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A MICROECONOMIC ASSESSMENT OF RTO'S IMPACT ON FIRMS OUTPUT: The case of TNO

Keywords: Return on R&D, research and technology organization, impact assessment, firm productivity

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A MICROECONOMIC ASSESSMENT OF RTO'S IMPACT ON FIRMS OUTPUT:

The case of TNO

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Abstract:

This study estimates the economic impact of Research and Technology Organisations (RTOs) on firms' productivity. The effectiveness and efficiency of public intervention has become a prominent aspect in the design of measures addressing RTOs, and their subsequent allocation of public support. This also holds for financing. As a way to indicate their relevance and role in the innovation system of RTOs such as the Dutch RTO, TNO, RTOs should therefore be able to indicate the impact of the knowledge they create on the economy. This goes beyond providing insight into the economic footprint of the financing of RTOs, i.e. "rippling effect" resulting from (re)spending of the financial support; on salaries, equipment, etc.

Results show that firms that use TNO services have 14-17 percent higher value added in the next year, compared to similar firms that did not use TNO services. We correct for selection bias of firms that use TNO services, by applying the propensity score matching method that ensures that firms in the treatment group and control group are comparable. For each firm in the treatment group, a counterfactual with a similar probability to use TNO services is selected in the control group. Our results are in line with existing research assessing the role and relevance of RTOs. We subsequently can conclude that the impact of RTOs is significantly positive on firm output.

JEL codes: C13, C26, D24, O32

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1 Introduction

The effectiveness and efficiency of public intervention has become a prominent aspect in the design of the policy mix addressing R&D, and the subsequent allocation of public support. This also holds for the financing of Research and Technology Organisations (RTOs) such as the Netherlands Organisation for Applied Scientific Research (TNO). In the course of the debate on public spending, it is important to show the RTO's role and relevance in the economy. This goes beyond providing insight into the direct and indirect effects of the financing of RTOs, i.e. the "rippling effect" resulting from (re)spending of the financial support; on salaries, investments in equipment, etc. It is even more important to be able to pinpoint the impact of the new technologies that the RTOs create on economic productivity of the recipients of these technologies.

This paper assesses the RTO impact beyond the traditional multiplier or qualitative analysis, with the use of econometric methods.[1] We compare the productivity (value added) of firms that use the TNO services with firms that do not use such services. Evaluations addressing the impact of RTOs on productivity have been conducted in a few studies; on RTOs in Denmark, Germany and France (Fraunhofer, 2010; Comin et al., 2018; Forsknings- og Innovationstryrelsen, 2011). These studies have demonstrated a positive and significant impact of RTOs on the firm's share of innovate sales and value added.

This analysis involves two important aspects: impact and correlation. Impact means the strength of the effect of the intervention, that is, how much improvement in the firm's performance we can expect if using RTO services. Correlation means the strengths of the statistical relationship between the intervention and firms' performance, that is, how strong is the co-movement of the two variables in question.

In this study, the impact is estimated at the firm level via the treatment effects methodology. In this methodology, subjects that received treatment are compared to subjects that did not receive treatment, but have similar characteristics (control group). That is, subjects from the control group would have been likely candidates for receiving treatment, but did not receive the treatment. The treatment group consists of all firms that use TNO services (e.g. TNO research projects conducted for firms) and the control group consists of all firms that did not use TNO services but did have R&D activities. We correct for the selection bias (specific type of firms use TNO research services) by matching each firm in the treatment group with similar firm(s) in the control group. In this study, we use a unique microeconomic panel dataset compiled from TNO and Statistics Netherlands (CBS) datasets. These unique data allows the first microeconomic impact assessment of a Dutch RTO.

Chapter 2 discusses the literature findings on the impact of RTOs. Chapter 3 and 4 describe the proposed four model specifications and the database. This is

[1] Note that within the framework of this econometric analysis, the concept of impact refers to the strength of the effect of the intervention, that is, how much improvement in the firm's performance we can expect if using RTO services. Our study does not address the correlation (i.e. the strengths of the statistical relationship between the intervention and firms' performance, that is, how strong is the co-movement of the two variables in question).

followed by the results of this study in Chapter 5. Chapter 6 concludes our findings on the impact of TNO on firms, which is found to be positive and significant.

