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Do Competitively Acquired Funds Induce Public Research Institutions to Behave Efficiently?

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Abstract

This paper analyzes the effect of public and private third-party funds on the efficiency of departments of Swiss public research institutions. Estimating an output distance function assuming that labor is used to produce master students and scientific publications, we find no statistically significant effect of private or public third-party funding on research efficiency. However, once we include technology transfer as an additional output, the coefficient of private funding is statistically significant. We further find that this disciplining effect of private funding is qualitatively robust in a setting controlling for endogeneity.

Keywords:
Efficiency, Research, University, Technology Transfer, Third-Party Funding, Public Finance

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1. Introduction

Research institutions are perceived as a central piece of the national innovation system. During the past years, political pressure to use research funding in an efficient manner has increased dramatically. Consequently, the measurement and evaluation of university productivity has become increasingly important in

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both the political and the academic sphere. A frequently used indicator for research output used in the academic literature on the measurement of university efficiency is the amount of acquired third-party funding. Examples include Cohn et al. (1989) for the US, Izadi et al. (2002) for the UK and Mensah and Werner (2003) for Germany. The most prominent example in the political sphere is the 'Research Assessment Exercise' in the United Kingdom, a large-scale operation that assigns a quality value to each research department and distributes funds accordingly. Similarly, the Swiss National Science Foundation (SNSF) which distributes the largest part of public third-party funding considers the acquisition of third-party funds a relevant output.

While the relevance of third-party funding has increased both in the political sphere and the academic literature, there are few articles analyzing the impact of different funding sources on research efficiency. Furthermore, both the theoretical and empirical findings are ambiguous, indicating that further research in this area is required to allow policymakers to make evidence-based decisions (van der Ploeg and Veugelers (2008)). This paper attempts to shed some light on this relationship by analyzing the effect of different funding resources on the efficiency of Swiss public research institution departments.

The three most important channels through which third-party funding could influence research efficiency are the administration effect, the misallocation effect and the discipline effect. The administration effect is the most obvious one. Applying for third-party funding and adhering to the corresponding monitoring duties is costly and time consuming, thereby reducing research efficiency. Both the misallocation effect and the discipline effect are caused by the information asymmetry between the donor and the researcher (see e.g. Kivistö (2005)). The misallocation effect reduces efficiency. Assuming that the utility function of the agent and the donor differ, and that the donor's information about the researcher's goals is imperfect, it can be optimal for the donor to restrict the use of funds by the researcher, thereby causing behavioral distortions leading to a suboptimal outcome. On the other hand, the discipline effect increases efficiency. The same restrictions that cause the misallocation effect can also work in the other direction, as such restrictions also limit the possibilities of the researcher to pursue his own goals and to use funds in an inefficient way.

The difficulty to identify the effect theoretically is aggravated by the fact that potentially all three effects might be nonlinear. Furthermore, assuming that creative control is more valuable in basic research than in applied research as proposed by Aghion et al. (2008b), the misallocation effect is a function of the innovation stage. The issue is further complicated by the fact that the degree of monitoring can be determined endogenously. The multitude of complex, nonlinear and adverse effects implies that the relationship between third-party funding and research efficiency remains an empirical issue.

In this paper, we do not analyze the effect of funding restrictions (see e.g. Mensah and Werner (2003), Kempkes and Pohl (2008), Kuo and Ho (2007)). Instead we use the distinction between third-party funding stemming from public and private donors to analyze the impact on the research efficiency of departments at Swiss public research institutions directly. We use survey data from the year 2005 to employ a stochastic frontier analysis, where the included outputs are the number of master degrees,[2] the number of scientific publications and the intensity of technology transfer. We examine the explanatory power of the share of funding stemming from private and public third-party sources for the efficiency of natural science, mathematics, physics, medicine, and economics departments.

Our starting point is a simple output distance function assuming that labor produces scientific publications and education of master students. In this setting, we do not find evidence for an impact of private third-party funds. The results in respect to public third-party funding are ambiguous. Since economists and politicians perceive the universities' third mission, technology transfer, as increasingly important, we construct a measure for the intensity of technology

[2] In 2005, Swiss Universities awarded all students with a degree (licentiat) equivalent to an M.Sc. in the anglo-saxon system. Bachelor's degrees did not exist at the time and are hence not included in this study.

transfer and include it in the production function. The share of private third-party funds in the total budget now exhibits a significantly positive impact on efficiency. This finding suggests that while research behavior is not monitored by the private sponsors, the transmission of the findings to firms is fostered by private funding.

A problem to identify the effect of funding on efficieny is that the quality and productivity of researchers might influence the ability to acquire third-party funding, private and public, in which case the estimates suffer from an endogeneity bias. In order to address this problem, we separate departments based on a survey question whether technology transfer has increased research funding resources and estimate the coefficients of private and public third-party funding for the two groups separately. We find strong evidence for reverse causality, but also support for the hypothesis that a positive causal effect beyond endogeneity exists.

Closely related to our work, Cherchye and Abeele (2005) find a positive correlation between the share of total third-party funding and research efficiency. Bonaccorsi et al. (2006) analyze the impact of private funds on efficiency and find a U-shaped correlation for Italian universities, for which private funding is of rather limited relevance though. Using data on individual researchers at the Louis Pasteur University, Carayol and Matt (2006) distinguish between public and private third-party funding and find a small effect of public funds on individual productivity.

We add to the existing literature by including a measure for technology transfer in our output distance function. By distinguishing between public and private third-party funding, our approach allows us to identify the differences between the two funding sources in the innovation stages of basic research and applied research, measured by scientific publications and technology transfer intensity. Furthermore, we address the problem of endogeneity between the ability to acquire third-party funding and efficiency by constructing an instrument capturing the presence of reverse causality. A further advantage of the paper is that the use of departments ensures the proximity to the decision making unit while our dataset covers whole university sector. Finally, we present the first estimations for the relationship between the funding structure and research efficiency in Switzerland.

