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EVALUATING THE IMPACT OF RESEARCH AND DEVELOPMENT POLICIES: THE CASE OF NORWAY

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I. ABSTRACT

Questa tesi analizza gli effetti dei crediti d'imposta e dei sussidi pubblici di R&S sulle imprese norvegesi nel periodo 2012-2014: il dataset è fornito dal CIS e comprende dati su 5045 aziende norvegesi, di cui 670 hanno ricevuto contributi in R&S dal governo nel periodo di riferimento. Utilizzando il Propensity Score Matching (PSM) e analizzando gli effetti medi del trattamento sui trattati (ATT), dimostriamo che gli incentivi pubblici in R&S possono aver aumentato la spesa in R&S delle aziende e contribuito alla creazione di nuovi prodotti e servizi, molti dei quali nuovi per il mercato. Troviamo, quindi, evidenze statisticamente significative di effetti di addizionalità sia negli input che negli output.

This thesis analyses the effects of public R&D tax credits and subsidies on Norwegian firms in the period 2012-2014: the dataset is provided by CIS and comprises data about 5045 Norwegian companies, among which 670 received R&D grants by the government in the reference period. Using the Propensity Score Matching (PSM) and analysing the Average Treatment Effects on the Treated (ATTs), we show that public R&D incentives may have enhanced companies' R&D expenditure and contributed to the creation of new products and services, most of them new to the market. Therefore, we find statistically significant evidence of both input and output additionality effects.

Key words: *R&D, Policy evaluation, Norway*

II. INDEX

1. INTRODUCTION

Research and Development and technological change have become widely used as sources of firm competitiveness. However, private investment in R&D seems to suffer from market failures that emerge in knowledge generation activities, such that the socially optimal investment level is larger than the level of private investment because of the presence of positive externalities. Furthermore, R&D projects comprise a technological risk which makes their return more uncertain than other types of investment: to that extent, large firms are less damaged than SMEs since they can spread the technological risk across a larger project portfolio. Another important impediment to research investment is represented by the limited access to external finance that companies which perform R&D activities have to face, with the consequence of relying to their own resources to undertake innovative projects. Credit constraints to Research and Development derive from information asymmetries between money lenders and firms, which causes high monitoring costs. In addition, R&D activities are not tangible, thus this type of investment is difficult to be collateralised.

For all these reasons, R&D tax incentives see their popularity increasing nowadays, especially in the OECD area: as a matter of fact, more than 20 OECD countries currently support private R&D investments through R&D tax credits and public subsidies.

Nevertheless, the capacity of fiscal measures provided by the public sector to stimulate R&D activities performed by firms is still to assess, particularly in relation to specific market conditions as the financial turmoil of 2008-2009: in this regard, some studies proved that, during the Great Recession of the last decade, R&D subsidies helped European manufacturing firms to keep their R&D intensity level stable, even though it did not rise. Finally, it is also questioned if the effects of public-sector R&D programs may change with respect to the features of recipient firms, in particular with the firms' size and sector.

The study provided in this thesis focuses on the effects of a public-sector R&D program on Norwegian firms: it is based on CIS data referring to the period between 2012 and 2014. We calculate the propensity scores (defining the probability of being offered R&D tax credits or subsidies by Norwegian government) through a Probit regression. Then, using the Propensity Score Matching (PSM), we match each company which received public support with a firm belonging to the control group with similar characteristics. Through the computation and the analysis of the Average Treatment Effects on the Treated (ATT), we try to capture additionality effects generated by the granting of R&D incentives.

As far as the structure of the thesis is concerned, Chapter 2 provides the theoretical background and a literature review on RRD policies' evaluation. Chapter 3 focuses on the history and the types of activity of R&D in Norway and on Norwegian policies to supporting R&D. Finally, the empirical analysis is performed in Chapter 4.

2. LITERATURE REVIEW ON R&D POLICIES

The main goal of this chapter is to provide a comprehensive theoretical background which can explain the elements involved in the empirical analysis performed in Chapter 4: the first paragraph focuses on Research and Development's definition and types of activity, its historical background and measurement techniques. The second paragraph addresses the issue of the evaluation of public R&D policies, while par. 2.3 comprises a description of input and output additionality effects, including how they are defined and why they should be considered in a policy analysis. Finally, the last paragraph describes the nature and the use of tax credits and public subsidies, also referring to previous literature to see if their application has been successful.

2.1 RESEARCH AND DEVELOPMENT

According to OECD (2015, p.4), "Research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge".

Research and Development activities are characterised by (at least) five criteria which have to be jointly satisfied: being aimed at new findings, being creative (based on original ideas), having an uncertain final outcome, being systematic (being budgeted and based on a plan), being reproducible and/or transferable.

An in-depth analysis about the types of R&D activity, Research and Development estimation techniques and the R&D historical background are provided below.

2.1.1 Types of R&D activity

The OECD (2015) describes the three types of research and development: basic research, applied research and experimental development.

Basic research is a type of research approach that is aimed at gaining a better understanding of a subject, phenomenon or basic law of nature: it is primarily focused on the advancement of knowledge rather than solving a specific problem. Basic research is also referred to as pure or fundamental research. Its concept emerged between the late 19th century and early 20th century in an attempt to bridge the gaps existing in the societal utility of science. Typically, basic research can be exploratory, descriptive or explanatory; although in many cases, it is explanatory in nature. The primary aim of this research approach is to gather information in order to improve one's understanding, and this information can then be useful in offering solutions to a problem; it analyses properties, structures and relationships with a view to formulating and testing hypotheses, theories or laws. The results of basic research are not generally sold but are usually published in scientific journals: it can be oriented or directed towards some broad fields of general interest, with the explicit goal of a range of future applications.

Applied research is original investigation undertaken in order to acquire new knowledge regarding a specific, practical aim or objective: it involves considering the available knowledge and its extension in order to solve actual problems. In the business sector, the distinction between basic and applied research is often marked by the creation of a new project to explore promising results of a basic research programme: the results of applied research are intended primarily to be valid for possible applications to products, operations, methods or systems; applied research gives operational form to ideas.

Experimental development is systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing or to improving existing goods, services or production processes (OECD, 2015).

Press (2013) states that companies belonging to the private sector tend to invest in experimental development, which is considered much more useful in economic terms since it usually consists of an implement of innovative ideas that have already been created and, maybe, patented. On the contrary, basic research can be considered as a public good: huge discoveries made in every single part of the world quickly fall in the hands of the public dominion, basically behaving differently from the corporations' mindset of keeping the mouths shut about innovative products, services or processes in order to gain a comparative advantage against competitors. That is why investment for basic research is provided by governments, that designate universities and public or private research institutes to enlarge the borders of human knowledge; on the other side, companies are less keen in sharing what their R&D departments have brought to light. The most dangerous risk, however, is that even public authorities could redirect their innovation funds to other parts of their budget in order to ensure welfare during periods of economic crisis or to take care of domestic specific issues: in this way, every nation tries to benefit from other countries' discoveries without having to sacrifice its own monetary resources. This type of free-riding attitude is known as the "tragedy of the commons": stating that basic research is a common, in a shared-resource system it is a situation where individual users, acting independently according to their own self-interest, behave contrary to the common good of all users by depleting or spoiling the shared resource through their collective action. Therefore, not only the scarce level of basic research's appropriability could undermine the possibility for developing and less-developed countries to exploit innovative discoveries and use them to perform a catching-up with respect to advanced economies, but it could also slow the worldwide process of technological progress down. Every single nation's GDP is subjected to an exponential growth that started with the Industrial Revolution and is still happening, boosted by several factors among which we can spot research and development. It is not a novelty that the unexplained part of economic growth, called the Solow Residual (Solow, 1957; Hall, 1989), could be -in fact- represented by technological progress: technology cannot be considered as a proper form of capital, but it is capable of generating a positive feedback. In terms of production, it increases wealth and generates more technological progress, enabling a virtuous cycle of exponential growth. Obviously, one investing in basic research cannot be sure about discovering an astonishing innovation; however, the key to succeed in that purpose apparently stands in a type of investment that is constant and set in a long-term perspective: the conventional threshold for a country to perform a successful R&D strategy is to allocate, in a persistent way over time, a significant share of its GDP to basic research. That is because the possibility of making a breakthrough follows a heavy-tailed distribution, in which extremely large events are only a bit rarer than mid-sized events; that is, the opposite of the well-known normal distribution, where very large events are so exponentially improbable that they never occur (Press, 2013).

