numerical value of indicator	Character of Indicator
1	Scientific Knowledge	**Publication,** Literature	Scientist	Technical oriented public	No	Output
2	Scientific Knowledge	Informal Knowledge Exchange: **conferences**	Scientist	Technical staff of companies	No	Output / Activity
3	Scientific Knowledge	Participation in **Standard** Setting Organizations (SSO)	Scientist	Branch of industry	No	Activity
4	Calibration service of measurement instruments	Protocol, **certificate**	Scientist(s)	Individual company	Yes	Impact
5	Direct cooperation projects with industry, SME or industrial networks	Knowledge Exchange	Scientists of PRO and company	Company(ies)	No / Yes	Output / Impact
6	Industry driven project (funded or unfunded)	Project results: knowledge, IP	Scientists of PRO and company	Company(ies)	Yes, but unknown	Outcome / Impact
7	Non-patentable IP, Know how	License	TTO	Single company (in each case)	Yes	Outcome / Impact
8	Invention	Patent	TTO	None	No / estimate only	Output
9	Invention	Patent with Licence	TTO	Single company (in each case)	Yes	Impact

Table 2: KIF of PTB. The list shows the most important transfer paths of KTT. Strong synergies are observed between line 9 and 5, 6. It is here, where most of the commercialisation of inventions occurs.

Having a first sight at the complete table, it is obvious, that the foremost activities are non-economical in nature. Some are economical in nature, but it is not obvious, what the actual impact in economic terms might be. This is especially the case for cooperative projects with industry, as it strongly depends on the transfer recipient, the ability of the company to develop and market a product. Please note, that for “real world” impact, a “pure” patent by itself does hold a virtual and estimated value only and falls within the CTTM effectiveness criterium of “political reward”. However, there are two effectiveness parameters, which bear impact: a patent, that not only had found a licensee but is also generating income. The second are calibration services, which serve to better define quality of products. Industry directly pays for these services at full cost, as this immediately benefits the production process.

4.2 The main output parameters

The subsector of PTB activities with a registered economical value is shown in figure 3 from the annual report 2017 [PTB 2017]. For completeness and comparison budgetary input is also shown. Note that the top three bars are downscaled by 10 for comparison. For the purpose of upkeeping a neutral position to all market participants, we are obliged to limit third party funding to 25 % of the budget. The monetary values shown in figure 3 are only a portion of all income of PTB. Research grants for R&D, international projects and fees from legal metrology are not included. All blue bars are either direct income from industry or third party funding with the specific goal of collaborating with the economy.

