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Public R&D support to enterprises in four R&D sectors: the mix of types of aid and policy agencies

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ABSTRACT

We examine how the amount of public R&D support to enterprises in different R&D sectors is related to the mix of types of aid and policy agencies. The question we ask is whether this amount increases or decreases with the number of types of aid and policy agencies in each sector. We use panel data on the amount of support received by Norwegian enterprises in the following four R&D sectors: the higher education sector, the institute sector, the health trusts, and the industrial sector. GMM regressions show that the amount of support is positively related to the number of policy agencies in all four sectors, and positively related to the number of types of aid in the industrial sector (the relationship is non-significant in each of the other three sectors). The estimation results therefore indicate that the amount of public R&D support increases in one of the R&D sectors (the industrial sector) when enterprises benefit from an increasing number of different types of aid, and increases in all sectors when enterprises benefit from an increasing number of different policy agencies.

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1. Introduction

Research and development (R&D) activity contributes positively to economic growth (Blanco, Gu, and Prieger 2016; Sokolov-Mladenović, Cvetanović, and Mladenović 2016). R&D activity leads to growth through its positive effect on innovation and technological progress, and through the positive link between such activity and total factor productivity growth (Haider, Kunst, and Wirl 2020; Blanco, Gu, and Prieger 2016). Based on OECD (2015), R&D comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge, and the use of this stock of knowledge to devise new applications.

According to Becker (2015), there is an increasing recognition of the benefits of public support to R&D investment. Several studies have found that public R&D expenditure can stimulate private or business R&D (Nilsen, Raknerud, and Iancu 2020; Carboni 2017; Huergo and Moreno 2017; Huergo, Trenado, and Ubierna 2016; Becker 2015; Garza et al. 2015; Chiang, Lee, and Anandarajan 2012; Lokshin and Mohnen 2012; Yang, Huang, and Hou 2012; Carboni 2011; Görg and Strobl 2007; Guellec and Van Pottelsberghe De La Potterie 2003), but some studies find no evidence of substantial additionality (Aristei,

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Sterlacchini, and Venturini 2017; Dimos and Pugh 2016; Gaillard-Ladinska, Non, and Straathof 2015), or evidence of either no additionality or substitution effects between public and private R&D expenditure (Marino et al. 2016). Furthermore, Hall, Mairesse, and Mohnen (2010) conclude that the private returns to R&D are strongly positive, while the social returns are even higher.

Many studies examine the impact of a single measure of public support on business R&D, for example, public R&D subsidies (Czarnitzki and Hussinger 2018; Aristei, Sterlacchini, and Venturini 2017; Dimos and Pugh 2016; Görg and Strobl 2007),[1] and R&D tax credits or incentives (Gaillard-Ladinska, Non, and Straathof 2015; Chiang, Lee, and Anandarajan 2012; Lokshin and Mohnen 2012; Yang, Huang, and Hou 2012). Dumont (2017) emphasises that 'estimates of the impact of a single policy instrument may be biased when other instruments are not considered in the estimation' (p. 1861). He claims that few studies have investigated the effectiveness of the combination of different measures of public support to business R&D. Six exceptions that we will highlight are Nilsen, Raknerud, and Iancu (2020), Huergo and Moreno (2017), Marino et al. (2016), Garza et al. (2015), Guellec and Van Pottelsberghe De La Potterie (2003), and Dumont's own study. Nilsen, Raknerud, and Iancu (2020) analyse all the major sources of direct and indirect R&D support (in Norway), Huergo and Moreno (2017) distinguish between public R&D funding programmes such as low-interest loans and national and European subsidies, Marino et al. (2016) assess the combination of the R&D tax credit regime with public R&D subsidies, Garza et al. (2015) compare R&D tax credits and direct R&D grants, while Guellec and Van Pottelsberghe De La Potterie (2003) focus on direct government funding and R&D tax incentives as forms of support.

Dumont (2017) examines the effectiveness of public support to business R&D in Belgium by considering jointly all available policy instruments. His study is based on a panel of firms with a continuous variable for public support instead of a binary or categorical variable. He emphasises that the use of a continuous variable for all support measures is in contrast with most of the small number of previous studies that have considered the combination of different R&D support schemes. Robust results in his analysis indicate that the combination of different measures decreases the effectiveness of public support in Belgium (especially when firms combine subsidies with several tax benefits).

The literature review so far emphasises the importance of focusing on public R&D support, since such support can stimulate business R&D and contribute positively to a firm's financial performance. It also emphasises the importance of examining how the total amount of public support for R&D is related to different R&D support schemes, because a single measure of public support is used in many studies. Although several previous studies have examined how public R&D support is related to business R&D, we know far less about how different support schemes for R&D are related to the total amount of public R&D support. The aim of this article is to generate new knowledge concerning the relationship between the total amount of public R&D support and different R&D support schemes.