2.1.2 Historical background

The term Research and Development, as we conceive it today, was introduced after World War II. Before that time the only type of research that was extensively considered was basic research: the latter was officially introduced by Cattell (1906), who used the terms "research" instead of "investigation" or "inquiry" and who referred to researchers as a job category. From that moment onward, basic and applied research were discussed in dichotomic terms, splitting the public opinion between the faction that considered basic research as the engine of progress and the group that saw it as an unproductive expense: so, if on one side the U.S. President Hoover defined basic research as “the soil of civilisation” (Woldegiorgis and Scherer, 2019, pp.64), Smith (the director of the US Bureau of Budget in the 1950s) suggested that a program for funding basic research should have been renamed “Science: The Endless Expenditure” (Godin, 2003).

At this point it would have been logical to distinguish between measures of research activity and measures of development activity. However, officials coined the acronym R&D (Research and Development) and kept on measuring the combination of the two activities, starting with the report from the President’s Scientific and Research Board in 1947 (Godin and Lane, n.d.). Two explanations were provided in order to explain the creation of this acronym. The first one suggests that the reason might involve accounting matters: the two activities were claimed to be interrelated, so firms did not have detailed accounting practices for separating the two and, thus, government agencies could not differentiate them for statistical purposes. A similar argument was brought up for setting boundaries between development and production activities: this particular claim was based on the tax code’s distinction between corporate expenditures for generating knowledge (research) versus expenditures for generating products (development) (Godin, 2003). According to the authors, the other reason could be political: as a matter of fact, merging these two activities had the effect of increasing the volume of expenditures devoted to research. Therefore, it might have helped candidates looking for symbolic and popular support for public funding of research activity.

2.1.3 Measuring R&D

For the analysis of R&D investment, Becker (2015) illustrates a panel data model based on the following equation:

$$r_{it} = \gamma' X_{it} + f_{it} + \varepsilon_{it}$$

where "r" stands for the total R&D expenditure (usually expressed in absolute values), "i" represents the cross-section units (in our case, a company or an industry), while "t" indexes the units of time (usually years); X denotes the vector of explanatory variables which can influence the level of R&D investment (being the dependent variable) and ε is the error term. Unobserved heterogeneity between the cross-section units (if this is additive and stable over time) can be controlled through to the introduction of fixed effects in the equation: thus, fixed effects are represented by "f"; in addition, some studies captured common technology shocks and other time-variant common effects by including time dummies in the formula (Becker, 2015).

Many studies have stressed that R&D investment should be considered in a dynamic framework: since R&D usually behaves as it had high adjustment costs, firms tend to smooth R&D investment over time (Hall et al., 1986; Lach and

Schankerman, 1989). Thus, most studies included a lagged variable in the overmentioned R&D investment equation:

$$r_{it} = \rho r_{i,t-1} + \gamma' X_{it} + f_{it} + \varepsilon_{it}$$

According to Nickell (1981), the inclusion of a lagged R&D variable needs the use of an estimator to avoid the downward bias, which might result when using a fixed effects estimator in the cases in which the reference time period is short: one of the most common estimators used in the R&D panel data literature is the first-differences generalised methods of moments (GMM) estimator (Anderson and Hsiao, 1982; Arellano and Bond, 1991). The first-differencing transformation removes the individual fixed effects from the model. However, this estimator may be subject to large finite sample bias in cases where the instruments available have weak predictive power: this happens, particularly, when a time series is remarkably persistent (as in the case of R&D) because lags will be unprecise predictors of future outcomes (Becker, 2015). Anyway, an efficient estimation of the GMM can be accomplished also in the case of highly persistent time series by using the systems approach developed by Blundell and Bond (1998)[1].

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[1] Blundell and Bond (1998) discussed the importance of exploiting initial condition information in generating efficient estimators for dynamic panel data models where the number of time-series observations is small: they focused on the individual effects autoregressive model, even though their results can be extended to dynamic models with regressors. They considered two estimators that could improve the precision of the standard first-differenced GMM estimator for the considered issue: one approach imposed an additional restriction on the initial conditions process, under which all the moment conditions available could be exploited by a linear GMM estimator in a system of first-differenced and levels equations; the second approach conditioned on the observed initial values to obtain a system that, under certain conditions, could be estimated consistently by error

The panel data model can be manipulated in order to measure the impact of tax credits or public subsidies on the Research and Development incentive equation. In the case of tax credits, a method could be including tax credits as a dummy variable equal to one if a credit is granted and zero otherwise: it is a straightforward technique, but its disadvantages include a significant level of imprecision (i.e., several firms may face different credit levels and, if it varies over time, that it is not separately identifiable from a time dummy); a more reliable method comprises a price variable (as an example, the user cost of R&D) that captures the marginal cost of R&D, through which the estimated R&D response is converted to a price elasticity (Becker, 2015).

As for public R&D subsidies, they usually are measured as a dummy variable or by their financial amount. More recently, subsidy effects have increasingly been studied through treatment effects analyses comparing "treated" firms (subsidy-receiving) and "untreated" firms (those companies which didn't receive public grants, being included in the control group).

components GLS. The authors proved that both can improve dramatically on the performance of the usual first-differenced GMM estimator when the autoregressive parameter is moderately high and the number of time-series observations is moderately small.

2.2 EVALUATION OF PUBLIC R&D POLICIES

2.2.1 Counterfactual and spillover methodologies

Several attempts to evaluate the impact of public R&D grants on Research and Development performance of the recipients has been made. Link and Scott (2019) referred to two methods already exposed by previous literature: counterfactual and spillover methodology.

Starting from the concept of a counterfactual analysis[2], Griliches (1958) hypothesized a counterfactual situation in which the pre-existent technology of a recipient firm (defined as status quo technology) is opposed to the granting of public R&D investments and to the subsequent new technology. However, Link and Scott (1998, 2011) depicted a different counterfactual scenario in which companies would try to replace with their own assets the resources granted by public investments and the new technology produced by the latter. Assuming a total private substitution of public R&D investment, Link and Scott (1998) suggested to focus the counterfactual analysis on what and how much the private sector has to invest to achieve the same benefits granted by public R&D investments; in the case in which markets failures and barriers to technology (see Link and Scott, 2019) prevent the private sector from replacing the public R&D output with a perfectly

[2] In the counterfactual analysis, the outcomes of the intervention are compared with the outcomes that would have been achieved if the intervention had not been implemented: this method allows to identify which part of the observed actual improvement is attributable to the impact of the intervention.

equal level of private R&D output, the authors proposed to base the counterfactual analysis on how much the private sector have invested to replace public R&D investments and what is the loss of value in quality terms deriving from the private sector's replacement of R&D output (Link and Scott, 2019).

The results of the counterfactual analysis represent the benefits of public R&D investments, also defined as the costs avoided by the private sector: these results are useful to determine the benefit-to-cost ratios[3], whose aim is to assess if public R&D investment is a more efficient way to generate new technology than private R&D investments (Link and Scott, 2019).