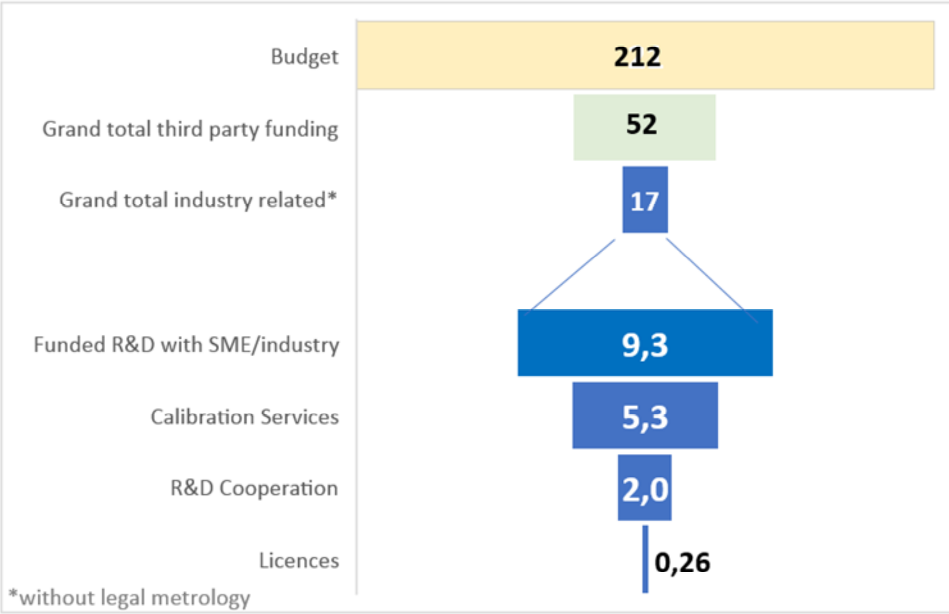

Fig. 3: KIF of fiscal data of PTB in million Euro. The input data are downscaled by a factor of 10 for comparison. Total third party funding and income from regulatory tasks are not shown and exceed these numbers considerably. The 52 million Euro in line two contain all income beyond basic funding by the federal government.

Non-fiscal data are presented in figure 4, which are activity, output and outcome based, as presented in table 2.

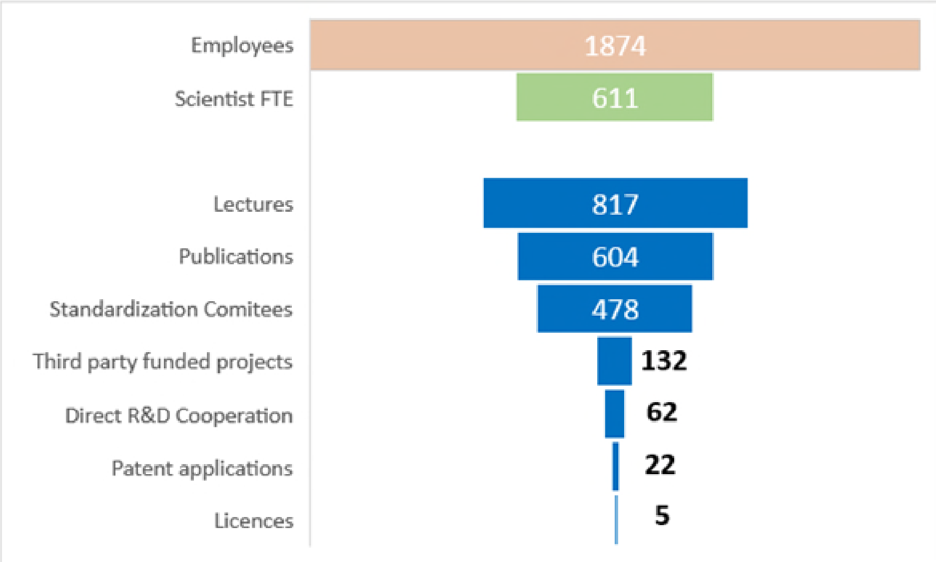

Figure 4: Non-monetary KIF of PTB. Dominating are broad aspects of KTT, which are hard to quantify monetarily, but where a large final economic impact is expected. Note, that standardization activities are completely absent in Fig. 4, the fiscal view. [WR 2017 and PTB data]-

In its executive summary of a recent PTB evaluation the WR concluded on transfer activities:

The manifold cooperation of PTB with industry are an important path of technology transfer. The institution maintains a very intensive exchange with professional associations and networks, which are oriented towards practical applications and play a central roll in technology transfer. Especially to emphasize are contributions (…) in the realm of (..) standardization. [Wissenschaftsrat 2017]

This broader view on the matter had been demonstrated in figures 4 and 5 quantitatively.

4.3 Survey based internal view

Patents as a subset of intellectual property (IP) are often viewed as central to technology transfer in the political debate. We performed a survey, how those who are the most active in this area, may look at their complete activity spectrum in the realm of technology transfer: the inventors. The survey was intranet based and anonymous. The total number of inventors were 216 in 2016, with a return of 66 a 30 % margin was reached. 89 % held a master or Ph.D. degree, while the rest had a degree from the universities of applied sciences (“Fachhochschulen”) or were technicians. A ranking scale from 1 (low) to 6 (high) was used, to quantify the sentiment on the questions. A binomial distribution was assumed and median values are not shown, due to the small discriminatory character of the scale of integer numbers. Results are shown in table 3

Question: significance of…	Mean	Standard deviation
…technology transfer	4,3	1,4
…industrial cooperations	4,6	1,6
…third party funding	4,3	1,6
…inventions	3,8	1,5
…standardization	3,7	1,9

Table 3: Average and standard deviation of responses. Ranking: 1 - little significance of technology transfer path; 6 – very high significance of technology transfer path

Looking at table 3, all transfer paths are of high relevance to the inventors. Noticeably inventions are ranked lower (3,8) than direct interaction with industry via cooperations (4,6) or third party funding (4,3). Comparing the latter two, cooperations are of a little higher importance. However, these precompetitive, risky, scientific cooperations with industry are often associated with no or little money flow – each party is paying for its own expenses.