The present study is based on the analysis in Dumont (2017), but unlike his study, we do not focus on the effectiveness of public support to business R&D. Instead, we use panel data to examine how the total amount of public R&D support received by firms is related to different support schemes for R&D in Norway, where firms are defined at the enterprise level. In the same way as in Dumont (2017), all available policy instruments are considered jointly. We contribute to the research literature on public R&D support along two dimensions. First, we do not restrict the analysis to the business sector only, but also include other R&D sectors. The following four R&D sectors are considered: the higher education sector, the institute sector, the health trusts, and the industrial sector. The industrial sector more or less corresponds to the business sector. Second, we do not measure policy instruments only by different types of aid, but also by different policy agencies. In the analysis, we use both continuous and categorical variables for types of aid and policy agencies, where we examine how the continuous variables are related to the total amount of public support for R&D with control for the categorical variables. The question we ask is not only whether the total amount of public R&D support to enterprises in each of the R&D sectors increases or decreases with the (continuous variable measured by the) number of different types of aid, but also whether the amount of support increases or decreases with the (continuous variable measured by the) number of different policy agencies. As far as we are aware, no previous study has examined how (the total amount of) public R&D support is related to the mix of types of aid and policy agencies. The results of the analysis can be potentially informative for enterprises' managements and various policy agencies, as enterprises' managements might prefer to maximise support, while policy agencies might be concerned about managerial possible strategies to maximise support across agencies and types of aid.

The rest of the article is organised as follows. In Section 2, we describe the data and the variables. The econometric approach is presented in Section 3. Descriptive statistics are given in Section 4. Section 5 presents the estimation results. Conclusions are provided in Section 6.

2. The data

We use panel register data of Norwegian enterprises from Statistics Norway. The data contains yearly information on public R&D support to enterprises in four R&D sectors in Norway in the period 2000–2018. The variables in the data are the amount of support, the year an enterprise receives support, type of aid, policy agency, and the R&D sector an enterprise is included. The amount of support received by enterprises is measured in 1000 NOK at constant prices (in 2017). The R&D sectors are the higher education sector, the institute sector, the health trusts, and the industrial sector.

There are 231,377 observations in the data. An observation, which is the unit in the data, is a type of aid that an enterprise has received from a policy agency in a specific year. Since we use panel data, an enterprise's R&D sector affiliation can vary between different years in the period 2000–2018. Therefore, an R&D sector consists of all enterprises that are registered in this sector for at least one of the years in 2000–2018.

Of the 231,377 observations, the amount of support is zero for 57,822 (25%) observations and negative for 297 (0.1%) observations. Both zero and negative values are excluded from the sample of observations due to how the dependent variable is calculated (see below). This reduces the sample to 173,258 observations. Since lagged levels of the key regressors are used in the estimations (see Section 3), we also exclude 84,110 observations from the sample. Furthermore, only one observation in one of the sectors (the health trusts) concerns support from a specific policy agency (the Norwegian

Seafood Research Fund), and this observation is excluded from the sample to avoid using a singleton explanatory variable which is a dummy variable (i.e. the dummy variable of the specific policy agency). The final sample therefore consists of 89,147 observations in total. There are 15,391 unique enterprises in the final sample of observations.

Due to how each of the four R&D sectors is created, not all sectors are mutually exclusive. However, there are very few observations included in more than one sector. We find that only one observation is included in both the institute sector and the industrial sector. None of the observations in the higher education sector or the health trusts are included in any of the other sectors.

Most of the observations in the final sample concern enterprises included in the industrial sector. The proportion of observations and the number of unique enterprises in each R&D sector are: the higher education sector (2% of the observations, 135 unique enterprises), the institute sector (4% of the observations, 195 unique enterprises), the health trusts (0.5% of the observations, 33 unique enterprises), and the industrial sector (94% of the observations, 15029 unique enterprises). The number of observations by type of aid, policy agency and year in each sector are shown in Table 2. Some explanations to the policy agencies are given in Table 1.

Calculations of the Variance Inflation Factor (VIF) indicate that we have a multicollinearity problem if we use dummy variables for both the policy agencies Innovation Norway and Siva in the regressions.[2] Therefore, Innovation Norway and Siva are merged into a separate category of policy agencies in each of the R&D sectors in the analysis.

The dependent variable used in the regressions is the log of the amount of support received by enterprises, while the explanatory variables are type of aid, policy

Table 1. Explanations to the policy agencies.

Policy agency	Explanation
EUs FP7 (2007–2013) and H2020 (2014–2020)	Funding programmes created by the EU/EC to support and foster research in the European Research Area
Export Credit Norway	Offers Norwegian and foreign firms financing when buying products from Norwegian exporters
Enova	Supports projects that reduce greenhouse gas emissions and develop new energy and climate technology
The Norwegian Seafood Research Fund	Contributes to R&D funding in the Norwegian seafood industry
The Norwegian Export Credit Guarantee Agency	Provides long-term guarantees in order to encourage Norwegian participation in international trade and exports
Innovation Norway	Supports firms in developing their competitive advantage and to enhance innovation
Siva	Invests in incubators, science parks, industrial parks and real estate through partial ownership of other firms
Investinor	Offers venture capital to internationally oriented competitive firms, primarily start-ups
The Research Council of Norway	Responsible for promoting basic and applied research and innovation
The Norwegian Space Agency	Responsible for organising Norwegian space activities, and for coordinating national space activities
Regional research funds	Grant scheme that aims to strengthen a region's research capacity through grants for research and innovation, and through mobilisation for increased R&D efforts
SkatteFUNN	R&D tax incentive scheme designed to stimulate R&D in Norwegian trade and industry

Export Credit Norway and the Norwegian Export Credit Guarantee Agency were merged into the governmental financial enterprise Export Finance Norway on 1 July 2021.