The paper is structured as follows: Section 2 discusses the theoretical framework and section 3 summarizes the existing empirical evidence. Sections 4 and 5 describe the applied methodology and the data. The estimation results are discussed in section 6. In section 7 we conclude the paper.

2. Theoretical Framework

The relationship between a researcher and the donor of third-party funds is typically modeled in a principal-agent framework (see e.g., Kivistö (2005)). The donor is the principal and the researcher is the agent. If the two have different utility functions, the principal faces a trade-off between monitoring and accepting diverging outcomes caused by information asymmetry and uncertainty. The relationship is further complicated by the presence of multiple principals with different utility functions, notably public and private donors.

There are three major channels through which third-party funds influence research efficiency. The most apparent effect is the administration effect. The acquisition of external funds requires the investment of time and money. Furthermore the principal might require the researcher to enclose details about the work progress, thereby affecting efficiency negatively due to the additional work caused by writing reports. The second channel through which efficiency might be affected negatively is the misallocation effect. Because of the difference in the utility functions, the principal has an interest to control the agent's behavior through restrictions. The problem is that these restrictions are based on incomplete information of the principal and will therefore lead to misallocation of resources (see e.g. Schiller and Liefner (2006)). The third channel, the discipline effect, influences research efficiency positively, because the restrictions on the utilization of funds decrease the ability of the agent to pursue his own goals (see e.g., Niskanen (1971), Niskanen (1975)).

The presence of multiple, adverse channels implies that even in a framework of binarily modeled monitoring decision, the impact on the efficiency of universities is ambiguous, implying that it remains an empirical issue. The theoretical relationship becomes even more convoluted if the intensity of monitoring is modeled continuously. The administration effect clearly increases in the amount of time the researcher devotes to reporting and justifying his behavior. The discipline effect on the other hand decreases if the monitoring intensity increases. As the researcher reports his behavior more accurately, the information asymmetry diminishes. Therefore the researcher's opportunities to pursue his goals decrease. This implies that the administration effect and the discipline effect react in the opposite way to an increase in monitoring intensity.

A further modeling complication is the potential non-linearity of the two effects. An example is that while the first draft of the research plan might actually increase efficiency, reporting each step will be very unproductive for the researcher. The discipline effect will be largest in the beginning as the information asymmetry is diminished the strongest. As monitoring intensity increases further, the information asymmetry decreases more slowly and the utility functions of the donor and the researcher become more congruent. Furthermore the danger of crowding out intrinsic motivation becomes more relevant (see e.g., Frey (1997), on the interplay between intrinsic and extrinsic motivation).

The relationship between the misallocation effect and research intensity is even less clear as multiple reasons for nonlinearity exist. First, the diminishing information asymmetry causes it to decrease. Second, the misallocation effect depends on the development stage as proposed by Aghion et al. (2008b). They develop a model in which the benefits of creative control are highlighted. Assuming that the main advantage of academia over the private research sector is the ability to experiment, they show that the optimal location of research depends on the innovation stage. The more advanced an idea is, the stronger are the benefits from developing it in the private sector and vice versa. This indicates that the relevance of who has creative control in the research process varies by development stage and so does the misallocation effect. Restraining the researcher is hence the more detrimental, the more basic the research project is. Third, the impact of the funder having creative control is nonlinear per se. The more detailed the research report needs to be, the more the monitoring process will have the character of ex-ante monitoring thereby decreasing the researcher's leeway more severely.

The three channels through which third-party funding might affect efficiency are opposing and nonlinear. Therefore theoretical prediction about the direction of the effect is ambiguous, implying that the net impact of third-party funding on research efficiency is an empirical issue.

We expect the monitoring intensity of private donors to increase in the innovation stage due to two reasons. First, the relevance of creative control decreases in the innovation stage. Secondly, the monitoring costs are decreasing in the innovation stage as the absorptive capacity of private donors is geared towards applied research. This implies that we expect the monitoring intensity and consequently the impact of private third-party funding on research efficiency to increase in the innovation stage. It is even possible that monitoring is not profitable for early stages of the innovation process, in which case no monitoring takes place at all.

In the short-run, politicians decide upon the monitoring intensity of public donors exogenously. In the long-run, politicians decide upon monitoring intensity endogenously as well. Presumably, the absorptive capacity of public donors is better for basic research and worse for applied research. Therefore the expected degree of monitoring increases less in the innovation stage for public donors than for private ones.

3. Literature Review

Aghion et al. (2008a) present macroeconomic evidence for the misallocation effect, showing that autonomy and productivity are positively related. Furthermore, Kempkes and Pohl (2008)) examine the efficiency of German universities and find that universities are more efficient, the more independent they are.

Duh and Kuo (2006) analyze a Taiwanese amendment that grants universities more autonomy and find that the effect increased efficiency.

Evidence supporting the discipline effect is presented in Mensah and Werner (2003) who evaluate the impact of financial flexibility on the efficiency of universities, using the share of unrestricted assets as a measure for financial flexibility. Applying a stochastic frontier methodology, they find a positive correlation between restriction and efficiency. This finding is supported by Kuo and Ho (2007) who examine a change in the budget regime in Taiwan that has led to more flexibility of the utilization of private funds. They find a negative impact of the policy adoption on the efficiency of universities. Agasisti (2009) analyses the relationship between competition and tertiary education in Italy and finds a positive effect. Similarly, Abbott and Doucouliagos (2009) find that competition for overseas students increases university efficiency in Australia.

Aghion et al. (2009) find that both positive and negative effects exist. They find a significant positive impact of autonomy on the Shanghai university ranking (see Liu and Cheng (2005), suggesting that a decrease in the misallocation effect increases productivity. Additionally, they show that an increase in the discipline effect measured by competition increases the ranking too. Similarly, Butler (2003) finds that introducing a funding distribution scheme based on output counts has increased the share of Australia's ISI publications despite declining resources, indicating the presence of a disciplining effect. She further presents evidence of the misallocation effect, as the quality of publications measures as the share of citations has stagnated in the same period.