Tassey (1997) and, later, Link and Scott (2011), developed a further technique to assess the impact of public R&D investment on the recipients: they referred to it as the "spillover economic impact analysis methodology", being an interview-based, multiple-equation method for the identification of social and private rates of return for public and private R&D. This methodology seems to be appropriate for the evaluation of publicly funded or privately performed research because the R&D output is only partially appropriable by private firms, while the rest spills over to society (Link and Scott, 2011).The determination of whether or not the public sector should fund R&D is linked to the assessment of a hurdle rate[4], estimating to what

[3] See Link and Scott (2019), pp. 23.

[4] A hurdle rate is the minimum rate of return required on a project or investment to be considered worthy of being funded.

extent the knowledge spillover (with public good features) has influenced the rate of returns of private sector [5].

2.2.2 Econometric models and other evaluation techniques

Polt and Rojo (2002) suggested other techniques to evaluate the economic impact of public-sector R&D programs, including econometric models, benchmarking analysis, innovation surveys, expert panels and peer reviews.

As far as econometric models concern, Link and Scott (2019) showed two examples of how econometric estimators are used to measure performance variables regarding public R&D incentives. In the first case, the authors showed the data before and after public R&D grants, in order to compare the performance of the public-sector R&D program. The correspondent econometric model is:

$$P_{i,t} = a_0 + a_1 \, RD_{t*} + \text{control variables} + \varepsilon$$

where $P_{i,t}$ stands for the relevant performance variable of the i_{th} firm (with "i" representing cross-sectional units) at time t, ε is a normally distributed random error term and RD represents public R&D grants becoming effective at time t*: therefore, RD will be equal to 0 for the time period before t* and equal to 1 after t* (Link and Scott, 2019). The authors reported that if a_1 is positive and statistically significant,

[5] For more details see Link and Scott (2019), pp. 6-7.

then the public-sector R&D program has a positive impact on the firm performance, all the other factors held constant (Link and Scott, 2019)[6].

With the second data series, the authors compared the performance of treated and untreated firms (that they intended to match in pairs through a matching method) after the granting of public R&D incentives, at time t*[7]; in this case, the econometric model takes the following general form:

$$P_t = b_0 + b_1E + \text{control variables} + \varepsilon$$

where P and ε are defined as in the previous example, whereas E is a dummy that divides the sample into those affected by the public-sector R&D program (for which E is equal to 1) and those matched pairs which are not affected (in this case, E equals to 0). If the estimated value of b_1 is positive and statistically significant, then public R&D grants have had a positive and measurable impact on the performance of treated firms, with respect to their untreated counterparts (Link and Scott, 2019).

[6] The authors consider a time series with k cross-sectional observations (i=1 to i=k) both before and after the effects of the public-sector R&D program. If, for all the observed firms, performance data are available for the entire time period (t=0 to t=n) and if the public-sector R&D program becomes effective at time t=t*, then there is the possibility for a comparison between the performance of the k firms before the public R&D program (Pi, for t=0 to t=t*-1) and after the program (Pi, for t=t* to t=n').

[7] If performance data are only available from t=t* to t=n for k treated companies (Pi,i = 1 to i=k) and for m untreated firms (Pj,j = 1 to j=m'), then the comparison over time for each pair of companies is between Pi and its matched Pj (Link and Scott, 2019).

Among different approaches, a special case is represented by a “productivity model”, which includes R&D into the production function[8] (see Czarnitzki et al., 2008). According to (Link and Scott, 2019), under a set of stylistic assumptions (i.e., the functional form of the production function and the relationship between the stock of technical knowledge and firms’ investments in R&D), an econometric model can be derived to estimate the rate of return to the companies’ investments in Research and Development (See Hall, 2010).

Benchmarking analysis comprises a performance’s comparison between firms which received public R&D grants to the best practice of all of the firms being studied or to an exemplary standard (Link and Scott, 2019): as an example, if the performance of treated firms (i.e., firms affected by a public-sector R&D program) is considered as Pi, and the theoretical goal of the program is to reach the level P*, then the comparison will be the performance of each firm to the benchmark P* (Link and Scott, 2019). Furthermore, it is possible to quantify the features of companies whose performance is near to the goal or far from it (for an example, see Polt et al., 2001).

Innovation surveys are considered by Polt and Rojo (2002) and by Licht and Sirilli (2002) as an evaluation methodology, while Link and Scott (2019) referred to them

[8] A production function is a mathematical representation of the relationship between a firm’s (or other units of analysis) output and the inputs which generate that output. It is generally represented as Q = F(L,K,T), where L is the flow of labour, K represent the stock of physical capital and T the stock of technological knowledge that is based on cumulated R&D investment.

as data collection tools which can be used both in economic assessment and economic impact studies. Many studies on European countries are based on a dataset provided by the Community Innovation Surveys (CIS): these surveys started in 1992 and have been keeping on every two years, covering multiple dimensions of the innovation processes and of government policy schemes (Licht and Sirilli, 2002).

As far as peer reviews concern, they are defined by United Nations as "the systematic examination and assessment of the performance of an entity by counterpart entities, with the ultimate goal of helping the reviewed entity improve its policy making, adopt best practices and comply with established standards and principles" (United Nations Development Programme, 2005, p. 17). Generally, speaking, experts are asked to review public sector research projects (Link and Scott, 2019): in the case of Research and Development, Ormala (1994) stated that evaluation panels are often used in Europe for public-sector policy and program evaluation, especially for those programs regarding the granting of R&D incentives.

2.3 INPUT AND OUTPUT ADDITIONALITY

When we mention the concept of additionality[9] in terms of public R&D policies, we refer to the net positive difference between the hypothetic level of

[9] See English Partnerships (2004) for the general definition and formula of additionality.

underinvestment (so, how much firms would have spent in R&D without public incentives) and the real amount of expenditures in Research and Development performed by companies thanks to the monetary support provided by the public sector. There are different types of additionality effects, but the next two paragraphs (par. 2.3.1 and 2.3.2) focus only on those that will be examined in the empirical analysis of Chapter 4.

2.3.1 Input additionality

We refer to an input additionality effect if companies which were offered incentives by the public sector to support Research and Development expenditure have been able to increase their investment in R&D thanks to the monetary help that they received (Georghiou and Meyer-Krahmer, 1992; Georghiou et al., 2002). Generally, this category of additionality is the most used in the R&D policy evaluation field in order to understand if the incentives granted by the public sector have been able to boost the level of R&D expenditures of the examined firms (Clarysse, Mustar and Wright, 2009). Many studies have proved the existence of a positive correlation between the granting of public incentives and an increase in R&D investments from those companies which received monetary support from their government or at regional level (see among Hall and Van Reenen, 2000; Aerts and Schmidt, 2008; Czarnitzki and Lopes-Bento, 2012). Studies about input additionality regarding crowding out effects[10] led to conflicting results: Aerts and Schmidt (2008) reported that it was absent in the majority of the analysed cases, while Marino et al. (2016) found a slight correspondence of crowding out effect for medium-high levels of public subsidies and, generally, under the R&D tax credit regime.

Input additionality can be divided in two sub-categories: direct and indirect input additionality (Madsen et al., 2008). Direct input additionality is that effect which ensures companies to increase their expenditure in Research and Development in a way that these firms would have never experienced without monetary support, that is by financing certain projects that they would have never been able to fund just counting on their own resources (Madsen et al., 2008). Indirect input additionality is also defined by the authors as the amount of knowledge acquired by firms through those projects carried out thanks to public incentives. Madsen et al. (2008) stressed the relationship between direct and indirect input additionality, proving that direct input additionality is a prerequisite for the indirect type of input additionality. In addition, the authors proved the necessary presence of direct input additionality effects for output additionality to be observed. However, according to the literature, there is not a direct and straightforward linkage between innovation inputs and outputs: as an example, Clarysse, Mustar and Wright (2009) claimed that

[10] We defined as a crowding out effect a situation in which increased interest rates lead to a reduction in private investment spending such that it dampens the initial increase of total investment spending.

knowledge spillovers might also derive from innovation projects which have not been funded with public grants, making it difficult to assess the nature of the relationship between input and output additionality.