The comparative lower ranking of standardization in the subset of inventor scientists is not surprising. While inventions are related to new scientific discoveries, potentially leading to new markets, standards are broadening the diffusion of existing technologies. Please notice the large standard deviation in tab. 3, showing a discrepancy in the survey set: Some rank standards as extremely important, some do not.

This can be observed in the correlation plot of figure 5 with dimensions of “inventions” and “standards”. Four areas are clearly visible: a small subsection (grey encircled area) ranks inventions and standards as low, supposingly adding an invention as a mere “scientific reward” criterium (number of inventions is part of the reporting KIF to the controlling department of PTB). The upper right green encircled area is of no surprise, as both transfer paths gain a positive assessment. However, the red and the violet marked areas are antagonistic: while a subset of the inventors (violet) esteems inventions as high and standards as low, the red subgroup considers it the other way around. This indicates, that PTB staff uses different transfer paths, depending on the specific technological challenge.

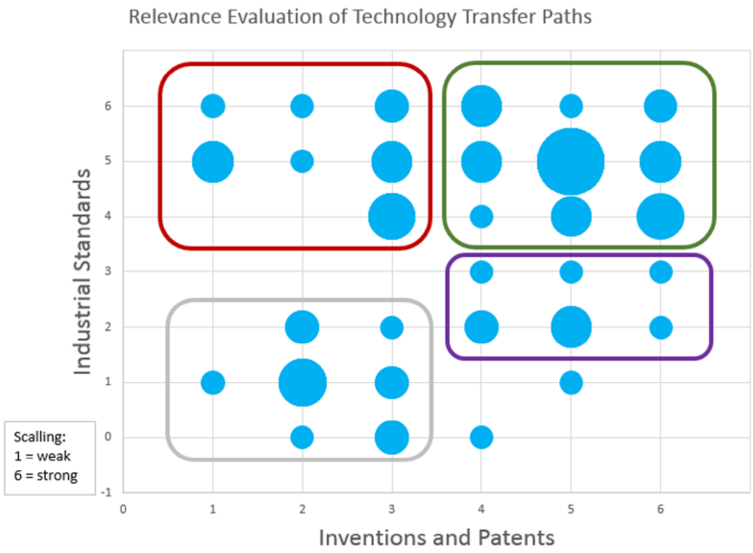

Figure 5: Correlation plot of the dimensions "inventions" vs. "standards". In the red and violet encircled areas differing transfer paths are valued the most.

Comparing table 4 with the integer and monetary output and activity figures 3 and 4 of the section 4.2, one can conclude that even the subset of inventors go beyond patents and value all transfer paths as high, regardless if there is a monetary incentive involved or not.

4.4 The external view

This subsection contains two separated parts: an exploratory survey conducted within a case study springing from a collaboration PTB/INMETRO[1] and a literature analysis of a larger survey on SME-PRO/HEI interaction in Germany.

To conduct the PTB/INMETRO survey, a total of 2122 firms were contacted, after consulting two databases: (i) 149 members of Association VDMA (Verband Deutscher Maschinen- und Anlagenbau, or the German Engineering Federation), who dedicate themselves to Measuring and Testing Technology and represent 80% of the revenues within the industry and; (ii) 1973 firms belonging to the branch code 26.51 ("production of measuring, controlling, navigation and similar instruments"), as classified by the International Standard Industrial Classification of all Ecconomic Activities, collected at the

[1] Inmetro (National Institute of Metrology, Quality and Technology) is the Brazilian NMI

data base “www.firmenwissen.de”. The survey was “typo 3” online-based. All VDMA members were contacted by telephone to reinforce the invitation. On the VDMA sample many declined the offer, as they were not producers of measurement instrumentation. Unfortunatly the feedback was low, containing 79 respondents or 4 % of the total set. Therefore the study can be viewed as exploratory only.