Direct evidence on the accumulated effect points to a mild positive influence of third-party funding. Cherchye and Abeele (2005) find a positive correlation between the share of total third-party funding and research efficiency. Bonaccorsi et al. (2006) analyze the impact of private third party funding on efficiency and find a U-shaped correlation for Italian universities, for which private funding is of rather limited relevance though. Using data on individual researchers at Louis Pasteur University, Carayol and Matt (2006) distinguish between public and private third-party funding and find a small effect of public funds on individual productivity but not of private funds. Similarly, Robst (2000), Robst (2001) show that the share of tuition in the total budget has no effect on the efficiency of the university system and individual institutions.

4. Methodology

Stochastic frontier analysis (SFA), the methodology we use in this paper for the estimation of the efficiency of universities, was developed in a parallel manner by Aigner et al. (1977) and Meeusen and van den Broeck (1977). These general formulations allow the estimation of both output- and input-distance functions, where cost functions represent a special case of input-distance functions (see e.g., Coelli et al. (2005)). Our data set does not contain information about input prices. Therefore it is not possible to estimate a cost frontier. Furthermore, the use of a cost function implicitly assumes that the production function is homogeneous with respect to inputs, corresponding to the assumption that public research institutions behave in an input minimizing manner. However, inputs of public research institutions are often decided upon by politicians. Since this implies an output maximizing behavior, the use of cost functions is problematic. Therefore we follow Abbott and Doucouliagos (2009) and estimate an output distance function in the form of a translog function. However, due to the relatively small sample size, we depart from their work by assuming that interactions between inputs and outputs are negligible, as the maximum likelihood estimator does not converge otherwise.

$$\begin{aligned} lny_{1,i} = \alpha_0 + \sum_{m=2}^{M} \alpha_m lny^*_{m,i} + \frac{1}{2} \sum_{m=2}^{M} \sum_{n=m+1}^{M-n} \alpha_{m,n} lny^*_{m,i} * lny^*_{n,i} \\ + \sum_{k=1}^{K} \beta_k lnx_{k,i} + \frac{1}{2} \sum_{k=1}^{K} \sum_{l=1}^{K-l} \beta_{k,l} lnx_{k,i} * lnx_{l,i} + \sum_{c=1}^{C} \gamma_c control + v_i + u_i \end{aligned} \tag{1}$$

The dimension i refers to the analyzed department. The dependent variable, the number of scientific publications, captures the amount of basic research and serves as the normalizing output. The remaining outputs appear as explanatory variables normalized by scientific publications, meaning that $y^*_m = y_m/y_1$.

These consist of the number of master degrees (Mas) approximating teaching output and technology transfer intensity (TT) measuring applied research. The vector x contains the amount of labor input differentiated by 'Academics' (Acad), and 'Technical and Administrative Staff' (Other).

The vector of control variables contains dummy variables for the following scientific fields: Natural Sciences (Nat Sci), Medicine (Med), Economics and Business (Econ and Bus), Mathematics and Physics (Math and Phy). The base category is engineering. Furthermore, dummy variables for the institution types 'University', 'University of Applied Sciences' (UAS) and 'Federal Research Institute' (Fed Res Inst) capture the differences to the base category 'ETH Swiss Federal Institute of Technology'. Finally, the vector of control variables includes the log of the total budget per employee ('Budget per Emp') to account for differences in the available budget.

v denotes a normally distributed error term, meaning that $v \sim N\left(0, \sigma_v^2\right)$. u refers to the technical inefficiency, which, by assumption follows a truncated-normal distribution. We model technical efficiency as a function of the vector z that contains the share of total budget financed by third-party funds differentiated by public and private sources:

$$u_i = \delta_0 + \delta_1 * Bsha\_Pub_i + \delta_2 * Bsha\_Priv_i + w_i \tag{2}$$

where $w \sim N\left(0, \sigma_w^2\right)$. The simultaneous two-step estimator proposed by Battese and Coelli (1995) allows us to estimate both equations 1 and 2 consistently.

An important problem of our identification strategy is that the quality and productivity of researchers might influence the ability to acquire third-party funding, in which case our estimates suffer from an endogeneity bias. The dataset allows us to tackle this issue directly as it contains a question where the respondents were asked: 'Has the financial position of your institute changed as a result of the knowledge and technology transfer?' This question corresponds to the existence of reverse causality. We distinguish non-winners from winners where winning is defined by whether additional research resources have resulted from technology transfer. We construct a variable for each public and private funding that takes the value of the share of third-party funding for non-winners and zero otherwise, as well as a corresponding variable for winners. Including all four variables in the estimations allows us to disentangle the effect of endogeneity and causal relationship. Assuming that no endogeneity bias exists, the two coefficient estimates for winners and non-winners should be the same. A higher coefficient for winners on the other hand indicates endogeneity.

5. Data

In Switzerland four types of public research institutes exist: cantonal universities, federal institutes of technology, universities of applied sciences and federal research institutions. Of the ten cantonal universities, only those in Lucerne (only social sciences and theology), Lugano (only social sciences and architecture) and St. Gallen (only economics, law and management) limit the range of covered disciplines, while the others offer a broad spectrum. The federal institutes of technology in Zurich and Lausanne focus on engineering, natural sciences, mathematics and physics. The universities of applied sciences have been pure teaching institutions until the middle of the nineties. Their mandate was broadened to include applied research in the disciplines they cover: engineering, management, social work, pedagogy, health professions and fine arts. Besides of these three types of higher education institution, there are four governmental research institutions: the Swiss Federal Institute of Aquatic Science and Technology (EAWAG), the Research Institute for Material Sciences and Technology (EMPA), the Swiss Federal Institute for Forest, Snow and Landscape Reseach (WSL) and the Paul Scherer Institute (PSI) which conducts research on energy technologies and elementary particles physics.