2.3.2 Output additionality

Output additionality is defined as that portion of products and/or services which companies could not have produced without R&D public incentives. It is based only on innovative outputs and, as in the case of input additionality, can be represented by direct and indirect effects (Georghiou et al., 2002; Madsen et al., 2008). We consider as direct outputs all those elements which involve the application of new ideas, like patents, prototypes and scientific publications. Indirect outputs, instead, are represented by the exploitation of new ideas to create or implement new products, services and processes (Madsen et al., 2008).

Unlike the case of input additionality, there is not a universally accepted measure of output effects (Roper and Hewitt-Dundas, 2016; Clarysse, Mustar and Wright, 2009): in terms of possible output additionality indicators, there are patents but also value-added, productivity, profits and number of employees' growth (Roper and Hewitt-Dundas, 2016).

Regarding the empirical representation of input and output additionality, further examples deriving from the empirical literature are provided in par. 2.4.1 and 2.4.2.

2.4 TAX CREDITS AND SUBSIDIES

Tax credits and subsidies are two policy tools that can be provided by the government to facilitate private R&D projects and to increase their number. A tax credit is an amount of money that companies can subtract from the taxes they owe to government: unlike exemptions and deductions, which reduce the amount of taxable income, tax credits lower the actual amount of owed taxes.

There are three types of tax credits: refundable, non-refundable and partially refundable. Refundable tax credits are the most beneficial credit because they are paid out in full: this means that a firm is entitled to the whole amount of the credit and if the refundable tax credit reduces the tax liability to below zero, the company can have a refund. Non-refundable tax credits are directly deducted from the tax liability until the tax due equals to zero: any amount greater than the tax owed is not paid out. Non-refundable tax credits are valid only in the year of reporting: they expire after the return is filed and could not be carried over to future years.

Finally, some tax credits are partially refundable: that can both decrease taxable income and lower tax liability.

A subsidy is a direct or indirect grant to firms and it can be provided in a direct or indirect form: direct subsidies involve an actual payment of funds toward a particular firm or industry, whether indirect subsidies are not represented by a predetermined monetary value or they do not involve actual cash outlays.

Economists have argued over the subsidies' effects on the market: many say that they distort the way demand and supply meet each other, while others suggest that usually governments don't spend on subsidies efficiently. Another problem is that subsidizing might corrupt the political process: even if a subsidy is scheduled with all the good intentions, it raises the profits of those receiving beneficial treatment, creating an incentive to lobby for its continuance. This potentially allows political and business interests to create a mutual benefit at the expense of taxpayers and/or rival firms or industries.

These policy instruments also have different perks: for example, many scholars contend that subsidies can provide the socially optimal level of goods and services which will lead to economic efficiency: the subsidy lowers the cost for the producers to provide goods and services; so, if the right level of subsidization is provided, the market failure should be corrected. In other terms, subsidies produce a positive effect when a market failure causes too little production in a specific area since they would push production back up to optimal levels.

2.4.1 Tax credits

One of the first works about the effects' evaluation of a tax-credit system was performed by Eisener et al. (1984). They set the begin of their research in 1981, the year in which the Economic Recovery Tax Act entered into force in United States: U.S. companies had the possibility to accept a credit that had to be spent in qualified research activities, identified as contract research for the 65% of the credit amount, whether the rest was intended to finance current expenses with the exception of depreciation. The credit was incremental, representing 25% of the excess of current qualified research and development expenditures over a base, which was company-specific and shifted in time. The authors computed the tentative credit as 25% of the increase in qualified R&D expenditures over base: the credit was claimed as equal to the tentative credit when federal income tax payable was positive and equal to zero otherwise. Their sample was composed by 592 firms: 76% of the latter was financed by those 66 firms whose 1982 R&D expenditure exceeded $100 million. The authors found the credit to be pro-cyclical and sensitive to inflation: in their opinion, the incremental tax credit for R&D had a limited potential for stimulating expenditures and, in some cases, it could have discouraged them; they also claimed that, from 1983 to 1985, the credit was likely to exceed the estimates made by the Treasury.

According to the authors, several modifications to the credit would have increased its incentive effects: the most important of these would have redesigned the moving-average base, so that increases in current expenditures would not have reduced future credits (Eisner et al., 1984).

Mansfield and Lorne (1985) performed one the first R&D tax-credit policy' evaluations in Canada. As in United States (Eisner et al., 1984), in 1981 Canada was applying a R&D tax-credit policy too: the nation relied on a taxable tax credit that represented from 10% to 25% of current and capital spending on R&D, with the percentage varying with the size of the firm and the location of its R&D activity; it also introduced a research allowance which allowed Canadian enterprises to deduct from their taxable income an amount equal to half of the increase in operating and capital expenditures for research and development (Mansfield, 1986). The econometric results of the above authors suggested that the special research allowance increased R&D expenditures by about 1% and that the investment tax credit increased them by about 2%. These impacts appeared to be appreciably less than the tax revenue losses recorded by the government.

A more recent analysis on the impact of R&D tax credits on innovations activities was performed by Czarnitzki et al. (2011). Taking into account the 1997–1999 period and considering a sample composed by Canadian manufacturing firms, they focused on the average effect of R&D tax credits on different innovation indicators like the number of new products, the amount of sales with new products and the originality of the innovation. In doing, so they used a 7-step non-parametric matching approach. The authors found out that recipients of tax credits showed significantly better scores on most performance indicators with respect to a hypothetical situation considering the absence of R&D tax credits: thus, they concluded that tax credits boosted output additionality effects (Czarnitzki et al., 2011).

Castellacci and Mee Lie (2015) focused on the importance of the sectoral dimension in the study of the effects of R&D tax credits on innovative enterprises: thanks to the meta-regression analysis (Stanley, 2001), they built a brand-new database which included pieces of information on a large number of recent firm-level studies on the effects of R&D tax credits, while their next step was spotting those factors that could explain discrepancies among the estimated effects. The results showed that, indeed, sectors matter: according to the authors, micro-econometric studies that have focused on a sub-sample of high-tech industries have, on average, obtained a smaller estimated effect of R&D tax credits. Moreover, the additionality effect of R&D tax credits is on average stronger for SMEs, firms in the service sectors, and firms in low-tech sectors in countries with an incremental scheme (Castellacci and Mee Lie, 2015).

Bodas Freitas et al. (2017) focused on how much additionality effects generated by R&D tax credits could vary across sectors by performing a micro-econometric analysis for Norway, Italy and France in 2004, 2006 and 2008. Regarding input additionality, the authors pointed out that companies placed in sectors where R&D is not so common may have some innovative traits but they usually don't invest significantly in Research and Development: in the case they would catch-up and improve their orientation towards R&D, even a small increase in R&D investments boosted by tax credit could have a significant effect on research and development intensity. Vice versa, an additionality effect in R&D oriented enterprises is more difficult to get since they already have invested in new technologies or more advanced processes. On the other hand, it is also true that companies with developed R&D departments have the possibility to improve some existing projects: in this way, they keep on innovating thanks to a fiscal stimulus (Bodas Freitas et al., 2017). The analysis was performed through three equations (as in Czarnitzki and Hussinger, 2004), estimating – respectively - the probability for a firm to receive R&D tax credits, the level of a company's R&D intensity as a function of the tax credits that the firm had received and the output additionality as a function of R&D intensity. The results of the matching is an estimate of the input additionality of R&D tax credits for each country, year and sectoral group. The authors found out that the input additionality effect was positive in both sectors with high and low R&D orientation. However, the effect was greater for firms in sectors with higher R&D orientation. A very similar result emerged for the output additionality effect that, reportedly, was positive for both sectors with a great incident on companies which were more oriented to innovation (Bodas Freitas et al., 2017).