The sample was mainly composed of SME, as 57% of them reported that they presented revenues up to € 5 million Euro in 2014 and 68% counted less than 50 employees. The firms show a high degree of innovativeness - only 11 % of them reported not to have introduced any innovation in the past. A total of 321 patents were owned by these firms. The questionnaire consisted of 23 questions, 9 of which directly exploring the connection between metrology and innovation. From these it could be deduced, that about half of the sample had contact with PTB and considered it an important innovation partner in the fields R&D and measurement capacity building. Using the ranking scale from 1 to 5 (5 = high estimate) this result was found: the respondents consider the two aspects of “innovations introduced into the market” and “capacity building in measurement instrumentation” on equal footing (average 2.8 each), thereby recognizing the different technology transfer paths introduced earlier.

A very large survey [RKW 2017] with respondents from 1735 SMEs and 946 PROs/HEIs was analysed. For completeness, statistical data of all 3776 projects were available. The third party funding program “ZIM” has an annual budget of about 500 million Euro, supporting innovative, risky and precompetitive research for SME. In the foreword of the study it is noticed, that innovation activity in firms with less than 50 employees is on the decline during the period studied, stressing the need for continuing support to motivate SME for industrial innovation.

An excerpt of the findings of the study is shown in table 4, where the KIF qualification is by the authors.

	Result after funding	KIF quality	Ref.
New product or service introduced	87 %	**Outcome** / major aim of program, however ecnomomical assessment through revenue prognosis only	p. 57
Opening up novel technology field	50 %	**Outcome** / *Non-economical parameter, but one major aim of the program*	p.5
R&D activity of SME	up 19 %	**Outcome** / *Soft parameter, not directly related to the theme of the funded project*	p.39
Revenue value 2016, two years after funding ended	0,26 million Euro	**Impact** / ecnomical	p. 65
New jobs created in the aftermath of project	1,1 per project	**Impact**	p. 5
Revenue expectation in 2018	0,52 million Euro	**Prognosis**	p. 67
Patenting ratio	25 %	**Outcome** / 75 %: patenting not viewed as cost-effective or protection through trade secret preferred	p. 55

Table 4: Result of large scale analysis of SME-PRO/HEI funding program named "ZIM" [RKF 2017]. It is noteworthy, that major immediate achievements in the top lines are of a non-monetary character. Economic impact is delayed and is not high in the first four years till 2018.

Concluding, both surveys convey the message, that direct economical impact parameters are difficult to verify, whereas support of innovativeness through activities of an PRO and by funding and/or collaborating with SME can be seen by a variety of output and outcome parameters.

4.5 Excursion on patenting and licensing

Noticing 1 300 000 patent applications in China for the year 2017, there is no way in diminishing the importance of patents in general and for a PRO. However, this paper attempts to point to all technology transfer activities of a PRO. And patents are a minor part.

Patents contain the best structured technical knowledge there is and patents of any monetary value must be owned by the PRO. If otherwise, the employee may be set into a serious conflict of interest. A recent study in China showed a relevant direct passage of PRO/HEI-inventions by the inventor to companies in the field of biotech, considerably reducing income [Fong 2017] and thereby jeopardizing output and impact KIF.

There is also no need to criticize "lacklustre performance of academic patenting" [OECD 2013], as laboratory setups in the applied sciences are in an early stage of development. Recently, by comparing literature data, we have shown, that revenue from patents in Europe from HEI and PRO with respect to industry licensing revenue is approximately off by factor of 500 to 1000 [Arundel 2012, Garambella 2008, Smandek 2014]. Synergies with other transfer paths are especially vivid in cooperations with industry and third party funding projects. It is here, where most of the licensing occurs. By concentrating on the effectiveness criterium of monetary value of patents, the TTO of PTB reached European average by 2014 [Smandek 2014]. A summary is given in Tab.5.