In 2005, the KOF Swiss Economic Institute conducted a survey among Swiss public research institutions. The questionnaire was sent to the directors of the research institutions and the heads of university departments.[3] The sample covers only fields related to technology and science: engineering, natural sciences, mathematics, physics, medicine, economics and business administration. 241 of the 630 questionnaires were returned, implying a response rate of 38.3%. The response rate varies substantially between the types of institutions (see table 1 in the appendix for more details). As a consequence, the cantonal universities are underrepresented, while federal institutes and universities of applied sciences are overrepresented.[4]

The data entails the number of master degrees measuring teaching output. Research output is quantified as the number of papers published in scientific journals. The survey further contains several questions concerning the relevance of various technology transfer channels. The respondents attribute a value between one and five to each channel, where one refers to 'not important' and five to 'extremely important'. The channels are divided into five groups: 'Informal contacts', 'Technical facilities', 'Education', 'Research collaboration' and 'Consulting'. The number of questions within each group ranges from two to nine. If the answers to the questions in the different groups were averaged afterwards to get one number measuring technology transfer, the different number of answers in each group would imply different weights between the groups. Therefore we construct our measure for technology transfer as the sum of the average relevance in each group. In order to test the sensitivity of our results in respect to the weighting scheme, we construct a variable where each form group is assigned an explicit weight according to the informal character of the form. Following Arvanitis et al. (2007) we assign weights from one to five to the channel classes 'Informal contacts', 'Education', 'Consulting', 'Technical facilities' to 'Research collaboration'. As the choice of weights is somewhat arbitrary, we also estimate a version of our model that allows the weights to be data-driven. In this version

[3]The questionnaire is available in German, French and English at http://www.kof.ethz.ch/surveys/structural/panel/wissensaustausch_2005.

[4]For more information concerning the data, see Arvanitis et al. (2008).

we include the average of the technology transfer groups 'education' and 'consulting' individually. The data does not allow the inclusion of all five channel groups separately. Therefore we further include the average relevance of the research related channel groups, namely 'Informal contacts', 'Technical facilities' and 'Research'.

Labor input is available by the categories 'Professor', 'Post doc', 'Graduate', 'Technical Staff' and 'Administrative Staff'. Due to multicollinearity problems, we aggregate professors, postdocs and graduates to 'Acad' and technical staff and administrative staff to 'Other' (Filippini and Lepori (2007), report similar problems).

Finally, the data includes information about financial resources of each department. Besides the overall budgets, the respondents disclose the share of third-party funds from governmental sources and from the business sector. We use this information to construct the two variables at the heart of this analysis. We denote third-party funds from the business sector divided by the total funds as 'Bsha Priv' and for third-party funds from governmental sources 'Bsha Pub'. The latter mainly contains funds from the two Swiss research promotion agencies 'Swiss National Science Foundation' (SNSF) and 'Innovation Promotion Agency' (CTI). The remaining funds consist of the global budget of universities from various sources.

In order to retain a substantial number of observations, we add 0.1 to all observations in order to eliminate observations taking the value 0.

This procedure ensures that corner solutions are feasible despite the logarithmic production function specification. Thereby it allows university departments to specialize in the output mix. 187 of the total 241 observations have no missing values in the utilized variables.

It is important to note that we do not account for research quality. Due to potential endogeneity issues, our approach does not allow to use acquired third-party funding or research expenditures as a proxy for quality-adjusted research output (see e.g. Kuo and Ho (2007), and Mensah and Werner (2003)). This drawback is not as substantial as it might seem though, as the direction of the bias is predictable (Robst, 2001). It is reasonable to assume that research quality and the acquisition of external funds are positively correlated. In this case, the true research output of departments with high output quality is underestimated. Consequently our efficiency estimates are underestimated, implying that the correlation between efficiency and the share of external funds is actually higher than our estimates show.

6. Results

Table A.4 displays the results of a regression based on the simultaneous two-stage approach proposed in Battese and Coelli (1995). The specifications shown in column one and two differ with respect to the included output variables. The estimation in column 1 assumes a simple output distance function that contains master degrees and scientific publications as outputs. Column two additionally comprises a measure for the intensity of technology transfer that weights different channels according to the degree of informality. Both output distance functions estimations behave well in the sense that all first-order coefficients of labor inputs are positive and significant. Furthermore, the outputs have the expected negative sign. The amount of budget available for each employee enters the distance functions significant and positive. This coefficient might capture the fact that the price of labor inputs depends on its quality. Alternatively it might reflect gains from capital endowment.

The dummy variables for scientific fields reveal that medical departments are less productive than engineering departments.

This finding probably reflects difficulties to attributing resources correctly to either the medical department at the university or the universities' hospitals. Furthermore, the productivity of engineering departments becomes significantly higher than the other departments if technology transfer intensity is accounted for. In respect to the type of academic institution, we find a negative coefficient for universities of applied sciences and a positive coefficient for cantonal universities in the regression including technology transfer.

The lower part of table A.4 shows the results of the second stage with inefficiency as the dependent variable. Rather surprisingly, the share of public funding exerts no significant impact in either of the specifications. Since the SNSF and the CTI evaluate all projects using an extensive peer-review process, the argument that no monitoring takes place is not valid. Potentially, positive and negative effects cancel each other out. Alternatively, the share of public funds may mainly impact basic research production and the inclusion of other output variables disperses the effect. This explanation coincides with the Swiss research policy that focuses on the promotion of basic research. Finally, we have argued that we underestimate the correlation between third-party funds and efficiency due to the positive correlation between quality and the ability to acquire third-party funding. Therefore public external funds might exhibit a significantly positive impact on research efficiency after accounting for quality. Corresponding to the mission of the funding agencies, this explanation indicates that the allocation process of public funds favors quality over quantity. The above arguments suggest that our results underestimate the effect of public third-party funds.