2 Literature

In this study, we analyse the *impact* of RTOs, and not the economic *footprint* of RTOs. Both impact and footprint are used to measure the effect of RTOs, but they require very different interpretations (Poliakov and Hu, 2016). The footprint measures the effect of RTO inputs (e.g. effect resulting from the purchase of for example office equipment), whereas the impact measures the effect of RTO knowledge creation (e.g. innovation). In other words, the economic *footprint* refers to how much RTO (re)spending on inputs brings about rippling effects on the rest of the economy in the form of additional output and jobs in the supply chain. On the other hand, the *impact* refers to the effect of RTO knowledge creation on the productivity and competitiveness of the economy.

Different studies have evaluated the impact of public support for R&D on the economy (Verhoeven et al., 2012; Hertog et al., 2015; Department for Business, Energy & Industrial Strategy, 2017) but fewer studies have evaluated the impact of RTOs on the economy. An evaluation of RTOs is more complex to estimate than public R&D support due to a number of reasons:

- Firstly, the impact of RTOs is very difficult to define. RTOs focus not only on innovation to support firms but also to address societal challenges, such as health or air quality aspects. Such societal impacts cannot be easily measured (in the existing data).
- Secondly, RTO impacts are more difficult to identify in the macro data, because RTOs are often rather small compared to the whole economy. Impacts of RTOs should therefore be assessed using microdata and such RTO microdata are not readily available.
- Lastly, RTOs do not have a clear starting and ending time with respect to the delivery of R&D related services. Hence there is no clear before and after period for the evaluation.

Nonetheless, a few studies have estimated the impact of RTOs. A Danish study (Forsknings- og Innovationstryrelsen, 2011) showed that firms that collaborated with RTOs had an additional 7.3% or approx. 5400 euro (40,118 kr) in productivity per employee and approximately 970k euro (7,181,122 kr) in additional value added, compared to the control group. They found comparable results for working together with universities although the additional productivity and value added were lower. The companies in the control group in general caught up to the productivity levels of the treatment group only after nine years.

Another study by Fraunhofer (2010) used the CIS data to estimate the effect of cooperation with public research institutions on a company's innovation. They applied a two-phase instrumental variable regression to correct for selection bias. In other words, they corrected for the fact that specific type of companies choose to cooperate with public research institutions. They have found that cooperating with a public research institute leads to a 13-17% increase in a firm's share of innovative sales in France. In Germany this was even 48-49%. The study suggests that the large difference between the results from France and Germany can be explained by the differences in the nature of their science policies. The German science policy is (i) more decentralized compared to France (decentralized at the Länder level) and (ii) focuses on knowledge and technology transfers through, for instance, technology transfer offices (Technologie-transferstelle) that bring firms and universities together.

A recent study of the Lund University on the impact of Fraunhofer services on the client firms (Comin et al., 2018) using, again, the instrumental variable regression, indicated that for every euro spent on Fraunhofer services by the client firms there is a considerable benefit of 13 euros of extra turnover generated.

3 Methodology

This paper aims to estimate the impact of TNO services on the output of the client firms. The output is determined as the value added. Measuring the impact of RTOs can be viewed similar to measuring the impact of R&D since the services of RTOs to a large part, albeit not fully, consist of R&D. The standard literature approach to measuring the R&D impact is via the production function. Production function describes the influence of production factors, for instance, capital and labour, on the value of production. For measuring the R&D impact, R&D is included as another factor of production[2] (Hall et al. 2010).

Another approach is a flexible equation specification where the list of the control variables and the functional form variables do not necessarily conform to the production function theory. Such specification was used, for instance, by Comin et al. (2018) for the impact assessment of the Fraunhofer Society in Germany. These approaches allow to identify the impact of an RTO input expressed in the terms of either elasticity (additional growth in value added when company spends 1% extra on value added) or return (extra euro earned for each euro spend on RTO). However, these production function based models are rather restrictive and the desired impact is very hard to assess due to an extremely small size of the RTO variable in relation to the output variable. We have been unsuccessful so far to pinpoint the TNO impact with these methods, although more sophisticated technics than we used so far might lead to a more definitive conclusions.

A less precise approach is to estimate the *average* RTO impact independently on the and other inputs in the firm. Verhoeven et al. (2012) used such an approach for the evaluation of the Dutch tax scheme WBSO for the R&D stimulation. We follow this approach.