Table 2. Descriptive statistics by R&D sector.

	Higher education sector	Institute sector	Health trusts	Industrial sector
Type of aid				
Equity investments	0	0	0	229
Loans and guarantees	6	3	0	3084
Network development	103	142	18	12964
Promotion	11	22	0	466
Services	51	37	7	11998
Subsidies	1766	3079	429	54733
Policy agency				
EUs FP7	176	437	44	1424
EUs H2020	59	149	14	620
Export Credit Norway	0	0	0	121
Enova	53	49	131	4261
The Norwegian Seafood Research Fund	50	162	0	196
County municipalities	158	193	9	2924
The Norwegian Export Credit Guarantee Agency	0	0	0	281
Innovation Norway, Siva	262	376	40	36741
Investinor	0	0	0	229
The Research Council of Norway	987	1554	188	7514
The Norwegian Space Agency	15	26	0	61
Regional research funds	150	199	28	976
SkatteFUNN	27	138	0	28126
Year				
2002	61	103	3	425
2003	71	116	3	948
2004	81	131	4	2058
2005	90	139	10	2709
2006	99	138	13	3017
2007	91	142	16	3281
2008	111	161	20	3367
2009	117	188	24	3518
2010	135	209	27	3653
2011	117	212	26	3852
2012	149	250	33	4922
2013	145	233	39	5698
2014	139	253	44	7504
2015	149	269	45	9107
2016	136	272	46	10694
2017	123	235	47	8593
2018	123	232	54	10128
Average number of types of aid	1.3	1.3	1.2	1.5
Average number of policy agencies	2.6	2.7	2.3	1.6
Number of observations	1937	3283	454	83474

agency, year and the key regressors. The key regressors are the number of different types of aid and the number of different policy agencies for an enterprise in a specific year. The dependent variable and the key regressors are continuous, while the other explanatory variables than the key regressors are dummy variables. The following reference categories for the dummy variables are used in the regressions: subsidies as type of aid, the Research Council of Norway as policy agency, and 2009 for the year dummies.

Based on the explanatory variables used in the regressions, calculations of the VIF indicate that we have no serious multicollinearity problem. We have also tested for a non-linear effect of each of the key regressors. This potential effect is tested by including each of these regressors squared as explanatory variables. Due to the multicollinearity problem, we will not use each of the key regressors squared as additional regressors.

3. The econometric approach

3.1. The econometric model

Many enterprises have received different types of aid from different policy agencies in at least one of the years in the period 2000–2018. As we examine how the total amount of public R&D support received by enterprises is related to different support schemes for R&D, we will not use the conventional panel structure of observations on enterprise for multiple time periods, where enterprise is the panel variable (denoted 'panelvar') and year is the time variable (denoted 'timevar'). Instead, the panel variable is created as a group function (the 'group' function in Stata) of enterprise, type of aid (type_of_aid) and policy agency (policy_agency) using the 'egen' command in Stata: 'egen panelvar = group(enterprise type_of_aid policy_agency)'. In the conventional way, the time variable is year. An observation in the data is a unique combination of the panel variable and the time variable, and these two variables are used to declare data to be panel data (i.e. the command 'xtset panelvar timevar').

We use an econometric model with one or more lags of the dependent variable in the analysis. The following equation of the amount of support, where one lag of the dependent variable is included, is assumed for each observation:

$$\ln y_{pt} = \alpha + \delta \ln y_{p,t-1} + \mathbf{x}_{pt}\beta + \mathbf{z}_{pt}\gamma + \varepsilon_{pt} \tag{1}$$

where y_{pt} is the amount of support received by enterprises, $\mathbf{x}_{pt} = (x_{1pt}, x_{2pt})$ is a row vector of the two key regressors, $\mathbf{z}_{pt} = (z_{1pt}, z_{2pt}, \ldots, z_{mpt})$ is a row vector of the other explanatory variables than the key regressors, and ε_{pt} is an error term, for the panel variable p in year t. x_{1pt} is the number of different types of aid, and x_{2pt} is the number of different policy agencies. (α, δ) are coefficients, and $(\beta, \gamma) = (\beta_1, \beta_2, \gamma)$ are column vectors of coefficients. The error term is a compound error term, comprising both a group-specific and an idiosyncratic component.

As explained in Section 3.2, GMM (generalised method of moments) dynamic panel data regression (the 'xtabond2' command in Stata) is used as regression technique, where the potential endogenous key regressors are instrumented with lagged values of the key regressors. Based on Kiviet, Pleus, and Poldermans (2017), the overidentifying restrictions can be tested by the Sargan and Hansen statistics if the number of instruments exceeds the number of explanatory variables. Since some degree of overidentification may have advantages regarding both estimation precision and the opportunity to test model adequacy (Kiviet, Pleus, and Poldermans 2017), we use both one and two period lagged levels of the key regressors as instruments. The use of up to two period lagged levels of these explanatory variables will reduce the number of observations.[3]