The extension of this result to other countries appears questionable. Both the CTI and the SNSF use peer-review processes including international experts to monitor the funded research. Presumably, this procedure promotes efficiency more than a strict bureaucratic approach. Our results may therefore be invalid for countries that organize research funding distribution and monitoring in a different way.

Similarly, column one of table A.4 reports an insignificant impact of the share of private funding on the efficiency of departments. Since private donors determine the amount of monitoring endogenously, the insignificant impact suggests that they conduct no or ineffective monitoring in respect to basic research. Potential explanations include the large costs that private donors incur in monitoring scientific research. While public authorities delegate monitoring to the SNSF and CTI that use a low-cost peer-review process, private companies have to build up absorptive capacities or buy in expertise in the respective fields.

Additionally, the nature of basic research renders contracts typically incomplete and difficult to enforce accurately, limiting the utility of monitoring further. These problems might induce private donors to abstain from monitoring activities.

The results in column two reveal, that the above finding change if the output distance function includes a measure for technology transfer intensity. The coefficient for private funding becomes significantly negative in column two. Since the dependent variable in the estimation refers to inefficiency, this result implies a positive impact of the share of private funding on the efficiency of departments. This finding indicates that private donors do not monitor basic research but take care that the results are transferred and monitor the process of applied research in an efficiency-enhancing manner.

In order to evaluate the relevance of endogeneity, columns three and four of table A.4 include interactions between the budget shares and a dummy variable capturing whether conducting technology transfer has increased the available research funding. The coefficients for public funding remains insignificant for both non-winners and winners in the specification without technology transfer measure. Its inclusion results in an insignificant value for non-winners and a significant negative coefficient for the share of public funding for winners. The latter suggests a positive correlation between efficiency and the acquisition of public funds. However, the insignificant and even positive estimate for non-winners indicates that the direction of causality goes from efficiency to acquisition and not the other way round. This provides a first hint that endogeneity has to be taken into account in order to establish a causal relationship between funding acquisition and efficiency. However, our instrument refers to the presence of reverse causality in respect to technology transfer. Since public funding focuses on basic research, the instrument controls imperfectly for endogeneity in this respect. Therefore these findings should be interpreted cautiously.

The share of private funds exhibits no significant coefficient for either non-winners or winners in the simple distance function displayed in column three. Column four allows us to analyze whether the significant coefficient in column two remains after accounting for endogeneity. The point estimate for the impact of the share of private funds turns out to be substantially higher for winners than for non-winners, indicating the presence of endogeneity. However, the coefficient remains significant for non-winners as well, though the significance level is lower. Furthermore, the relatively stable estimate for the coefficient for non-winners suggests that a relation between the share of private funds and efficiency exists after controlling for reverse causality.

In order to evaluate the robustness of our results, table A.5 reports a number of variations in the specification of the output distance function. Columns one and two refer to the main results. Columns three and four use alternative definitions of the measure for technology transfer. Notably, we include an unweighted measure in column three while column four shows the results for the separate inclusion of three technology transfer measures referring to the channel groups education, research and consulting.

Finally, columns five and six report estimations that introduce the shares of budget in an alternative way. Instead of estimating two regressions simultaneously, we include the log of the budget shares directly in the output distance function. Since university managers can influence the share of third-party funding, deviations from the optimum reflect mismanagement. Therefore modeling them in a two-stage setting is appropriate from a theoretical perspective. However, the two-stage methodology restricts inefficiency in a more complicated manner, potentially resulting in a degenerated distribution of inefficiency. Therefore an econometrics perspective suggests the direct inclusion of the budget shares in the output distance function. In order to reconcile these opposing perspectives, we present our results using both methodologies.

Varying the definition of the technology transfer measure shown in columns two to four barely affects the coefficients for inputs and outputs. Furthermore, the estimates for the shares of third-party funding remain stable.

Comparing the results in columns one and five, as well as columns two and six reveals that the output distance functions stay robust to the inclusion of budget shares directly in the output distance function. The positively significant coefficient for the share of private funding indicates that the findings in respect to private funding remain valid. However, the share of budget financed through third-party public funds turns out significantly positive and significantly larger than the coefficient for private funding in the two specifications excluding and including a technology transfer measure,

indicating that the results based on the two-stage methodology might underestimate the influence of funding financed by third-party public funding. As argued above, this finding coincides with the mechanics of monitoring conducted by the SNSF and the CTI and corroborates our hypothesis that public funders do a better job in monitoring academic research.

7. Conclusions

Using a simple output distance function which assumes that labor input produces scientific publications does not yield a significant impact of private funds and an ambiguous effect of public funds. As both economists and politicians perceive technology transfer as an increasingly important task of public research institutions, we construct a measure for technology transfer intensity. Including it in the production function reveals that private external funds exhibit a significantly positive influence on the efficiency of public research institution departments. However, the problem of endogeneity plagues the identification strategy. Therefore we construct an instrument based on information related to reverse causality and find strong evidence of endogeneity. Nevertheless, our result of a positive causal effect of the share of private third-party funding on the efficiency of departments remains valid qualitatively, although the size of the effect is found to be smaller than in the setup not controlling for endogeneity. These findings suggests that while private donors do not monitor basic research behavior, they do foster efficiency in respect to applied research and the transmission of the findings.

Using external funds as a measure for research production has become increasingly popular, not only in science but in politics as well. One example is the 'Research Assessment Exercise' in England, which considers acquired external funds as one output of universities. Consequently, the impact of external funds on the behavior of researchers is highly relevant. Our paper attempts to answer some of the related questions. While it is clear that the categories public and private funds might capture quite heterogeneous funding sources, our data only allows the separation of these two broad categories. It is left to future research to delve deeper into the issue and analyze the impact of more accurately specified funding sources on the behavior of researchers.