Sterlacchini and Venturini (2018) analysed the additionality effects of R&D tax incentives on the research activity of manufacturing firms based in France, Italy, Spain and the UK: the reference period was between 2007 and 2009, while the cross-sectional sample was composed by EU manufacturing companies with ten or more employees. The impact of R&D tax incentives was estimated through the non-parametric method of Propensity Score Matching (PSM), which matched each company benefitting from fiscal incentives with the most similar firm belonging to the control group of firms that didn't receive monetary help from the public sector. The authors found out that, in all the countries except Spain, granting R&D tax incentives led to a statistically significant increase of R&D intensity in terms of R&D expenditures over sales; this effect, however, was only driven by SMEs. In addition, Sterlacchini and Venturini (2018) found evidences of substantial additional effects in UK and Italy by estimating the benefit-cost ratio of R&D tax policies.

2.4.2 Public subsidies

Input and output additionality effects have been evaluated also with respect to subsidies: as an example, Czarnitzki and Licht (2006) estimated the impact of public R&D grants on firms' R&D and innovation output in East and Western Germany. They perform a comparison between the output effect generated by investments funded through public subsidies and the one caused by R&D expenditure financed by the companies themselves. The authors compared recipients and "untreated" firms through the Propensity Score Matching (as in Sterlacchini and Venturini, 2019), using firm-level data derived from the Mannheim Innovation Panel. Both input and output additionality effects seemed to be more significant in the case of those firms which received subsidies. Moreover, during the transition period, input additionality had been less present in Western

Germany than in the Eastern part even though Western Germany was more dynamic and productive: that is why the authors suggested a redistribution of public research and development grants, a solution aimed at homogenising and rising the general innovation output of the country (Czarnitzki and Licht, 2006).

Czarnitzki and Lopes Bento (2012) studied the effect of public funding on internal R&D investment and on total innovation intensity on a cross-country comparative level. The authors used harmonised micro data from five different countries and applied the Propensity Score Matching to identify the treatment effect: they discovered that, on average, firms would have invested significantly less if they would not have received subsidies, confirming the presence of input additionality effects. Then, through the estimation of the treatment effects on the untreated (ATU), the authors assessed that, with the exception of one country, all the governments of the sample would benefit from an extension of their subsidy policies (Czarnitzki and Lopes Bento, 2012).

Marino et al. (2016) studied the effect of public R&D subsidies on private R&D expenditure in a sample of French firms during the period from 1993 to 2009. The authors evaluated if there were input additionality effects of public R&D subsidies by distinguishing between R&D subsidies recipient and non-recipient firms. In addition, combining difference-in-differences with propensity score and exact matching methods, they assessed the effect of R&D subsidies between recipients and firms belonging to the control group, as well as between differently treated (small, medium and large subsidy recipient) firms. Furthermore, the authors implemented a dose–response matching approach to determine the optimality of public R&D subsidy provisions. Marino et al. (2016) found evidence of either no additionality or substitution effects between public and private R&D expenditure. Crowding-out effects were more pronounced for medium-high levels of public subsidies and, generally, under the R&D tax credit regime.

Aristei, Sterlacchini and Venturini (2017) analysed the effects of R&D subsidy policies in European economies during the period of the 2008 financial crisis: they wanted to see if manufacturing enterprises that had received public subsidies invested more in R&D. In doing so, they used as database homogenous firm-level data of the largest European countries from 2007 to 2009. The analysis was performed by using the Propensity Score Matching (PSM) and parametric estimations, which proved that - during the crisis - the enterprises that received the subsidies did not lower their Research and Development intensity, but they exploited public grants to keep on innovating. However, the same firms did not rise their own internal investments in innovation and, generally, their R&D intensity level was similar to those who were not subsidised. The authors rejected the hypothesis of a full crowding-out: on the contrary, they proved that public subsidies slapped a band-aid on a possible reduction of private innovation investments due to the financial crisis; so, public grants dampened counter-cyclical effects (Aristei, Sterlacchini, Venturini, 2017).

3. RESEARCH AND DEVELOPMENT IN NORWAY

This chapter is dedicated to the R&D activities in Norway. The first section describes the historical evolution of the latter and the current international position of Norway, whether the second part of is focused on the country's R&D sectors. The last section analyses Norwegian R&D policies, along with their evaluation.

3.1 A HISTORICAL OVERVIEW OF R&D IN NORWAY

In order to understand the recent trends about R&D policies in Norway, it is better to recall the historical phases which boosted the interest of the government towards the implementation of a national innovation system.

3.1.1 Nineteenth and Twentieth centuries

Before modernisation, Norway's economy mainly relied on fishery, forestry, mining and agriculture. According to Fagerberg (2016), only starting from the end of the 19^{th} century the country was no more characterised by the exploitation of raw natural resources but by a new, energy-intensive and export-oriented economic system. During the 20^{th} century, industries set their production towards metals, chemicals, pulp, paper and fertilizers. From 1970 onwards, the oil and gas sectors were developed thanks to the knowledge acquired during the previous years, deriving from early research and development activities that came to life. Thus, Norwegian industries preferred to buy services from the public research organizations[11] rather than investing in internal R&D departments: as a result, the share of innovative activities in industrial value added was relatively low compared to other countries. The historical development of the Norwegian R&D system appears to be defined by a relevant path dependency: as a matter of fact, it seems that the important role that the primary sector has had during the past centuries has contributed to create an environment dominated by resource-based innovation. On the other hand, the development of new industries that are less closely linked to natural resources, despite the support of public policy, has not been as efficient as its counterparts (Fagerberg et al., 2009)[12]. The failure of modernising policies in Norway is not due to a form of resistance from those firms belonging to the leading sectors: instead, it is the reflection of the fact that Norwegian resource-based sectors have shown considerable dynamism in developing knowledge and adapting to new challenges (Castellacci et al, 2009). Therefore, even though fishery and the oil and gas sectors remain economically important, it is clear that the period of prosperity based on the exploitation of Norway's offshore natural resources is coming to an end (OECD, 2008).

[11] The first Norwegian university was founded in Oslo in 1811, followed by other research institutes: an agricultural university was established in 1859 and a public research organization focusing on ocean and marine research in 1900, while the country's first technical university was founded in Trondheim in 1910. Only in 1949 a National Research Council was established.

[12] For instance, the initial enthusiasm towards electronic industries, while leading to a number of scientific achievements, did not translate into a lasting industrial success.