Equation (1) can be classified as a static panel data model if $\delta = 0$ (Baltagi 2005). As the panel data covers (almost) two decades, omitted dynamics may cause the static (panel data) model (i.e. Equation (1) for $\delta = 0$) to be incorrectly specified. Based on the static model, we have therefore tested the data for autocorrelation at different lag lengths, where we have used the Cumby-Huizinga general test for autocorrelation in time series (the command 'actest' in Stata) and the Arellano-Bond test for autocorrelation (the command 'abar'). We have also used the Wooldridge test for autocorrelation in panel data models (the command 'xtserial'). Since 'xtabond2' is not supported by the commands 'actest' and 'abar', we use two-step efficient GMM regression (the 'ivreg2' command) as regression technique when performing the Cumby-Huizinga general test and the Arellano-Bond test.[4] The two tests for autocorrelation are performed after the command 'ivreg2 ln$y$ z_1 z_2 … z_m (x_1 $x_2 = x_{1,\mathrm{lag}}$ $x_{1,\mathrm{lag2}}$ $x_{2,\mathrm{lag}}$ $x_{2,\mathrm{lag2}}$), gmm2s cluster-(panelvar) endog(x_1 x_2)', which is equivalent to the command 'xtabond2 ln$y$ z_1 z_2 … z_m x_1 x_2, ivstyle(z_1 z_2 … z_m $x_{1,\mathrm{lag}}$ $x_{1,\mathrm{lag2}}$ $x_{2,\mathrm{lag}}$ $x_{2,\mathrm{lag2}}$, equation(level)) twostep h(1)'. Here $x_{j,\mathrm{lag}}$ denotes the one and $x_{j,\mathrm{lag2}}$ denotes the two period lagged level of x_j ($j = 1,2$). When performing the Wooldridge test, we use the following command: 'xtserial ln$y$ z_1 z_2 … z_m x_1 x_2, output'. The three tests show that the presence of autocorrelation is strongly supported for each R&D sector (even for higher lags for the Cumby-Huizinga general test and the Arellano-Bond test).[5]

Since we find strong support for autocorrelation, the alternative to the static model would be a dynamic specification, that is, a model including one or more lags of the dependent variable. We have tested two dynamic specifications. In the first specification, we include both the one and two period lagged levels of the dependent variable, while only the one period lagged level of this variable is included in the second specification. According to Roodman (2009), we check for serial correlation of order n in levels by looking for correlation of order $n + 1$ in differences. When using the first specification, we find that the Pr > z value for the Arellano-Bond test for AR(2) in first differences is less than 0.05 for the institute and industrial sectors (both z values are negative), while the Pr > z value is greater than 0.10 for the two other sectors and for all sectors when using the second specification. As a result of this, Equation (1) is used as the dynamic specification in the regressions, that is, (1) is the equation to be estimated for each sector.

3.2. The regression technique

We may have an endogeneity problem associated with the key regressors. First, we may have a causality direction in the way that the amount of support received by an enterprise can be affected by these regressors, which will be examined in this article. Second, we may have the opposite causality direction from the amount of support to the key regressors, since an enterprise with aiming to increase its amount of support may try to increase the number of types of aid or policy agencies (or both).

Endogeneity is an econometric issue that leads to inconsistent estimators of the parameters in linear models (Wooldridge 2002, 2013). If we suspect each of the two components in $\mathbf{x}_{pt}$ to be an endogenous variable, we cannot assume that each of these variables is statistically independent of ε_{pt}. However, ε_{pt} is assumed to be statistically independent of each component in $\mathbf{z}_{pt}$.[6]

In order to account for potential endogeneity, we use GMM dynamic panel data regression as regression technique in the analysis. The regression technique is designed for (among other things) situations with a linear functional relationship, a dependent variable that depends on its own past realisations, and regressors that are not strictly exogenous (Roodman 2009).

Let lny_{lag} denote the one period lagged level of ln$y$. Then, the command used in the GMM regressions is as follows: xtabond2 ln$y$ lny_{lag} z_1 z_2 … z_m x_1 x_2, ivstyle(lny_{lag} z_1 z_2 … z_m $x_{1,\mathrm{lag}}$ $x_{1,\mathrm{lag2}}$ $x_{2,\mathrm{lag}}$ $x_{2,\mathrm{lag2}}$, equation(level)) twostep h(1) robust. As can be seen from this command, we use the following specified options: (i) the one period lagged level of the dependent variable, the other explanatory variables than the key regressors and the one and two period lagged levels of the key regressors are standard instruments (the 'ivstyle' option), (ii) the levels equation should use the instruments (the 'equation' option), (iii) the two-step estimator is to be calculated instead of the one-step estimator (the 'twostep' option), (iv) h(1) specifies that the estimate of the covariance matrix of the idiosyncratic errors is equal to the identity matrix, and (v) twostep robust requests Windmeijer's finite-sample correction for the two-step covariance matrix (Windmeijer 2005).

4. Descriptive statistics

Table 2 shows that the number of observations has been much higher in the industrial sector than in the other R&D sectors in each year of the observation period, and the difference is larger towards the end of this period than at the beginning. The number has also been higher in the institute sector than in the higher education sector, and higher in the higher education sector than in the health trusts, in each year of the period. We see from the table that the number of observations has tended to increase over time in the institute and industrial sectors until 2016. While the number has declined in the last two years of the observation period in the institute sector, there has been a decrease from 2016 to 2017 and an increase from 2017 to 2018 in the industrial sector. In the higher education sector, there has been an upward trend in the number until 2012, a decrease from 2012 to 2014 and an increase from 2014 to 2015, and a downward trend in the period from 2015 to 2018. The number of observations has been relatively low each year in the health trusts, but there has been an upward trend in the number throughout the observation period.