The estimation of dynamic effects provides an additional direction of future research, as this paper, due to the cross-sectional nature of the data, studies only static effects. Dynamic effects might arise, because if external funds flow to the most efficient researchers, the less productive researchers will acquire less funding resources. This opens the possibility of selection, either through self-selection based on income or promotion decision by supervisors. This might have an impact on the average researcher quality and consequently on research productivity.

A further politically relevant topic not addressed in this paper is that third-party funds might have effects on the behavior of researchers beyond the impact on efficiency. Of particular relevance for politicians is the possibility that private third-party funding induces the researcher to devote more time and effort to applied projects, thereby reducing the work devoted to basic research (see e.g., Florida and Cohen (1999), Geuna (2001) Schiller and Liefner (2006) and Banal-Estañol and Macho-Stadler (2008). Finally, the present state of research does not identify the relevance of individual channels but only the aggregate correlation. Disentangling these effects might be a further interesting path of research.

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Appendix A. Appendix: Tables

Table A.1: *Population, data sample and response rates by department*

Institutions	Population	Sample	Response Rate (%)
ETH-domain			
Swiss Federal Inst. of Technology Zurich	87	45	51.7
Swiss Federal Inst. of Technology Lausanne	31	12	38.7
Federal Research Institutes	11	11	100.0
University of			
Basle	32	11	34.4
Berne	84	33	39.3
Fribourg	17	5	29.4
Geneva	46	15	32.6
Italian Switzerland	9	2	22.2
Lausanne	69	12	17.4
Neuchâtel	22	6	27.3
St. Gallen	21	8	38.1
Zurich	74	22	29.7
University Applied Sciences of			
Berne	13	9	69.2
Central Switzerland	10	5	50.0
Eastern Switzerland	36	14	38.9
Italian Switzerland	7	2	28.6
Northwestern Switzerland	27	17	63.0
Western Switzerland	12	4	33.3
Zurich	22	8	36.4
Total	630	241	38.3

Table A.2: *Summary Statistics of variables*

Variable Name	Variable Description	Obs	Mean	Std. Dev.	Min	Max
Publ	Scientific Publications*	187	3.35	-1.94	2.30	6.91
Mas	Number of Master Degrees*	187	2.37	-2.35	2.30	6.40
TTTotal 1	Unweighted Technology Transfer*	187	2.51	0.40	1.63	3.12
TTTotal 2	Channel Informality Weighted Technology Transfer*	187	3.58	0.41	2.71	4.23
TTEdu	Educational Technology Transfer*	187	0.91	0.42	0.10	1.54
TTRes	Research Technology Transfer*	187	0.94	0.40	0.10	1.55
TTCon	Consultancy Technology Transfer*	187	0.96	0.49	0.10	1.63
Acad	Full-time Academic Staff*	187	3.00	1.14	0.47	6.21
Other	Full-time Administrative Staff*	187	1.95	-1.58	2.30	6.62
Budget per Emp	Budget per Employee*	187	11.40	0.88	7.32	12.84
Engineering	Engineering (Dummy)	187	0.35	0.48	0.00	1.00
Nat Sci	Natural Sciences (Dummy)	187	0.14	0.35	0.00	1.00
Med	Medicine (Dummy)	187	0.23	0.42	0.00	1.00
Econ/Bus	Economics and Business (Dummy)	187	0.18	0.39	0.00	1.00
Math and Phy	Mathematics and Physics (Dummy)	187	0.10	0.30	0.00	1.00
Fed Inst Tech	Federal Institute of Technology (Dummy)	187	0.26	0.44	0.00	1.00
Fed Res Inst	Federal Research Institute (Dummy)	187	0.05	0.23	0.00	1.00
UAS	University of Applied Sciences (Dummy)	187	0.24	0.43	0.00	1.00
University	Cantonal University (Dummy)	187	0.44	0.50	0.00	1.00
Bsha Pub Nowin	Public Third-Party Funds/Total Funds Non-Winners	187	9.45	18.75	0.00	100.00
Bsha Pub Win	Public Third-Party Funds/Total Funds for Winners	187	14.93	17.82	0.00	84.15
Bsha Priv Nowin	Private Third-Party Funds/Total Funds Non-Winners	187	3.49	11.24	0.00	81.00
Bsha Priv Win	Private Third-Party Funds/Total Funds Winners	187	14.52	21.29	0.00	93.12
	* used in logs in the estimations.					

Table A.3: *Cross-correlations among the variables*

	Publ	Mas	TTTotal 1	TTTotal 2	TTEdu	TTRes	TTCon
Publ	1						
Mas	-0.0541	1					
TTTotal 1	-0.095	0.1890*	1				
TTTotal 2	-0.0646	0.1778*	0.9912*	1			
TTEdu	-0.1405	0.2922*	0.8932*	0.8631*	1		
TTRes	-0.0712	0.1428	0.9639*	0.9679*	0.8082*	1	
TTCon	-0.0882	0.1802*	0.8384*	0.8188*	0.7218*	0.6950*	1
Acad	0.6197*	0.2361*	0.0602	0.0787	0.0134	0.0703	0.0465
Other	0.4172*	-0.0658	0.1677*	0.1829*	0.0491	0.1881*	0.1252
Budget per Emp	-0.0357	0.2341*	0.0945	0.0801	0.1560*	0.0842	0.0846
Engineering	-0.2372*	0.2063*	0.3031*	0.3026*	0.3103*	0.3076*	0.2116*
Nat Sci	0.1903*	0.0597	-0.0862	-0.0868	-0.0629	-0.1066	-0.0503
Med	0.1869*	-0.5227*	-0.1109	-0.0927	-0.2542*	-0.0449	-0.1458*
Econ/Bus	-0.2592*	0.2321*	0.119	0.0852	0.2323*	0.0307	0.2232*
Math and Phy	0.2286*	0.0379	-0.3840*	-0.3643*	-0.3672*	-0.3456*	-0.3656*
Fed Inst Tech	0.2687*	0.1445*	-0.047	-0.0353	-0.0137	-0.0352	-0.0557
Fed Res Inst	0.1690*	0.0292	-0.0588	-0.0522	-0.094	-0.0691	0.0093
UAS	-0.6337*	0.2891*	0.2096*	0.1946*	0.2717*	0.1854*	0.1793*
University	0.2309*	-0.3899*	-0.1121	-0.1126	-0.1791*	-0.097	-0.1093
Bsha Pub Nowin	-0.06	-0.1951*	-0.4805*	-0.4667*	-0.4323*	-0.4335*	-0.5040*
Bsha Pub Win	0.0499	0.1022	0.3517*	0.3765*	0.2847*	0.3589*	0.2922*
Bsha Priv Nowin	-0.1356	-0.0651	-0.056	-0.0626	-0.0061	-0.0909	-0.0123
Bsha Priv Win	-0.0923	0.1682*	0.3636*	0.3685*	0.3711*	0.3281*	0.3561*