We use the treatment effects methodology, for which two groups have been defined: the treatment and control group. The treatment group includes firms that use TNO services. The control group includes similar firms that do not use TNO services.

The impact is measured in growth rates and not in levels of value added because it is important to measure only the additional impact of TNO services. For instance, when we compare a firm that used TNO services and a firm that did not, it is almost certain that the two firms start from a different level of value added (before using TNO services). We are not interested in the difference in levels as it may be that one firm is simply larger than the other, which may have nothing to do with TNO services. Instead, we are interested in the growth in value added after using TNO services compared to the growth the other firm observes, as this effect may be attributed to the use of TNO services.

The treatment effect – or the impact of RTO services – can best be explained using potential outcomes. Potential outcomes describe the firms' output when it would have been in the opposite group. As an example, consider a firm that used RTO services. The potential outcome would be the firms' increase in value added

[2] Here a caveat must be added over the measuring of the impact of R&D on output, because a large part of R&D is directed towards quality improvement and non-market goods which do not influence the measured level of output (Griliches 1973).

when it would not have used RTO services. Then, the average treatment effect is defined as the mean difference between the treated and untreated firms taking into account counterfactual, potential, outcomes.

Ideally, we would like to randomize the treatment group, that is, to assign TNO services randomly to the population of firms (controlled experiment). This would rule out any form of selection bias. However, this is impossible. We are dealing with observational data, where firms that outsource R&D activities to TNO choose themselves to become a TNO client. Therefore, we cannot simply take the difference between the two sample means, because the treatment group may have some specific characteristics different from the control group which affects the firms' output. Hence, a subsample of similar firms belonging to both control and treatment groups need to be created at the first step (matching) and then the average treatment effect is estimated at the second step (the estimation procedure). The matching procedure ensures that the control group only consists of firms with similar characteristics to the firms in the treatment group. In this way, selection bias is corrected for as the firms in both treatment and control group are comparable.

Step 1: Matching treated and untreated firms

The matching of firms in order to create the control group is done as follows. For each treated firm a matching untreated firm, the counterfactual, is selected for the control group. The firms are matched based on the likelihood to select themselves to use TNO services. The likelihood is determined by specific firm characteristics. The firm characteristics are firm size in terms of employment, capital stock and expenditures on R&D. These three firm characteristics are used because they are considered as standard factor inputs for defining value added in the production function (Hall et al., 2010). All the matched counterfactual firms together form the control group. The treatment and control group will be compared as a whole and thus the individual links between two matched firms are not relevant anymore in the second step.

Two types of matching techniques are used: Propensity Score Matching (PSM) and nearest Neighbourhood Matching (NNM). PSM matches comparable firms based on the predicted probability of treatment. That is, PSM matches firms based on how likely they are to use TNO services. The likelihood is determined by employment, labour and R&D. These probabilities are called propensity scores and are calculated using a logit regression Or in other words, the probability of being a TNO client ($\mathbb{P}(D_{i,t} = 1)$) is a logit function of capital stock ($K_{i,t}$), employment ($L_{i,t}$) and R&D expenditures ($KC_{i,t}$):

$$\mathbb{P}\big(D_{i,t} = 1 \big| \, L_i, K_i, KC_i\big) = \frac{\exp(a_0 + a_1 L_{i,t} + a_2 K_{i,t} + a_3 KC_{i,t} + \epsilon_{i,t})}{1 + \exp(a_0 + a_1 L_{i,t} + a_2 K_i, t + a_3 KC_i, t + \epsilon_{i,t})}, (2)$$

where dummy $D_{i,t}$ equals one when firm i uses TNO services in year t.

The second matching technique, NNM, measures the distance between the matched firms on the same characteristics, labour, capital and R&D expenditures.

Step 2: Estimating the effect based on treatment and control group

After the first step, treatment and control group are comparable, and the impact of TNO services or ATE can be estimated using the following formula:

$$\frac{VA_{i,t}-VA_{i,t-1}}{VA_{i,t-1}} = a_0 + a_1 D_{i,t-\theta} + \epsilon_i, \quad (3)$$

where the left hand side of the equation explains the growth rate of value added of the firm *i* in year *t*, the dummy $D_{i,t-\theta}$ equals one if firm i uses TNO services in year $t-\theta$ and zero otherwise, and the coefficient a_1 is indicates the sought impact or the relation between TNO services and the firm's value added. The lag of one year ($\theta = 1$) yields a significant impact of TNO services.