In each of the R&D sectors other than the industrial sector, most of the observations concern subsidies as type of aid. The proportion of subsidies (i.e. the number of observations concerning subsidies in per cent of the total number of observations) is 91% in the higher education sector, and 94% in the institute sector and the health trusts. This proportion is much lower in the industrial sector (66%). Some of the observations in the higher education sector, the institute sector and the health trusts concern network development (4–5%) and services (1–3%), but the proportions of these types of aid are much higher in the industrial sector (16% and 14%, respectively).

About half of the observations in the higher education sector (51%) and the institute sector (47%) concern the Research Council of Norway as policy agency, while this proportion is somewhat lower in the health trusts (41%) and significantly lower in the industrial sector (9%). In the higher education sector, the institute sector and the health trusts, not insignificant proportions of the observations concern Innovation Norway/Siva and EUs FP7 as policy agencies. About three tenths of the observations in the health trusts (29%) concern Enova as policy agency. Most of the observations in the industrial sector concern Innovation Norway/Siva (44%) and SkatteFUNN (34%) as policy agencies.

There are small differences in the average number of types of aid between the four R&D sectors. This average number is highest in the industrial sector, and lowest in the health trusts. The average number of policy agencies is significantly lower in the

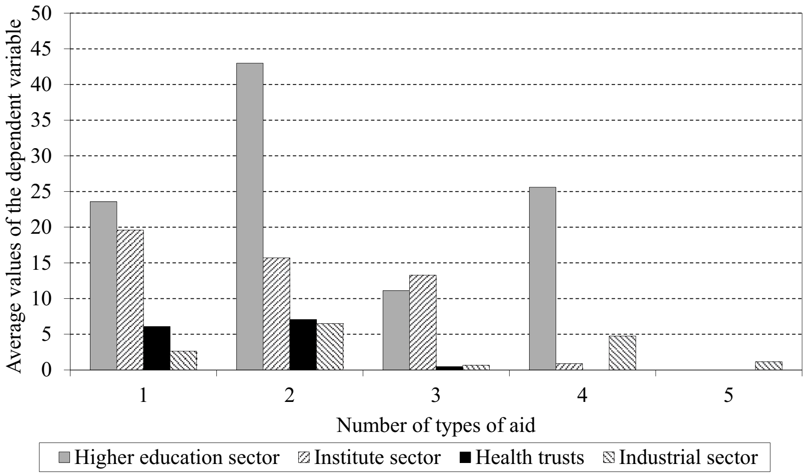

Figure 1. The average values of the dependent variable (the log of the amount of support) by R&D sector and the number of types of aid. Notes: 1) The log of the amount of support received by enterprises is used as the dependent variable. 2) The average values of the dependent variable are measured in million NOK (constant prices in 2017) in the figure.

industrial sector than in the other three sectors, and the highest average number is found in the institute sector.

Furthermore, we see from Figure 1 that the average amount of support received by enterprises is not a monotonically increasing or decreasing function of the number of types of aid in the higher education sector, the health trusts or the industrial sector. In the institute sector, the average amount of support is a decreasing function of this number. Figure 2 shows that the average amount is not a monotonically increasing or decreasing function of the number of policy agencies in any of the sectors, but there is an upward trend in the average amount in the institute sector.

5. The estimation results

Table 3 shows the estimated relations between the dependent variable and explanatory variables in each of the R&D sectors, where the log of the amount of support received by enterprises is the dependent variable. The estimated results in the table are based on the regression technique described in Section 3.2. The dummy variable for the policy agency Investinor is omitted by Stata in the regression in the industrial sector. Due to space limitations, the results from the relations between the dependent variable and the year dummies are not shown in the table.

5.1. The key regressors

We see from Table 3 that the estimates of the number of policy agencies, which is one of the key regressors, are not very sensitive with respect to type of R&D sector. Based on the econometric model, the amount of support received by enterprises is found to be

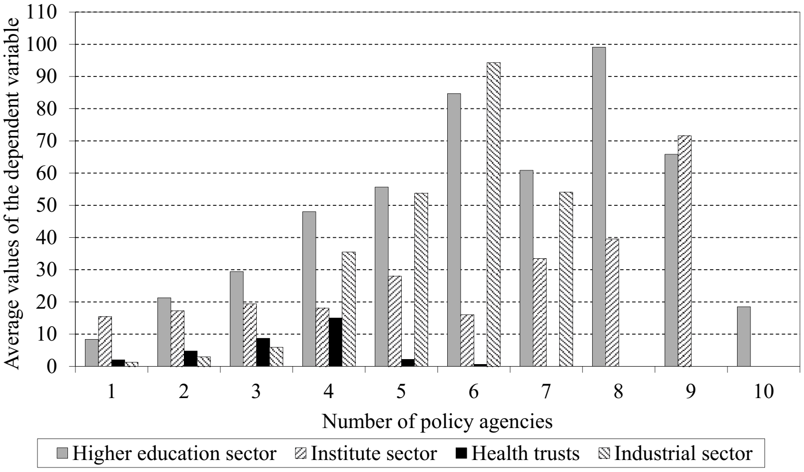

Figure 2. The average values of the dependent variable (the log of the amount of support) by R&D sector and the number of policy agencies. Notes: 1) The log of the amount of support received by enterprises is used as the dependent variable. 2) The average values of the dependent variable are measured in million NOK (constant prices in 2017) in the figure.

positively related to the number of policy agencies in all sectors, i.e. we have the same qualitative result in each sector.