3.1.2 The new millennium

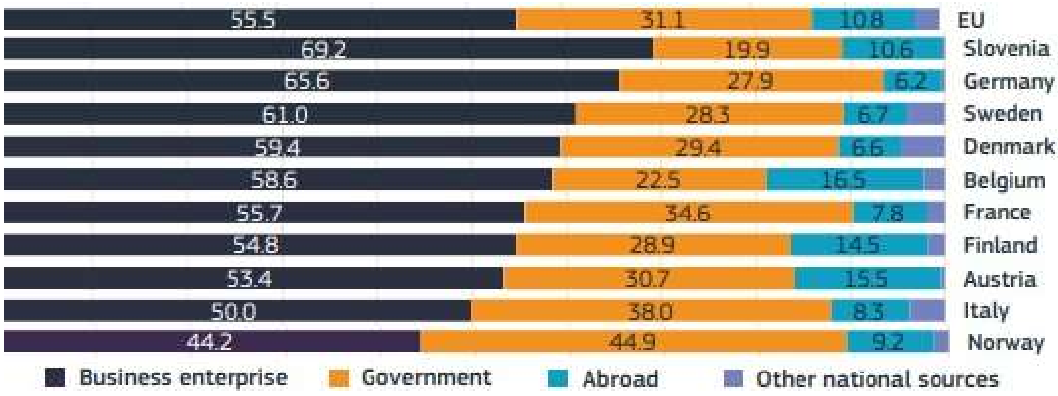
Several important changes in the government's way to manage research policies took place in the early years of the new millennium: in 2002 a dedicated division was created within the National Research Council to support R&D activities in firms. In the same year, the government also introduced a new scheme for subsidizing firm-level R&D, the SkatteFUNN, whose main features will be analysed in section 3.3.2.

In 2003, the Ministry of Trade and Industry developed and published the plan for a comprehensive R&D policy: this plan described an effort for increasing Norwegian research and development, including both national and regional institutions; it also emphasized the need for an active coordination among stakeholders and between different parts of the government. A year later, in 2004, the central government created a new organization named "Innovation Norway" (IN) merging several existing public bodies providing economic support and services to business industries: despite the name, however, most of Innovation Norway's budget was initially used to subsidise activities in rural areas. During the last twenty years, the Norwegian contribution to knowledge advancements has been remarkable: the good level of the country's scientific production in many areas is well recognized at the international level and the country records high shares of human resources in science and technology and R&D (OECD, 2008). Lately, however, Norway's economic performance has been victim of a sort of paradox: in spite of having levels of productivity and income among the highest in the world, the Norwegian R&D and innovation indexes are not impressive if compared to those of other northern European countries, such as Sweden and Finland (OECD, 2007; Grønning et al, 2008). A deeper discussion about the international position of Norway in terms of research and development is provided in the following paragraph.

3.1.3 Norwegian international R&D position

Recent trends provided by the European Commission (2018) allow us to understand what is the current Norwegian situation in terms of Research and Development by comparing national data to those of European and OECD countries:

Figure 1: GERD financed by sector (%), 2015



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies (Eurostat, OECD, UNESCO)

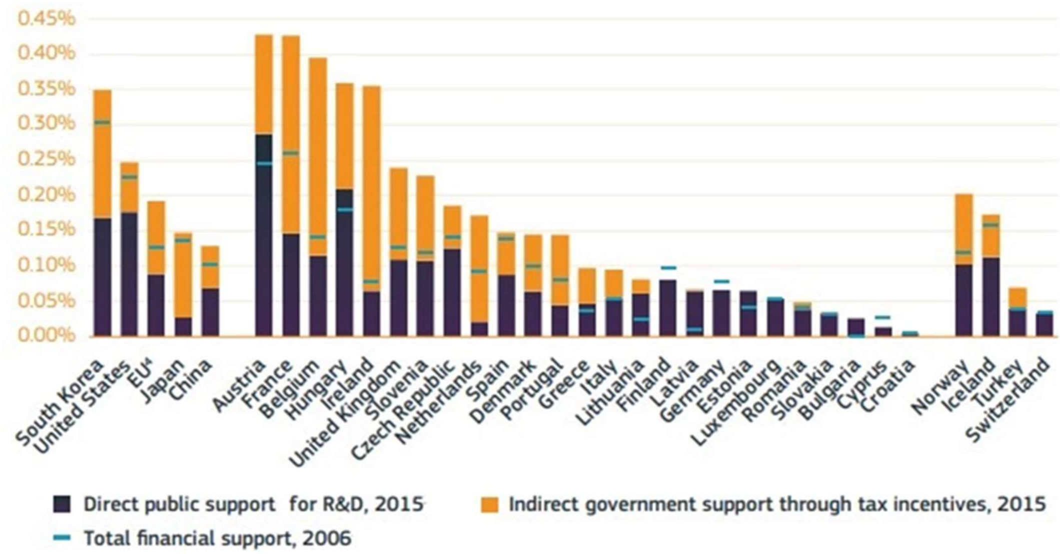
Gross domestic expenditure on research and development (GERD) is constructed by adding together the intramural expenditures on research and development financed by different sectors: the involved sectors are business enterprises, government, foreign financers and other national sources. Figure 1 compares Norwegian GERD to the average gross domestic expenditure on research and development of the European countries and to the GERD of those single EU nations that had a good performance in terms of R&D in the analysed period. Speaking about the general European situation, more than half of EU GERD was financed by the private sector, around 30% by the government, 11% by foreign funders and less than 5% by other national sources: a very similar pattern was shared by other European countries which had significant performance in terms of research and development, like Denmark, Belgium, France, Finland, Austria and Italy; the European nations which were characterised by the best scores in terms of R&D - Slovenia, Germany and Sweden- saw their GERD financed by business enterprises for more than 60%, by the government for less than 30% and by other funders for 15% or less. As far as Norway concerns, in 2015, the government financed 45% of Norwegian GERD and the same share was coming from the business sector; only 9% of Norwegian gross domestic expenditure on R&D came from abroad while less than 2% was financed by other national sources.

Figure 2: Business R&D intensity, 2016 and compound annual growth, 2007-2016

Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies (Eurostat, OECD, UNESCO)

Focusing on business R&D intensity, we can see that in 2016 the Norwegian performance was fairly similar to the European average (see Figure 2): the Norwegian business sector spent more than 1% of GDP in research and development, like the United Kingdom, the Czech Republic and the Netherlands. The European level of business R&D intensity was slightly higher, but the Norwegian private expenditure for research and development was greater in terms of growth: as a matter of fact, the compound annual growth rate for Norway considering the period going from 2007 to 2016 was around 3% while in the EU it was equal to 2%.

Figure 3: Public support for business R&D as % of GDP, 2006 and 2015



Source: DG Research and Innovation - Unit for the Analysis and Monitoring of National Research and Innovation Policies (Eurostat, OECD, UNESCO)

Figure 3 shows the percentage of public support for business research and development as a percentage of GDP both in 2006 and 2015. As far as Norway concerns, this percentage has increased during the years: in 2006, it was between 0.10% and 0.15%, the same as the European Union average. In 2015, the percentage of Norwegian public R&D as a share of GDP was around 0.20%, growing by 1.27% during the analysed years[13] : again, very similar to the value of the European Union.

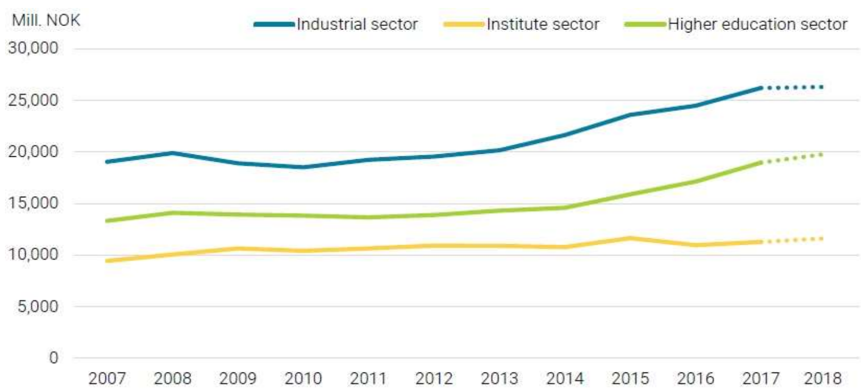
[13] Computation performed by the author, considering that in 2006 the Norwegian GDP was equal to 345,6 billion USD (2011 PPP $) and in 2015 it was around 385,8 billion USD (2011 PPP $). The growth rate is calculated by the compound annual growth rate (CAGR).
Data retrieved from https://data.worldbank.org/.