4 Data

The treatment group consists of all firms that used TNO services between 2008 and 2015. The control group consists of all firms which were engaged in R&D activities but have not used TNO services between 2008 and 2015. In this study, TNO services refer to the TNO research projects acquired by firms that:

- include both contract research (company pays full amount) as well as projects with competitive funding from TNO (company pays only part);
- is a selection (5.5%) of all TNO research projects.
  TNO services also include fundamental research and research projects acquired by governments and institutions, which falls outside the scope of this study;
- are only partly considered as R&D. Some TNO projects - such as consultancy, measurement, testing and standardization, and feasibility and policy studies (OECD, 2015) – cannot be considered as R&D. In this study, TNO research projects refer to all services.

Microdata at the firm level come from TNO and Statistics Netherlands (CBS). Value added, R&D expenditure, and depreciation (as proxy for capital) are expressed in constant 2014 euros. R&D personnel is excluded from the total personnel in FTE to avoid double counting with R&D expenditure in the regression. The TNO services are expressed in constant 2014 euros and refer to the payments of firms for TNO research projects. More information on the data sources can be found in Annex A: Data sources.

Firms that are included in the dataset have the following criteria:

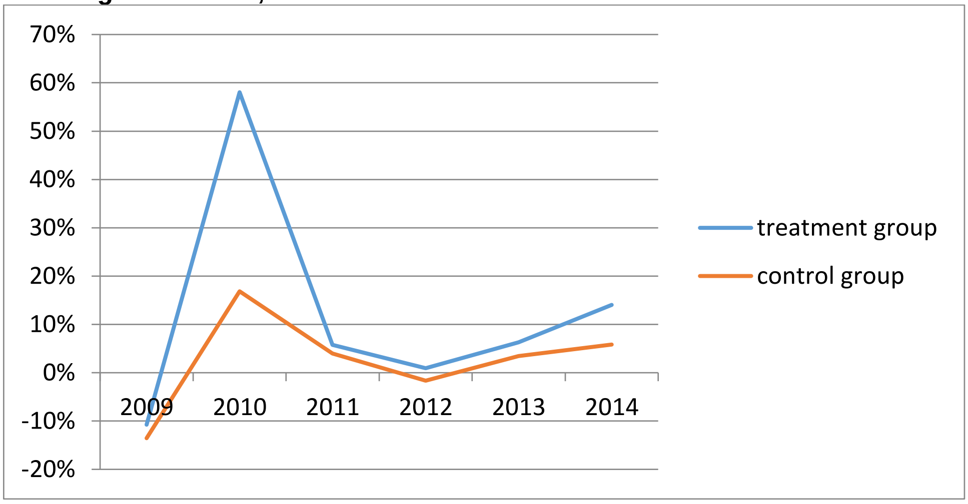
1. They belong to the following four sectors: manufacturing, transport, construction and mining and quarrying. These are, by far, the four largest manufacturing sectors that the firms belong to.
2. TNO spin-offs are excluded from analysis, to avoid any biases in the data. That is, all firms related to TNO BV Companies are removed.
3. Firms with excessive productivity levels are removed. For instance, the sample included firms with a productivity of over three million euro per FTE, which seemed unrealistic. This corresponds to removing the top 0.1% observations regarding productivity.
4. Firms should have at least three FTEs.
5. Outliers regarding value added growth are removed at 0.05% and 99.95% level, using winsorizing (Reifman and Kevton (2010)). Some observations showed a growth rate of more than 2100% or lower than -1400% which seemed unrealistic.

The table below summarizes the main indicators for the treatment and control group. After matching, total number of observations is 2,868. The treatment group consists of 264 firms while the control group has 1,089. The firms in the treatment group are generally more R&D intensive, more productive, larger and more innovative compared to the control group. For instance, the productivity is 117,705 euro of value added per employee while this is 82,400 in the control group. This indicates that firms outsource R&D activities to TNO have a different character than the firms in the control group. The average growth rate in value added is also higher in the treatment group as shown in the figure below. This is the case for every year, especially 2010. However, this could be caused by the lowest number of observations in 2010.