If we instead use the number of types of aid as key regressor, the estimates are highly sensitive with respect to type of R&D sector. In the regressions, the amount of support is positively related to the number of types of aid in the industrial sector, while the estimated relations are not significant in the other three sectors (even at the 10% level).

These results indicate that the amount of public R&D support increases in the industrial sector if the number of types of aid increases, while the estimated relation is not found significant in the higher education sector, the institute sector and the health trusts. The results also indicate that the amount increases in all R&D sectors if the number of policy agencies increases.

In order to increase the amount of public R&D support, enterprises should therefore try to combine support schemes from several different policy agencies, *ceteris paribus*. The amount of support to enterprises in the industrial sector will also increase by combining schemes from several different types of aid, while the amount does not seem to be related to the number of types of aid among enterprises in the other three sectors (*ceteris paribus*). The estimation results are to a small extent in line with the descriptive statistics, in the sense that the (observed) average amount of support is not found to be a monotonically increasing or decreasing function of the number of types of aid or policy agencies in most of the four R&D sectors.

The question then is whether these estimated effects are economically substantial, and if so, whether there are short-term or longer-term substantial effects? It follows from the econometric model in Section 3.1 that the partial derivative of the estimated value of the log of the amount of support in year t with respect to one of the key regressors in the same year is equal to the estimated coefficient of the key regressor, $\partial\widehat{\ln y_{pt}}/\partial x_{jpt} = \widehat{\beta}_j$

Table 3. Estimated effects of explanatory variables on the dependent variable (the log of the amount of support) in each R&D sector, GMM dynamic panel data regressions.

	Higher education sector			Institute sector		
Explanatory variables	Coef.		SE	Coef.		SE
Dependent variable						
One period lagged level	0.584	***	0.057	0.546	***	0.042
Type of aid						
Loans and guarantees	2.885	***	0.293	2.115	***	0.329
Network development	−0.838		0.573	−0.951	**	0.464
Promotion	−2.121	**	0.941	−0.913		0.577
Services	−0.234		0.693	−1.705	***	0.660
Policy agency						
EUs FP7	−0.955	**	0.391	−2.057	***	0.162
EUs H2020	−0.698		0.465	−2.065	***	0.202
Enova	−2.325	***	0.515	−4.106	***	0.417
The Norwegian Seafood Research Fund	−2.422	***	0.592	−1.866	***	0.293
County municipalities	−1.661	***	0.532	−2.488	***	0.347
Innovation Norway, Siva	−2.383	***	0.301	−2.717	***	0.188
The Norwegian Space Agency	−3.559	***	0.853	−3.836	***	0.445
Regional research funds	−1.560	***	0.370	−2.858	***	0.239
SkatteFUNN	−0.513	**	0.245	−2.481	***	0.260
Number of types of aid	0.486		0.303	−0.169		0.164
Number of policy agencies	0.275	**	0.113	0.430	***	0.061
Constant	2.299	***	0.573	4.045	***	0.446
Wald chi2			432.330			1230.810
Prob > chi2			0.000			0.000
Arellano-Bond test						
AR(1)			0.000			0.000
AR(2)			0.913			0.427
Sargan test			0.000			0.012
Hansen test			0.000			0.008
Number of instruments			35			35
Number of groups			346			576
Number of observations			1937			3283
Dependent variable						
One period lagged level	0.608	***	0.073	0.419	***	0.007
Type of aid						
Equity investments				1.398	***	0.131
Loans and guarantees				1.545	***	0.034
Network development	−1.607		1.302	−3.005	***	0.042
Promotion				−1.266	***	0.114
Services	−1.984	***	0.715	−1.979	***	0.034
Policy agency						
EUs FP7	−1.672	***	0.458	−0.470	***	0.062
EUs H2020	−1.071	**	0.515	0.052		0.074
Export Credit Norway				2.270	***	0.240
Enova	-1.055	***	0.262	−0.304	***	0.048
The Norwegian Seafood Research Fund				−0.129		0.120
County municipalities	0.704		1.458	0.069		0.071
The Norwegian Export Credit Guarantee Agency				1.450	***	0.223
Innovation Norway, Siva	−1.249	***	0.403	−0.430	***	0.031
Investinor						Omitted
The Norwegian Space Agency				0.015		0.129
Regional research funds	-1.693	***	0.494	−0.479	***	0.051
SkatteFUNN				−0.164	***	0.028
Number of types of aid	−0.347		0.377	0.228	***	0.031
Number of policy agencies	0.429	***	0.146	0.100	***	0.019
Constant	3.432	***	0.700	3.597	***	0.063
Wald chi2			4832.330			200606.470
Prob > chi2			0.000			0.000
Arellano-Bond test						

(*Continued*)

Table 3. (Continued).