Both the direct public support and the indirect government support through tax incentives were respectively 0.10% of the national income.

3.2 NORWEGIAN R&D SECTORS

Statistics Norway provides the time series of R&D expenses for three main sectors: the industrial (or business) sector, the institute sector and the higher education sector. So, while the industrial sector comprises business enterprises, the institute sector involves private-non-profit research institutes and R&D institutes mainly controlled and funded by the central government. Last but not least, the higher education sector, is composed by universities, specialised university institutions, state university colleges and university hospitals (Solberg and Wendt, 2019).

Figure 4: R&D expenditure in Norway by sector of performance. Health trusts are included in higher education sector and the institute sector. From 2007 to 2018. Fixed 2010 prices.



Source: Statistics Norway and NIFU, R&D statistics

As we can see in Figure 4, since 2007 the private sector has been the one with the highest amount of expenditures in research and development: starting from NOK 20000 million in 2007, private expenses for R&D slightly decreased from 2008 to 2010; subsequently, they experienced a considerable growth exceeding NOK 25000 million in 2016. The higher education sector shares a similar pattern, yet its level of expenditures in R&D was below NOK 15000 million in 2007 and it took over in 2014, reaching NOK 20000 million in 2018. The R&D expenditures performed by the research institution sector has been around NOK 10000 million during all the period considered, probably because these research units are mainly funded by the central government, whose strategy is to invest a constant amount of resources in R&D. A deeper overview about the role of research institutes and universities is provided below.

3.2.1 The research institute sector

According to Euraxess Norway (2018), the Norwegian research institute sector is composed by a large number of institutions which differ widely in terms of scientific focus, tasks, organisation, financing and historical background: the sector counts a total of over 200 institutions, 70 of which describe R&D as their primary activity. A public funding system has been introduced for the research institutes and it is distributed according to four performance indicators: scholarly publication, income from nationally commissioned research, income from international sources and number of doctoral degrees completed. Generally speaking, the institutes have been grouped into four categories: primary industry, environmental, social science and technical-industrial institutes. The primary industry institutes[14] have been developed to meet the needs of the public administration and primary industries for research-based knowledge: they cooperate with actors in the primary industries, often sole proprietorships or micro-companies, to define research needs and carry out research activities. The primary research institutes also play a key role to transfer and apply research-based knowledge to the industries and perform wide-ranging administrative tasks on behalf of the public administration within their areas of expertise and responsibility.

The environmental institutes[15] conduct applied research in the fields of the environment, climate, cultural history, social science and natural science. Along with conducting research, the they also provide research-based expertise, advice and assistance to the Ministry of Climate and Environment in the context of national

[14] This category includes the Norwegian Institute of Bioeconomic Research, the Nofima (a research institute providing data to the fishery and food sectors), the Centre for Rural Research, the SINTEF (for marine pollution, marine transport, fishery technology, bio-marine processing, offshore wind, oil and gas) and the Norwegian Veterinary Institute.

[15] Among the environmental institutes there are the Centre for International Climate and Environmental Research, the Nansen Environmental and Remote Sensing Centre, the Norwegian Institute for Cultural Heritage Research, the Norwegian Institute for Air Research, the Norwegian Institute for Nature Research, the Norwegian Institute for Water Research and, also, The Institute of Transport Economics.

and international forums and carry out studies of environmental issues on commission from the ministry.

The technical-industrial institutes[16] operate in a broad range of subject areas and disciplines within the fields of natural science, technology, environmental science and technology management: research from these institutes is commissioned primarily by companies and industries with a high level of R&D activity. The technical-industrial institutes operate to a large extent on an international market: therefore, they play a crucial role in bringing new technology to Norwegian industry from abroad.

The social science institutes[17]' research activities vary from basic to applied research: the public sector is the most important commissioner of research for all the social science institutes. The institutes are dispersed throughout the country: some are regionally oriented, with close ties to the region in which they are located as regards research topics and the organisations commissioning the research, while others analyse topics of national interest. Additional research institutes funded by the central governments could be museums, health institutions, registries and

[16] Inside this category there are the Norwegian Seismic Array, the Institute for Energy Technology, the Norwegian Computing Centre, the Norwegian Marine Technology Research Institute, the Norwegian Geotechnical Institute, the Northern Research Institute ICT, the Tel-tek, the International Research Institute of Stavanger and, finally, the SINTEF (for Energy and Petroleum Research).

[17] Among the national science institutes we find the Work Research Institutes, the Peace Research Institute of Oslo, the Institute for Social Research, the Ragnar Frisch Centre for Economic Research, the Uni Research and the NTNU Social Research, the Nordic Centre for Studies in Innovation, Research and Education, the NOVA, the Norwegian Institute of International Affairs, the Institute for Research in Economics and Business Administration and other realities.

archives, institutions with a social science-oriented research profile and institutions with a natural science and technology-oriented research profile.

3.2.2 The higher education sector

According to the Nordic Institute for Studies in Innovation, Research and Education (2015), institutional autonomy, decentralization, managerialism and market have been the most important topics regarding crucial reforms of the higher education sector both in Norway and in the rest of Europe: these changes can be summarised by the restructuring and mergers in the university college sector (Kyvik 2002; Kyvik 2008) and by the performance-oriented measures introduced with the Quality Reform[18] (Maassen et al. 2011; Maassen et al. 2008).

As a result of the latest reforms, today's Norwegian higher education can be divided in two sectors: the university sector and the non-university sector. The university sector includes four universities and seven university colleges or specialised institutions in the fields of business administration, agriculture, veterinary medicine, architecture, music, etc.; these courses last from four to seven years. The non-university sector comprises twenty-six state colleges and several minor private

[18] The Quality Reform (2003) was introduced with the aim of improving the quality of the academic formation in Norway, prescribing stronger institutional responsibility for students, closer follow-up, more feedbacks and new forms of assessment. It introduced a new quality assurance system and degree structure, marking a change in the Norwegian higher education policy landscape.
For deeper information, see: Nordic Institute for Studies in Innovation, Research and Education. (2015).

colleges (some of which receive public funding): they principally offer short-term courses of two- or three-years' duration. University courses in theology, law, medicine, dentistry, etc. take five to seven years, whether those in engineering, business administration, etc. take four to five years. In Norway, it is very common to delay the access to higher education, to be a part-time student or to take a break in order to travel, work or to do one's military service: that is why the average age of the student body is, usually, quite high (it was of 29 years old for high level students in 1996) (Naess and Aamodet, 1992).

3.2.3 R&D personnel

Solberg and Wendt (2019) provide a detailed description of the Norwegian personnel working in the R&D field. In 2017, 85000 people performed R&D activities in Norway and more than 75% of them were employed in professional positions such as researchers or academic staff; the remaining third as technicians or other supporting staff. The increasing number of researchers coincides with a significant growth in the proportion of research staff with a doctorate: in the last 40 years, the proportion of doctorates has gone from below 30% to nearly 50%. In the same period, the share of doctorates in the institute sector has increased from 10% to 54%. In the industrial sector, the proportion of R&D personnel with a doctorate has long remained stable at about 10%: one explanation of this low percentage could be that many employees in the industrial sector with a doctorate are not researchers but have other types of positions. Among researchers or the academic staff who participated in R&D in 2017, 38% were women: the health trusts had the highest proportion of women (51%), whether the female percentage of researchers or academic staff in the higher education sector was 48%, followed by 41% in the institute sector; the industrial sector had the lowest proportion of women among researchers or academic staff, 23%. According to Solberg and Wendt (2019), the increase in researchers with a doctorate is related to a long-term and conscious political commitment to researcher recruitment in Norway: because of the increase in the number of fellowship positions, there is the belief to expect further growth in the coming years. Another important feature to underline is the increasing number of foreigners among doctoral candidates: as a matter of fact, in 2018 658 people with foreign citizenship obtained a doctorate in Norway (around 42% of the total), when in 1999 foreigners accounted for 10% of the doctoral candidates: the proportion of foreign nationals among doctoral candidates is significantly high in science and technology. In the past 5 years, about half of them had European citizenship, 33% of them were Asian and 12% came from the African continent. However, while the number of doctorates is increasing, the proportion who pursue a career outside the university field is also rising.