Table 1: Characteristics of treatment and matched control group, mean and standard deviation, 2008-2014, in 2014 prices

		Treatment group	*Control group*
Firms		264	1,089
Observations		578	2,290
R&D intensity (R&D per euro value added)	KC/VA	0.12 (0.36)	0.07 (0.25)
TNO intensity (TNO services per euro value added)		0.002 (0.02)	-
Productivity (euro value added per FTE)	VA/L	117,705 (109,163)	80,510 (69,452)
Firm size in FTE	L	984 (1,683)	250 (364)
% of revenue due to product or process innovation		26% (29%)	24% (27%)

Figure 1: Average growth rate in value added in treatment and control group, in annual growth rates, 2009-2014



5 Results

5.1 Estimates

Benefits from RTO services are manifold; enhancing the innovation performance of the recipient firm can be measured with various innovation indicators. However, the integral economic indicator of the impact of RTOs involvement is the productivity gains is measured in terms of the firms output (value added). This study aims at estimating the impact of the firm's expenditure on TNO services on the firm's output.

In this study, TNO services includes research projects that Dutch firms have acquired from TNO. The impact of TNO services is measured as the additional value added growth after a firm used services from TNO. To isolate the effect of TNO services, these firms have been compared to a control group. The control group consists of firms that did not use TNO services but did take part in R&D activities.

We have estimated treatment effects for the whole sample as well as per sector: industry, mining, transport and commercial services. Only the subsample industry yielded significant effects. Since the sector industry comprises 89 percent of total observations, the significant result for industry drives the estimate for the whole sample to a significant impact as well.

Table 2 shows results of the first step of the PSM model, the matching procedure that creates the control group. The results indicate the strength of our matching variables. The results show highly significant coefficients for employment, capital and R&D. That is, employment, capital and R&D are significant predictors for firm propensity to use TNO services. The pseudo R squared of 0.22 is satisfactory considering the diverse and unbalanced nature of the underlying data panel. This implies that the employment, capital and R&D expenditure can be considered as good matching variables.

Table 2: Firms characteristics that define firm likelihood to use TNO services (the first stage logit regression)

Dependent variable: TNO services dummy	D	Coefficient	Standard error
Labour	L	0.715***	0.077
Capital	K	0.290***	0.051
R&D	KC	0.142***	0.020
Pseudo R2 of the first-stage regression	0.221		
LR Chi2 of the first-stage regression	637.7		
Prob>chi2	0.000		
Observations	2,867		

Significance level indicated by *** refers to one percent.

Table 3: Results on the average treatment effect of the TNO services (the second stage NNM/PSM regression)

Full sample		
Dependent variable: value added growth rate in year t+1 $\frac{VA_{i,t} - VA_{i,t-1}}{VA_{i,t-1}}$	Propensity Score Matching	Nearest Neighbour Matching
Coefficient of TNO services dummy	0.1445**	0.1874*
Standard error	0.0641	0.0994
P-value	0.025	0.059
No. of observations	2,550	2,550

Significance level indicated by ** refers to five percent and by * to ten percent.

The second step of the PSM and NNM model estimates the impact of TNO services estimated as the average treatment effect. Table 3 provides the estimation results for both models. The coefficient at the TNO services dummy indicates that a firm's investment in TNO services brings about on average an extra 14.5-18.7 percent cumulative growth in value added in the next year for that firm. The 14.5 percent is obtained by comparing firms that use TNO services with firms that were just as likely to use TNO services but did not. The second estimate of 18.7 percent is obtained by comparing firms that use TNO services with firms with a similar employment, capital and R&D levels.

5.2 Assessment of the matched subsamples

In order to assess the capacity of matching the similar firms in the control and treatment group, we compared the ultimate matched control and treatment groups regards the three main firms' characteristics: labour, capital and R&D expenditures (without TNO input). As Table 1 shows, the treatment group consisting of larger, more capital-intensive and more R&D-intensive firms. We have looked at the two ultimate subsamples that were selected during the matching process and used for the treatment effect estimation. Comparing these treatment and control subsamples on the same characteristics as the general treatment and control samples, we still find that the firms in the treatment group were still on average larger in terms of employment, capital and R&D expenditures. This is true for the sample which includes firms from all sectors, as well as for the subsample consisting only of industrial firms. This can be attributed to a certain weakness of the treatment effect methods which failed to eliminate completely the differences in the ultimate treatment and control samples on which the estimation of treatment effects was carried out.