	Acad	Other	Budget per Emp	Engineering	Nat Sci	Med	Econ/Bus
Acad	1						
Other	0.5940*	1					
Budget per Emp	0.0114	0.0223	1				
Engineering	-0.1191	-0.0606	0.0876	1			
Nat Sci	0.1372	0.0053	-0.0166	-0.2998*	1		
Med	0.1165	0.3876*	-0.1918*	-0.3989*	-0.2245*	1	
Econ/Bus	-0.2407*	-0.3358*	0.1177	-0.3441*	-0.1936*	-0.2576*	1
Math and Phy	0.1774*	-0.0224	-0.0019	-0.2382*	-0.1341	-0.1783*	-0.1538*
Fed Inst Tech	0.1941*	-0.0826	-0.0082	0.3056*	-0.1064	-0.2678*	-0.1548*
Fed Res Inst	0.1698*	0.1543*	-0.0147	-0.0238	0.3757*	-0.1299	-0.112
UAS	-0.3953*	-0.2318*	0.3157*	0.3509*	-0.1601*	-0.3076*	0.1887*
University	0.0914	0.2027*	-0.2577*	-0.5617*	0.0617	0.5605*	0.0254
Bsha Pub Nowin	-0.1248	-0.1699*	-0.3156*	-0.0812	-0.0526	0.1003	-0.1184
Bsha Pub Win	0.044	0.0066	-0.0116	0.1049	0.0708	-0.0687	-0.0245
Bsha Priv Nowin	-0.2199*	-0.1697*	-0.0933	0.0685	-0.0782	-0.0735	0.1199
Bsha Priv Win	-0.0475	-0.069	0.0076	0.1121	-0.0787	-0.1540*	0.2613*

	Math and Phy	Fed Inst Tech	Fed Res Inst	UAS	University	Bsha Pub Nowin	Bsha Pub Win
Math and Phy	1						
Fed Inst Tech	0.2178*	1					
Fed Res Inst	-0.0776	-0.1416	1				
UAS	-0.1837*	-0.3354*	-0.1338	1			
University	0.0004	-0.5323*	-0.2123*	-0.5029*	1		
Bsha Pub Nowin	0.2055*	-0.0187	-0.0311	-0.118	0.1321	1	
Bsha Pub Win	-0.1238	0.059	0.0177	0.0726	-0.1227	-0.4243*	1
Bsha Priv Nowin	-0.0693	-0.1206	-0.0634	0.1387	0.0161	0.2620*	-0.2616*
Bsha Priv Win	-0.2090*	-0.0614	-0.0031	0.1035	-0.0333	-0.3455*	0.2311*

	Bsha Priv Nowin	Bsha Priv Win
Bsha Priv Nowin	1	
Bsha Priv Win	-0.2130*	1

* signifies a significant correlation among variables at the 5% level

Table A.4: *Main Results*

	1	2	3	4
Acad	0.685***	0.174***	0.655***	-0.005
	(0.182)	(0.014)	(0.181)	(0.064)
Other	0.189*	0.057***	0.193*	0.061
	(0.112)	(0.001)	(0.109)	(0.040)
$Acad^2$	0.011	-0.002	0.017	0.021
	(0.042)	(0.005)	(0.041)	(0.014)
$Other^2$	0.032	0.012***	0.038	0.016***
	(0.030)	(0.000)	(0.028)	(0.006)
Acad_Other	-0.064	-0.020***	-0.072	-0.024
	(0.062)	(0.001)	(0.059)	(0.016)
Mas	-0.465***	-0.048***	-0.453***	-0.057***
	(0.033)	(0.005)	(0.029)	(0.019)
Mas^2	-0.054***	-0.010***	-0.054***	-0.011***
	(0.004)	(0.001)	(0.004)	(0.003)
TTTotal		-0.821***		-0.850***
		(0.006)		(0.030)
$TTTotal^2$		-0.025***		-0.018***
		(0.001)		(0.006)
Mas_TTTotal		0.019***		0.016**
		(0.003)		(0.007)
Budget per Emp	0.248***	0.015***	0.242***	0.011
	(0.067)	(0.004)	(0.065)	(0.022)
Nat Sci	-0.010	-0.206***	-0.008	-0.174***
	(0.142)	(0.003)	(0.140)	(0.058)
Med	-0.433*	-0.232***	-0.376	-0.201***
	(0.252)	(0.019)	(0.238)	(0.073)
Econ and Bus	0.233	-0.153***	0.215	-0.102*
	(0.160)	(0.001)	(0.160)	(0.054)
Math and Phy	0.106	-0.241***	0.162	-0.207***
	(0.166)	(0.023)	(0.164)	(0.078)
Fed Res Inst	0.126	-0.092	0.129	-0.006
	(0.192)	(0.110)	(0.192)	(0.065)
UAS	-0.284	-0.066***	-0.361*	0.021
	(0.210)	(0.011)	(0.192)	(0.060)
University	-0.033	0.156***	-0.039	0.091
	(0.133)	(0.001)	(0.134)	(0.056)
Constant	-0.921	3.405***	-0.838	3.482***
	(0.798)	(0.054)	(0.791)	(0.271)
lnsig2v				
Constant	-1.327***	-38.504***	-1.319***	-3.385***
	(0.391)	(0.146)	(0.348)	(0.147)
Inefficiency				
Bsha Pub	0.009	0.004		
	(0.014)	(0.005)		
Bsha Priv	-0.002	-0.020***		
	(0.008)	(0.005)		
Bsha Pub NoWin			0.015	0.002
			(0.012)	(0.006)
Bsha Pub Win			-0.016	-0.294***
			(0.013)	(0.096)
Bsha Priv Nowin			-0.016	-0.027*
			(0.016)	(0.015)
Bsha Priv Win			0.004	-4.493***
			(0.008)	(1.733)
Constant	-0.707	-1.100***	-0.611	-1.063***
	(0.779)	(0.170)	(0.648)	(0.254)
N	187	187	187	187