	Higher education sector		Institute sector	
Explanatory variables	Coef.	SE	Coef.	SE
AR(1)		0.002		0.000
AR(2)		0.980		0.370
Sargan test		0.507		0.000
Hansen test		0.429		0.000
Number of instruments		30		38
Number of groups		99		30969
Number of observations		454		83474

$(j = 1, 2)$. Approximately, the estimated coefficient of one of the key regressor can be interpreted as the increase in the estimated value of the log of the amount of support by a unit increase in the key regressor.

The estimated coefficient of one of the key regressors can be considered as the short-term effect on the estimated value of the log of the amount of support by a marginal change in the key regressor. Table 3 shows that the estimated coefficient of the number of different policy agencies is higher in the institute sector and the health trusts than in the higher education sector, and higher in the higher education sector than in the industrial sector. Based on the number of different policy agencies, we find that the estimated short-term effect is equal to 0.430 in the institute sector, 0.429 in the health trusts, 0.275 in the higher education sector, and 0.100 in the industrial sector. However, the estimated short-term effect of the number of different types of aid is higher than the corresponding effect of the other key regressor in the industrial sector, since the former effect is 0.228 in this sector.

We can interpret the estimated coefficient of the number of different policy agencies as approximately the percentage increase in the estimated value of the amount of support by a unit increase in this key regressor. This can be seen as follows: If x_{jpt} increases by one unit, $x_{jpt}= 1$, it follows that

$$\Delta \ln y_{pt} = \ln y_{1pt} - \ln y_{0pt} = \ln\left(\frac{y_{1pt}}{y_{0pt}}\right) = \ln\left(\frac{\Delta y_{pt} + y_{0pt}}{y_{0pt}}\right) = \ln\left(\frac{\Delta y_{pt}}{y_{0pt}} + 1\right) \approx \frac{\Delta y_{pt}}{y_{0pt}}.$$

Here $\Delta y_{pt}/y_{0pt}$ is the percentage change in the amount of support. In the last step, we used that $\ln(k+1) \approx k$ for small values of k. Since $\Delta \ln y_{pt} = \widehat{\beta}_j \Delta x_{jpt} = \widehat{\beta}_j$, a unit increase in x_{jpt} can be associated with approximately a $100\widehat{\beta}_j$ percentage increase in y_{pt} $(j = 1, 2)$. As an approximation, an increase in the number of different policy agencies by one unit can therefore be associated with an increase in the estimated value of the amount of support of 43% in the institute sector and the health trusts, 28% in the higher education sector, and 10% in the industrial sector. A corresponding increase in the number of different types of aid can be associated with (approximately) an increase in the estimated value of the amount of 23% in the industrial sector.

The estimated longer-term effect consists of the estimated short-term effect, as well as that the amount of support in year t may affect the estimated value of the log of the amount in year $t + 1$. Based on the econometric model, the partial derivative of the estimated value of the log of the amount of support in year $t+1$ with respect to the amount in year t is equal to the estimated coefficient of the log of the amount of support divided by the amount in year t, $\ln y_{pt} = \widehat{\beta}_j x_{jpt} = \widehat{\beta}_j$. We see from Table 3 that the estimated coefficient of the one period lagged level of the dependent variable is positive in each R&D sector (see Section 5.2), and highest in the health trusts and lowest in the industrial sector. This means that the estimated longer term effect is higher than the estimated short-term effect in each sector, but that the difference between the effects becomes smaller when the amount of support in year t increases.

If the amount of support in year t increases by q per cent, $\Delta y_{pt}/y_{0pt} = (y_{1pt} - y_{0pt})/y_{0pt} = q$, then we can interpret the estimated coefficient of the log of the amount of support multiplied by q as approximately the percentage increase in the estimated value of the amount of support in year $t+1$ by this percentage increase in the amount of support in year t. The reason for this is that

$$\Delta \ln y_{p,t+1} = \delta \Delta \ln y_{pt} \approx \delta \frac{\Delta y_{pt}}{y_{0pt}} = \delta q,$$

where $\Delta \ln y_{p,t+1} \approx \Delta y_{p,t+1}/y_{0p,t+1}$. We see that an increase in y_{pt} of q per cent can be associated with approximately a $100\hat{\delta}q$ percentage increase in $y_{p,t+1}$. For example, an increase in the amount of support in year t by 10% can therefore be associated with approximately an increase in the estimated value of the amount of support in year $t+1$ of 6% in the higher education sector and the health trusts, 5% in the institute sector, and 4% in the industrial sector. Thus, the effects of the key regressors on the estimated value of the amount of support can be economically substantial in the same year, but also substantial in the following years due to the dynamic specification.

5.2. *Other explanatory variables than the key regressors*

Table 3 shows that the amount of support received by enterprises in each of the R&D sectors increases with increasing one period lagged level of the amount. Thus, enterprises with a high one period lagged level of the amount of support have a higher amount in the current year than enterprises with a lower one period lagged level, *ceteris paribus* (see Section 5.1). The dynamic specification was introduced since the panel data strongly support the presence of autocorrelation.