KIF per 1000 FTE	research institutes (EU)	PTB
invention disclosures per year	22	30
patent applications per year	12	33
claimed patents per year	10	14
licences per year	7	14
licence income (without biotech) / ths. €	105	324
cooperation agreements	74	137
Source: Arundel et al. 2013 / PTB data		

Table 5: Comparison of pan-European survey of PROs (HEIs not shown) and PTB. Licensing income without biotech refers to the finding of the survey, that 89 % of all European royalties originate from biotech, not accessible for an s institute based on physical technologies.

4.6 Mathematical pitfalls of KIF

Even though the German WR strongly discourages comparison of KIF across fields of research and tasks of HEI/PRO, as quoted in section 3, this is often tacitly performed. Therefore a few remarks on the merits of KIF in TT are necessary:

Error margins and standard deviations are nearly never added, resulting in calculated numbers of exceeding accuracy. As an example the variation of the invention rate of PTB is about 15 %.

Normalizing of KIF may be a very resonable action to compare institutions with different budgets, employees etc. Elementary math will lead to a doubling of the percentage error margin (if both original error margins had been identical), but the situation is even more serious. In the benchmark-comparison table 5 we followed strictly the recommendation of using the number of scientific FTE in units of 1000 as the denominator. However, not all scientists are active in R&D activities, as pointed out earlier, which would create a higher benchmark achievement of PTB. On the other hand, we have a lot of technicians in our lab, that are obviously also involved in technology transfer activities but not included in the Full Time Employees (FTE) number of scientists, leading to a reduction of the KIFs.

Upscaling is often used, if absolute numbers are viewed as not being sufficient as an effectiveness criterium. The US Association of University Technology Managers (AUTM) reported 1.3 trillion US $ as a contribution to the US economy for a period of 13 years [AUTM 2017] The number was generated by multiplying the licensing income by the inverse average licensing ratio and by the number of years. PTB will reach the 3 million Euro licensing level by the end of 2018, since licensing income started to flow in 2008. Performing the same mathematics for PTB results in a total contribution to the German economy between 40 and 60 million Euro by patenting activity alone. With a revenue cost value of 0,2 million Euro per workplace in German industry this results in about 250 job-years. Not bad for a TTO of three FTE! But does this upscaling contain any more information than the thin bar in the lower segment of figure 3?

Non-binominal distributions: Licensing income is known to be at least of the log-normal type, which is common in economics and nature [Limpert 2001]. But the first moment - the average - of a log-normal is infinite, so are all higher order moments. Therefore quantiles, such as the median, are the adequate descriptive parameters. A 2007 study [Silverberg 2007] shows evidence of an even “more skewed” distribution of the Pareto-type. Analysing the data from the pan-European HEI/PRO survey [Arundel 2012] shows a bunching of income close to the 0 to 100 000 Euro value and up from the 0,5 to 2 million Euro value - the “average” in the middle is occupying the “empty space” in between [Arundel 2012]. It can be reasonable assumed, that this very “fat tail distribution” is based upon the finding of the study, that 89 % of the royalties stem from bio-tech, making engineering and physics incomparable with the first.

5 Conclusion

We have presented a spectrum of output, activity and outcome parameters that may serve as KIF for a specific institution. These KIF are accessible by normal reporting at low coordination costs and follow a abroad view of all technology transfer activities of a large PRO. Because of the variety of diverse tasks of a PRO in the public interest, ranking according to a standardized KIF-set set is highly questionable. Direct impact can be monitored in services or development contracts, which are paid at full costs. Licensing income can also be transposed as revenue generating in the economy. Even though measurable by simple mathematics, it is one the least important impact contributions in the technology transfer of a PRO. All major achievements of a PRO in the limited field are visible through output, outcome and activity parameters, but hard to quantify economically. Real impact is mainly accessible through surveys, which are usually cost intensive and beyond the scope of a single institution. Even if company surveys are performed for HEI/PRO with respect to industry-interaction many parameters are of a “soft” non-monetary based nature. To look at a much broader scope of transfer activities of HEI/PROs, especially including “public value” as the underlying scheme is recommended by relevant studies and institutions within this decade.