The table shows stochastic frontier estimates for various output distance functions using a translog functional form assuming separability between outputs and inputs. The dependent variable is the logarithmized number of scientific publications. The results portray estimations of a simultaneous two-stage approach, where the dependent variable in the second stage is the estimated inefficiency of the first stage.
The table shows coefficients, robust standard errors are in parentheses.
*, ** and *** denote significance levels 10%, 5% and 1%.
Column 1: no technology transfer (TT) measure
Column 2: informality weighted TT measure
Column 3: no TT measure, budget shares for winners and non-winners
Column 4: informality weighted TT measure, budget shares for winners and non-winners separately

Table A.5: *Sensitivity Analysis*

	1	2	3	4	5	6
Acad	0.685***	0.174***	0.153***	0.122***	0.753***	0.223***
	(0.182)	(0.014)	(0.035)	(0.000)	(0.181)	(0.028)
Other	0.189*	0.057***	0.048*	0.013***	0.160	0.024
	(0.112)	(0.001)	(0.028)	(0.000)	(0.106)	(0.035)
$Acad^2$	0.011	-0.002	0.001	-0.004***	-0.005	-0.008
	(0.042)	(0.005)	(0.011)	(0.000)	(0.040)	(0.009)
$Other^2$	0.032	0.012***	0.015***	0.014***	0.053*	0.021***
	(0.030)	(0.000)	(0.004)	(0.000)	(0.028)	(0.003)
Acad_Other	-0.064	-0.020***	-0.022**	-0.009***	-0.070	-0.015
	(0.062)	(0.001)	(0.011)	(0.000)	(0.059)	(0.010)
Mas	-0.465***	-0.048***	-0.015*	0.011***	-0.443***	-0.051***
	(0.033)	(0.005)	(0.008)	(0.000)	(0.037)	(0.006)
Mas^2	-0.054***	-0.010***	-0.007**	-0.010***	-0.051***	-0.010***
	(0.004)	(0.001)	(0.003)	(0.000)	(0.004)	(0.001)
TTTotal		-0.821***	-0.883***			-0.784***
		(0.006)	(0.027)			(0.013)
$TTTotal^2$		-0.025***	-0.024***			-0.024***
		(0.001)	(0.007)			(0.003)
TTEdu				-0.658***		
				(0.000)		
$TTEdu^2$				-0.505***		
				(0.000)		
TTRes				-0.160***		
				(0.000)		
$TTRes^2$				-0.373***		
				(0.000)		
TTCon				-0.147***		
				(0.000)		
$TTCon^2$				-0.032***		
				(0.000)		
Mas_TTTotal		0.019***	0.014*			0.012***
		(0.003)	(0.008)			(0.002)
Mas_TTEdu				0.042***		
				(0.000)		
Mas_TTRes				-0.008***		
				(0.000)		
Mas_TTCon				-0.017***		
				(0.000)		
TTEdu_TTRes				0.839***		
				(0.000)		
TTEdu_TTCon				0.034***		
				(0.000)		
TTRes_TTCon				0.017***		
				(0.000)		
Budget per Emp	0.248***	0.015***	0.016*	0.023***	0.293***	0.064***
	(0.067)	(0.004)	(0.008)	(0.000)	(0.071)	(0.006)
lnBsha Pub					0.108***	0.071***
					(0.040)	(0.000)
lnBsha Priv					0.031	0.026***
					(0.033)	(0.007)
Constant	-0.921	3.405***	2.492***	1.007***	-1.776**	2.558***
	(0.798)	(0.054)	(0.025)	(0.000)	(0.829)	(0.048)
lnsig2v						
Constant	-1.327***	-38.504***	-38.262***	-40.496***	-1.515***	-37.699***
	(0.391)	(0.146)	(0.155)	(0.066)	(0.343)	(0.154)
Inefficiency						
Bsha Pub	0.009	0.004	0.005	0.008		
	(0.014)	(0.005)	(0.005)	(0.006)		
Bsha Priv	-0.002	-0.020***	-0.020***	-0.027***		
	(0.008)	(0.005)	(0.006)	(0.006)		
Constant	-0.707	-1.100***	-1.252***	-1.394***	-0.332	-1.374***
	(0.779)	(0.170)	(0.182)	(0.209)	(0.455)	(0.102)
N	187	187	187	187	187	187

The table shows stochastic frontier estimates for various output distance functions using a translog functional form assuming separability between outputs and inputs. The dependent variable is the log of the number of scientific publications. Columns 1 to 4 display the results of a simultaneous two-stage approach, where the dependent variable in the second stage is the estimated inefficiency of the first stage. The table shows coefficients, robust standard errors are in parentheses.

*, ** and *** denote significance levels 10%, 5% and 1%. All regressions include dummy variables for scientific fields and institution types.

Column 1: no TT measure; Column 2: informality weighted TT measure;

Column 3: unweighted TT measure; Column 4: three separate TT measures;

Column 5: no TT measure, budget shares included directly in the distance function;

Column 6: informality weighted TT measure, budget shares included directly;