The result for the industrial sector is to some extent in line with the study by Antonelli and Crespi (2013). They explore the causes and effects of persistence in the discretionary allocation of public subsidies to R&D activities, where such activities are performed by private firms. Their empirical results show that past grants increase the probability to access further funding.

The amount of support in the institute and industrial sectors is higher if enterprises receive subsidies (the reference category) instead of network development or services, but lower if they receive subsidies instead of loans and guarantees. In the higher education sector, the amount is positively related to loans and guarantees, negatively related to promotion, and not significantly related to network development and services.

We also find that the amount of support in the industrial sector is lower if enterprises receive subsidies instead of equity investments, but higher if they instead receive promotion. In the health trusts, the amount is higher if enterprises receive subsidies instead of services. The amount of support is not significantly related to network development in the health trusts and promotion in the institute sector.

When focusing on policy agencies, we see from the table that the amount in the higher education sector, the institute sector and the health trusts is higher if enterprises receive support from the Research Council of Norway (the reference category) instead of support from another policy agency. The only exception is that the amount is not significantly related to EUs H2020 in the higher education sector and county municipalities in the health trusts (at the 10% level).

Finally, in the industrial sector, the amount is higher if enterprises receive support from Export Credit Norway or the Norwegian Export Credit Guarantee Agency instead of support from the Research Council of Norway. The amount is lower if they instead receive support from many of the other policy agencies (than from the reference category), but the amount is not significantly related to EUs H2020, the Norwegian Seafood Research Fund, county municipalities and the Norwegian Space Agency (10% level).

6. Conclusions

We have examined whether the amount of public R&D support to enterprises in each of the R&D sectors increases or decreases with the number of types of aid and policy agencies. The four R&D sectors are the higher education sector, the institute sector, the health trusts, and the industrial sector. We use panel register data of Norwegian enterprises for the period 2000–2018. A regression technique (GMM) that account for potential endogeneity is used in the analysis.

The estimation results indicate that the amount of public R&D support increases with the number of policy agencies in all four R&D sectors. The results also indicate that this amount increases with the number of types of aid in the industrial sector, while there is a non-significant relationship between the amount of support and the number of types of aid in the other three sectors (the higher education sector, the institute sector and the health trusts).

Enterprises with the strategy of increasing the amount of public R&D support should therefore try to increase the number of policy agencies for a given number of types of aid. Alternatively, they should try to increase the number of types of aid for a given number of policy agencies, but only for enterprises included in the industrial sector. In short, enterprises included in this sector should combine support schemes from several different types of aid or from several different policy agencies (or both) to increase the amount.

Although we find a positive relationship between the amount and the number of types of aid in the industrial sector, the results in the study by Dumont (2017) indicate that the combination of different measures decreases the effectiveness of public support. It follows from his analysis that programme managers who aim to stimulate business R&D should provide R&D support to firms with a limited number of different support schemes for R&D rather than firms with several different schemes.

There is at least one limitation to this study that we will emphasise. This limitation is that we have to a small extent accounted for firm characteristics when examining how the amount of public R&D support to enterprises in the R&D sectors is related to the number of types of aid and policy agencies. Some studies find, for example, that small firms are more likely to obtain an R&D subsidy than large firms (Busom 2000), and small and medium-sized enterprises (SMEs) use the R&D tax credit programme less than large firms (Labeaga, Martínez-ros, and Mohnen 2014). Other studies find that diversified and commercially successful firms are more likely to use R&D tax incentives, while those with high productivity are more likely to obtain R&D subsidies (Busom, Corchuelo, and Martínez-Ros 2015). Therefore, the amount of public R&D support can be related to such firm characteristics (as, for example, firm size). There is thus a need for further evidence of how the amount of public support to firms in different R&D sectors is related to different support schemes.

As mentioned in Section 3.1, the error term comprises not only an idiosyncratic component, but also a group-specific component. To a certain extent, this would provide at least some control for firm-specific but unobservable influences that do not change (much) over the observation period.

Notes

1. The survey by Zúñiga-vicente et al. (2014) examines the empirical literature on the relationship between public R&D subsidies and private R&D investment over the past five decades.
2. All calculations of the VIF are based on OLS, where we do not account for potential endogeneity.
3. We will not use three period lagged levels (or higher lags) of the key regressors as instruments, as this will further reduce the number of observations.
4. The ‘q0’ option is used when applying the Cumby-Huizinga general test, which specifies that tests of autocorrelation at specific lag orders are to be conducted under the null hypothesis of no autocorrelation at any lag order.
5. The Cumby-Huizinga general test shows strong support for autocorrelation for lag orders up to nine for all R&D sectors (all p values are less than or equal to 0.05). When performing the Arellano-Bond test, we find strong support for autocorrelation for lag orders up to seven for all sectors (all z values are at least 1.96). The Wooldridge test shows that the null hypothesis of no first-order autocorrelation is strongly rejected ($\text{Prob} > F = 0.000$) for each sector.
6. This is not obvious as the key regressors are computed on the basis of the other explanatory variables (than the key regressors and the year variable). We assume, however, that an enterprise that aims to increase its amount of support will primarily try to increase the number of types of aid or policy agencies, and to a lesser extent be concerned with the composition of the support in terms of different types of aid or policy agencies.

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