6 Outlook

While quantifying the success spectrum of HEI/PRO activities in the realm of KTT remains a concurrent discussion, new challenges are ahead: Open innovation can spur the rapidity of R&D activities, but may also contain a complicated and hidden hierarchy of copyright settings, e.g. in software development. As big data is gaining tremendous importance the question occurs for a PRO, which ought to be public access to foster information and knowledge to the public as a whole. However, some of them are of economic value to private companies and could be licensed, partially regaining tax payer´s money.

Glossary of terms

CTTM	Contingent Technology Transfer
FTE	Full Time Employee
HEI	Higher Education Institution
KIF	Key Indicator Figures
PTB	Physikalisch-technische Bundesanstalt
PRO	Public Research Organisation
R&D	Research and Development
SDO	Standard Developing Organisation
SME	Small and Medium Enterprises
TTO	Technology Transfer Office
WR	Wissenschaftsrat (Scientific Advisory Board to the Federal Government)

Acknowledgement

T. L. Souza acknowledges the support received from the CAPES Foundation (process no. 99999.100071/2014-1) and also thanks Prof. Dr. K. Blind, TU Berlin, for his advice during the stay in Germany

References

AUTM (2017) " AUTM U.S. Licensing Activity Survey – FY 2016", www.autm.net/resources-surveys/research-reports-databases/licensing-surveys/ [1.4.2018]

Arundel, A., Barjak, F., Es-Sadki, N., Hüsinng, T., Lilischkis, S., Perrett, P., Samuel, O. (2012); „Respondent Report of the Knowledge Transfer Study (data for 2010), European Knowledge Transfer Indicators Survey, Code of Practice Implementation Report", produced by empirica GmbH, Fachhochschule Westschweiz and UNU-MERIT for the European Commission, DG Research and Innovation, available from:http://www.knowledge-transfer-study.eu [6 July 2013]

Blickpunkt Öl (2018) , http://www.blickpunkt-oel.de/wirtschaft-und-staat/ [24.4.2018]

Blind, K; Ti, A. (2015) "Researchers' participation in standardisation: a case study from a public research institute in Germany", J. Technology Transfer: 40, 2, 346 - 360

Bozeman, B. (2000) "Technology transfer and public policy : a review of research and theory"; Research Policy; 29, 627 - 655

Bozeman, B.; Rimes, H.; Youtie, J. (2014) "The evolving state-of-the-art in technology transfer research: revisiting the contingent effectiveness model"; Research Policy; 44, 34 – 49

Carayannis, G., Barth, Th. D., Campbell, D. F. J. (2012) "The Quintuple Helix innovation model: global warming as a challenge and driver for innovation, J. Innovation a. Entrepreneurship, 1, 2; http://www.innovation-entrepreneurship.com/contente/1/1/2 [17.1.2018]

Depner, H., Gorynia-Pfeffer, N., Vollborth, T., (2014) "Wirksamkeit der defförderten FuE-Projekte des zentralen Innovationsmprogramms Mittelstand (ZIM), Expertise 2-14, Referat VI C 5, http:// www.rkw-kompetenzzentrum.de [15.1.2018]

Fong; P. S. F., Chang, X., Chen, Q. (2018) "Faculty patent assignment in the Chinese mainland: evidence from the top 35 patent application universities, J Technohol Transf 43:69-95, doi.org/10.1007/s 10961 -015-9434-7

Gambardella, A., Harhoff, H., Verspagen, B. (2008), "The value of European Patents", European Management Review (2008) 5, 69-84

Leydesdorff, L.; Etzkowitz, H. (1998) "The Triple Helix as a model for innovation studies "; Science & Public Policy; 25, 3, 195 – 203

Leysesdorff, L.; Etzkowitz, H. (2000) "Can 'the public' be considered as a fourth helix in university-industry-government relations?"; Science and Public Policy; 30, 1, 55 - 61

Limpert, E., Stahel, W. A., Abbt, M. (2001) “Log-normal Distributions across the Siences: Keye and Clues May • BioScience, Vol. 51 No. 5, p. 341

Meissner, D., Polt, W., Vonortas, N.S. (2017) “Towards a broad understanding of innovation and its importance for innovation policy”, J. Technol. Transfer 42: 1184-1211

Molas-Gallart, J., Salter, A., Patel, P., Scott, A., Duran, X. (2002) “Measuring third stream activities”, Brighton: SPRU.