To somewhat strengthen our reasoning as to the presence of the TNO effect, the different lag structures of the specifications were investigated. For instance, the impact of TNO project was tested with no lag at all, as well as with lags of one or two years (that is, the impact of the TNO projects on the value added comes one or two years after the intervention). In addition, the leads of one and two years were tested too (that is, these effect of TNO comes about one or two years before the TNO intervention). These specifications check for the spurious TNO effect arising from generally higher growth rates in the treatment group than in the control group. If it were the generally higher growth rates in the treatment group that were causing the TNO effect, then the effect would be present at different lags and leads. However, that was not the case. The TNO effect manifested itself only with a one or two year lag. Therefore, we may conclude, that the results are still valid despite the certain weakness of the matching procedure.

5.3 Interpretation

Results show that firms that use TNO services have on average 14.5-18.7 percent more growth in value added in the next year. This result can be interpreted with a number of alternative scenarios:

1. Firms are inclined to involve TNO in more advanced projects with a higher probability of success. If the probability to success would be low, the firm would simply not invest in TNO services, as the cost is high. Therefore TNO services seem to yield a higher impact than average firm R&D activities.
2. Another interpretation is that TNO possesses certain assets that create additional value for firms when involved in their innovation process. The assets are for instance their knowledge base, infrastructure and experience. In this case, the interpretation would be that if a firm uses TNO services, it's value added is expected to grow more than if the firm wouldn't have used TNO services (i.e. the outcome of the innovation process would be 'better' because of the involvement of TNO and the deployment of its assets - a 'magic wand' scenario).
3. A third explanation is that firms, by cooperating with TNO, obtain new capabilities that strengthen their innovation capacity and change their innovation behaviour. This could help them create higher value added growth in the long run. Although it should be noted that this study measured an impact the one year after using TNO services instead of over the long term. Therefore, we believe that our results do not match well with this scenario.

Therefore, we can conclude that TNO has a significant and positive effect on value added growth of the beneficiary firms.

6 Conclusions

In this paper we have attempted to estimate the impact of the Dutch RTO TNO on the output of the beneficiary firms. The output is measured as the additional value added growth the next year after the intervention. This impact is estimated by comparing firms that use TNO services (the treatment group) to firms that do not use TNO services (the control group). However, it should be noted that this study looked only at the impact of TNO services used by Dutch firms which is only a small part of the total TNO services. Other TNO services including fundamental research and services to governments fall outside the scope of this study.

The main issues with estimating the impact of TNO services are selection bias of firms. Firms that outsource R&D activities to TNO select themselves as a user of TNO services. Therefore a fair comparison between the treatment group and the control group should take into account a possible circular reasoning whether a firm more productive because it used TNO services or - the opposite – whether more productive firms use TNO services. We address this issue by only comparing matched firms that have similar characteristics. The Propensity Score and the Nearest Neighbour matching methods have been used. The firms' similarity likelihood is estimated based on employment, R&D expenditure and capital stock.

Results show that TNO services bring about an impact in the form of additional growth of value added of the client firms one year after the intervention. The average size of the impact lies in the range of 14.5-18.7 percent of the extra value added growth in the next year. The impact seems quite large and we believe this might be caused by the fact that firms could be inclined to involve TNO in more advanced research projects with a higher probability to success. TNO services therefore yield a higher impact than average firm R&D activities.

Although we have made efforts to correct for a possible self-selection bias of the TNO client firms, further research is needed to strengthen the results with the use of additional techniques that deal with selection bias.

The assessment of RTO services impact on value added provides a partial view only, since the RTO services also aim at improving product quality and non-market goods, such as public health and better environment. However, societal impact is very difficult to measure for an RTO as a whole, and can only be carried out for specific research projects via the cost-benefit analysis. This societal impact would be additional to the impact measured in this study.

The unique study's dataset offers more opportunities of analysis than so far pursued. They would allow assessing the TNO effects on various innovation indicators rather than value added as well as to use alternative econometric methods on the impact of TNO services on the value added of the recipient firms.