Molas-Gallart, J., Castro-Martínez, Elena (2006) “Ambiguity and conflict in the development of “Third Mission” indicators”, selected papers presented at the 9th International Conference on Science and Technology Indicators; (Scientometrics: an international journal for all quantitative aspects of the science of science, communication in science and science policy): 74 (2008), 1/2, 13 S., ISSN 0138-9130

OECD (2013) “Commercialising public research: new trends and strategies”, dx.doi.org/10.1787/9789264193321-en

PTB Annual Report 2017 (2018), Fischer Druck Peine, ISSN 0340-4366

Silverberg, G., Verspagen, B. (2007) “The size distribution of innovations revisited: An application of extreme value statistics to citation and value measures of patent significance, Journal of Econometrics 139, pp. 318-339

Smandek, B.; Barthel, A.; Winkler, J.; Ulbig, P. (2010) “Balanced score card implementation for IP Rights management in a public research institution”; Measuring Business Excellence: journal of organizational performance management; 4, 65 – 76, also presented at IFKAD 2010

Smandek, B., Barthel A., (2014) "Inside View of a Technology Transfer Office – A Benchmark Perspective", Proceedings of the University-Industry Interaction Conference, 23. – 25. April, Barcelona

RKW (2017) „Wirksamkeit der geförderten zentralen FuE-Projekte des Zentralen Innovationsprogrammes Mittelstand (ZIM)“ („Efficacy of the funded R&D-projects via the central innovation program(ZIM) for SME“), RKW Kompetenszentrum der Deutschen Wirtschaft e. V. www.rkw-kompetenzzentrum.de

Souza. T. L.; Brandi. H. (2009). Tripple-Helix applied: Brazilian Metrology as a tool for competitiveness and innovation. In: 7th Biennial International Conference on Universitv. Industry & Government Linkages. Glasgow.

Unctad 2016; www.unctadstat.unctad.org [31.1.2016]

Wissenschaftsrat (2016-1), Wissens- und Technologietransfer als Gegenstand institutioneller Strategien Drs. 5665-16; www.wissenschaftsrat.de/download/archiv/5665-16.pdf [15.1.2018], Unabbriviated, translated quote from the German original: *Diese Vielfalt von Transferaktivitäten und -prozessen macht deutlich, dass ein einfaches lineares Modell von Transfer im Sinne einer Übertragung von bereits erarbeitetem explizitem und dokumentiertem Wissen in andere gesellschaftliche Bereiche in en meisten Fällen unrealistisch ist und zu kurz greift. Allerdings scheinen sich nicht wenige Akteure im Wissenschaftssystem auch heute noch vielfach an einer zu einfachen Vorstellung von Transfer zu orientieren*

Wissenschaftsrat (2016-2): „Empfehlungen zur Spezifikation des Kerndatensatz Forschung‘“, Wissenschaftsrat, Drs. 5066-16, Berlin.

Wissenschaftsrat (2017), Stellungnahme zur Physikalisch-Technischen Bundesanstalt, Drs. 6216-17

Unabbriviated, translated quote from the German original: *Die vielfaltigen Kooperationen der PTB mit der Industrie stellen einen wichtigen Weg des Technologietransfers dar. Die Einrichtung pflegt einen sehr intensiven Austausch mit Fachverbänden und Netzwerken mit anwendungsorientierter Ausrichtung, die für den Technologietransfer eine zentrale Rolle spielen. Besonders hervorzuheben sind die Beiträge zum Wissenstransfer, den die PTB im Rahmen ihrer Aktivitäten zur Regelsetzung und Normung leistet.*