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Vitae

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Jinxue Hu is a research scientist in economics at TNO. She obtained her MSc degree in Economics and Business at the Erasmus University Rotterdam, specializing in “Strategy, entrepreneurship and organization” as well as “Urban, port and transport economics”. She is an economic researcher involved in several (European) research projects. She has worked on the topics innovation, energy and environmental economics. Her work mainly involves data analyses, cost benefit analyses, regression analysis, input-output and economic modelling.

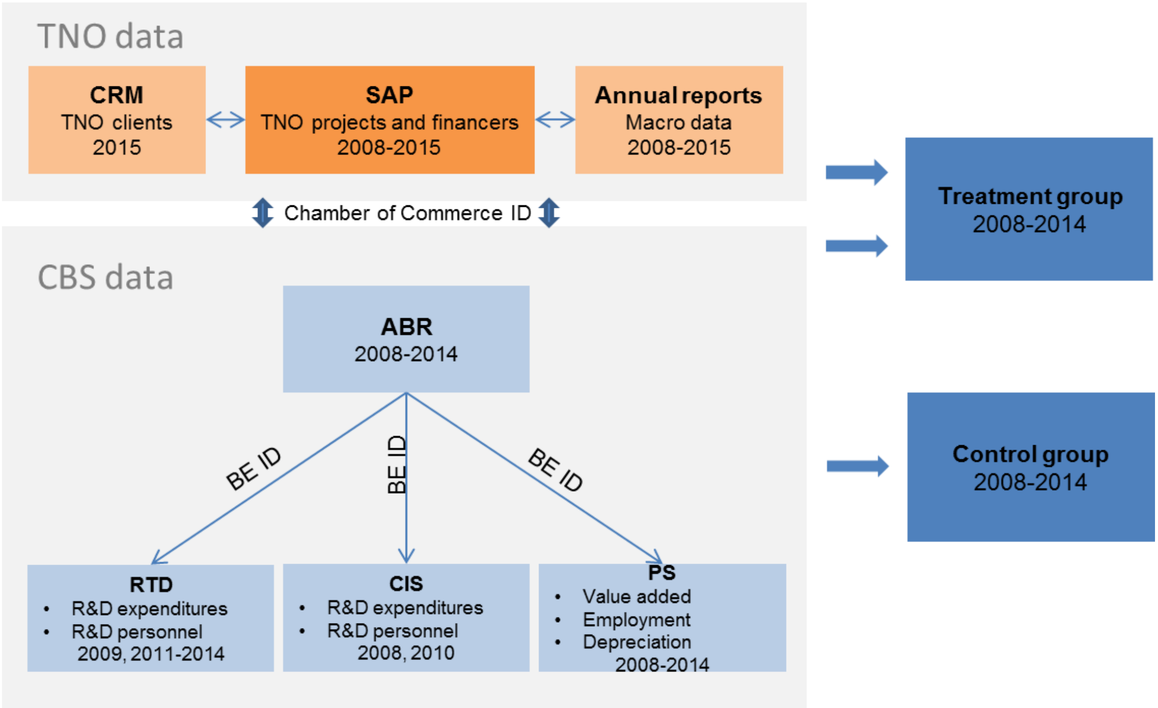
Dr. Marcel de Heide is senior research scientist specializing in innovation economics. He has been with TNO since 2012. Along with carrying out numerous research projects, he provides policy advise for the European Commission in management and support of innovation policy formulation and delivery. He holds a Ph.D. degree in Economics from the Erasmus University Rotterdam and an MSc. degree in Industrial Design Engineering from the Delft University of Technology.

Dr. Hettie Boonman is a research scientist in Economics at TNO. She holds a master degree in Econometrics and PhD degree in Economics from the University of Tilburg. The field of research of her PhD lies on the crossing road of industrial organization and real options theory. Currently, her research focusses on economic and environmental impact assessment modeling using a computational general equilibrium model. Also data analyses and input-output analysis are part of her daily activities.

Annex A: Data sources

Several databases are used in this study and are represented in the figure below. On the one hand we used TNO data on R&D activities that companies have outsourced to TNO. On the other hand we used data from Statistics Netherlands (CBS) on the performance of companies that have outsource R&D activities to TNO (treatment group) and companies that have not outsourced R&D activities to TNO (control group). The performance is measured as productivity (value added per employee). Firms using TNO services form the treatment group and all other companies that perform R&D activities form the control group. The control group is needed for proper measurement of the effect of R&D activities outsourced to TNO and acts as a benchmark.

Figure 0.1: Schematic overview of linked databases



Database names: Algemeen Bedrijven Register (ABR), Research and Technology Development (RTD), Community Innovation Survey (CIS), Productie Statistieken (PS)

The TNO microdata, mainly provided by the SAP system, includes detailed information on each research project between 2008 and 2015. For each project the amount of R&D activity in euros and the financing company (proxy for company using the services) are relevant. The TNO data can be linked to the CBS microdata through the Chamber of Commerce ID. In this way we are able to obtain R&D expenditure, R&D personnel, value added, employees, depreciation for each company from the CBS microdata.

Not all firms that use TNO services are included in the treatment group because of a number of reasons. The Chamber of Commerce ID could be missing for instance. The PS data was not bought for a very small part of the firms, as PS data was only bought for the four largest sectors in which TNO services are used by companies. TNO spin-offs were excluded to avoid bias in the data. And finally, sometimes simply the CBS data was missing.

Annex B: Results from other model specifications

Two other model specifications which often come up in the literature of R&D impact assessment have been explored in this study as well. This Annex describes these models, which in the end did not yield statistically significant estimates of TNO impact. The reason for the insignificant impact is in our view that these theoretically-based models were not fully appropriate to answer the research question at hand.

Measuring the impact of RTOs can be for instance viewed similar to measuring the impact of R&D, more so that the services of RTOs to a large part, but not fully, consist of R&D. Taking this approach to assessing RTOs impact, we then apply the growth accounting framework where the production function of the firm depends on the usual factors of production as well as R&D as another factor of production. Here a caveat must be added over the measuring of the impact of R&D on output, because a large part of R&D is directed towards quality improvement and non-market goods which do not influence the measured level of output (Griliches 1973). We will further refer to RTO as TNO on which data the analysis was carried out.

It is common in the literature on the return on R&D to postulate the Cobb-Douglas production function of a firm with three factors of production: labour, capital and knowledge (R&D) input (Hall et al. 2010). We could add a fourth production factor – the TNO services as input into the firm. Thus the firm production function of firm i in year *t* is of the following form:

$$Y_{it} = A_i K_{it}^{\alpha} L_{it}^{\beta} KC_{it}^{\gamma} T_{it}^{\eta}$$

where Y_{it} is value added, K_{it} is capital, KC_{it} is knowledge capital and T_{it} is TNO services. The TNO services can be considered in this formulation as a specific type of capital, similar to the knowledge capital but not equivalent to it. Annual flows of TNO input can be accumulated into stock via the perpetual inventory method, as with the usual knowledge capital. The above model leads to two specifications:

(i) the return specification which assumes constant return to R&D investment (euros per one euro invested, similar to return to financial investment)

$$\Delta \ln Y_{it} = \alpha \Delta \ln K_{it} + \beta \Delta \ln L_{it} + \rho \frac{\Delta \ln KC_{it}}{Y_{it}} + \sigma \frac{\Delta \ln T_{it}}{Y_{it}}$$

and

(ii) elasticity specification which assumes constant elasticity of value added with respect to R&D investment (percentage gain in value added with the one-percent increase in R&D expenditure.

$$\Delta \ln Y_{it} = \alpha \Delta \ln K_{it} + \beta \Delta \ln L_{it} + \gamma \Delta \ln KC_{it} + \eta \Delta \ln T_{it}$$

However, we find that these production function based models are too restrictive, because TNO services are too small compared to the other input factors in the production function. The median TNO intensity (to value added) is only 0.029 percent (mean is only 0.09 percent), with the intensity of the first quartile of the distribution of 0.007 percent and the third quartile of 0.130 percent. Compared to the values of the other factor inputs in the production function (e.g. mean of R&D intensity is 13%), TNO becomes far too small to produce meaningful results.

Besides the production function specification, we also explored the difference-in-differences specification. This method regresses the difference between the treatment and control group as well as the difference in the trend of each group. The difference-in-differences method assumes a period before the treatment (before the TNO services were introduced) and after the treatment (after the TNO services were introduced). However, available data do not allow the proper application of this method. The TNO services do not have a clear starting and ending time within the time period of the dataset. Firms use TNO services in one year, a few years sequentially of a few years in different time periods. The simplification of the method taking into account just the use of the TNO services by companies did not yield statistically significant impact estimates.