3.3 R&D POLICIES IN NORWAY

The following paragraphs provide the description of the main Norwegian public policies to support R&D and their evaluation.

3.3.1 R&D subsidies

Norwegian R&D subsidies have traditionally been distributed to enterprises in the form of direct grants: the golden rule appears to involve "matching grants", where firms are supposed to finance 50% of the projects they apply for. Klette and Møen (1998) underlined that this about-mentioned money is taken from companies' research and development budgets: hence, it would have been spent on R&D anyway. However, they proved that firms did not seem to reduce their private R&D budget if they received subsidies: this means that that the additionality effect was around one, implying that one krone in subsidy pushed firms to invest one krone more in research and development. Earlier research based on surveys from the 1970s, 1980s and 1990s, always summarised by Klette and Møen (1998), showed that 34% of subsidized projects would not have been carried out without public grants, 48% of them would have been postponed and 18% would have been totally performed without the support of the government. Klette and Møen (1999) and Møen (2004) evaluated a large Norwegian R&D subsidy program directed towards the IT industry running from 1987 to 1990: comparing subsidized and non-subsidized firms within the high-tech industries, they found little evidence in favour of the subsidized firms being more successful. The authors conducted their studies by considering the performance of the involved enterprises and comparing them to the other production units belonging to the country's manufacturing and IT sector; then, these data were measured against those of the manufacturing and IT companies in the rest of the OECD area: with respect to the intensity and time dimension of the treatment, a regression framework was used so that continuous variables could be utilized in addition to a dichotomous classification. Recently, a large part of reports concerning research and development literature in Norway are provided by Statistic Norway (in Norwegian, Statistisk sentralbyrå), which is a public research institute whose purpose is to gather, analyse and publish statistic information about economics, population and society.

3.3.2 R&D tax incentives: the SkatteFUNN

The SkatteFUNN is a rights-based tax deduction scheme designed to stimulate research and development activities in Norwegian companies. Cappelen (2010) described the birth of this scheme stating that in 2000 the Hervik Commission proposed the introduction of a R&D tax credit in Norway Commission in a green paper for the Ministry of Trade and Industry: the commission was ordered to suggest policy measures aimed at encouraging industry to invest more in research and development. In 2000, the Norwegian Parliament had already agreed to increase the level of R&D investments as a national priority and had decided that, by 2005, the relative percentage of research and development expenditure as a share of GDP should have reached at least the OECD average. Therefore, the scheme was presented in connection with the national budget for 2002, passed by the Parliament in December 2001 and brought into force for the fiscal year 2002: it was called SkatteFUNN and it was designed to be a tax-credit scheme, implying that a certain percentage of a firm's private expenditure for R&D investments is deductible against taxes. In order to be entitled of the benefits, the candidates must meet the relevant terms and have their project plan approved by the SkatteFUNN secretariat which is part of the Research Council of Norway; in addition, Innovation Norway - which is another governmental agency - helps enterprises through the application process and makes a first assessment of the ideas that are worthy of the statal support. The research and development expenditures must be approved by the tax authorities, which mainly base their judgement on a statement from the applicant's auditor. At the beginning, only SMEs[19] could apply for the SkatteFUNN, now a 20% deduction could be granted to small enterprises if their employees are less than 250, if they have an annual turnover not exceeding 40 million euro or an annual

[19] In Norway, the criteria that a firm must have to be defined as a SME are having less than 100 employees, invoicing an annual turnover of less than NOK 80 million (around 10 million euro) and having a total annual balance sheet less than NOK 40 million (about 5 million euro).

balance sheet total not exceeding 27 million euro and if less than 25% of the company is owned by a large enterprise; in 2003, large companies were included as well and they can deduct a maximum of 18% of expenses related to an approved research and development project from taxes. In order to promote the cooperation between universities and the business sector, under this tax-credit scheme a firm could purchase R&D services from universities and R&D institutes for another NOK 4 million. Moreover, if the enterprises did not perform research and development activities privately, they could purchase R&D services for a total of NOK 8 million. The tax-credit scheme provides a list of activities that are defined as research and development: the proposed project must be focused and limited and they have to be directed towards creating new knowledge, information or experiences which are presumed to be used by enterprises to develop new or improved products, services or manufacturing methods. If the tax credit is higher than the tax payable by the company, the difference is paid to the firm in the form of a negative tax or a grant; if the firm is not in a tax position at all, the amount of the tax credit is paid to the firm as a grant (Cappelen, 2010). According to Fagerberg (2016), the SkatteFUNN should have consisted in a tax-credit scheme, but since most of the firms that apply for receiving support pay a small amount of taxes, the major part of the support seems to be given as a subsidy. The scheme offers a strong incentive for companies to cooperate with external R&D providers, which benefit financially from this arrangement. In budgetary terms it is the largest among the government's innovation policy instruments; however, only a small part of Norwegian firms applies for this kind of monetary support: it may be because most of them do not see themselves as research and development performers or because there is a low cap on subsidies (Fagerberg, 2016). The reality seems to agree with the author: as a matter of fact, around 75% of the total support given through the scheme is paid out as grants. The payment is made when the tax authorities have completed their tax assessment and occurs the year after the actual research and development expenses have taken place. The scheme reduces the marginal cost of those enterprises whose R&D expenses are low and seems more generous to small firms than to the large ones. For those companies that would have spent on research and development more than the maximum amount in the scheme, the SkatteFUNN gives few or no incentives to increase R&D investments, even though they are spurred to qualify for the scheme and receive the tax deduction (Cappelen, 2010).

3.3.3 The evaluation of Norwegian R&D policies

In 2007, among all the other works, Statistic Norway uploaded two reports regarding the research and development field. In "The relationship between the Norwegian R&D tax credit scheme and other innovation policy instruments" (Statistic Norway, 2007), the main goal was to study how participation in the Norwegian R&D tax credit scheme affected the probability of being offered other research and development and innovation subsidies: direct grants and the

Skattefunn were compared in terms of additionality and profitability through a probit model analysing the probability of receiving monetary help. No evidence suggesting that using R&D tax credit increased the probability of receiving direct R&D subsidies was found, but the authors could not exclude the possibility of an immediate positive effect. At the individual firm level, direct subsidies and the tax credit seemed to be complementary, while at the innovation system level they behaved as substitutes, as the probability of receiving direct subsidies had fallen after the introduction of the tax credit scheme. Then, the additionality of the R&D tax credit was compared to the direct subsidies: the estimation showed that each public krone spent on tax credits for firms investing below the 4 million cap on intramural R&D increased private intramural R&D by 2.68 kroner. In "Input additionality in the Norwegian R&D tax credit" (Statistic Norway, 2007), the principal goal was to determine to what extent the SkatteFUNN induced Norwegian innovative enterprises to invest more in research and development than they would have done in any other case: using a difference-in-difference regression approach and comparing growth in R&D investments for firms above and below the 4 million tax credit cap, the obtained result suggested that that the Norwegian tax credit scheme for research and development was able to help firms to increasing their R&D investments. As far as the estimated input additionality effect concerned, it seemed to be driven by companies which did very little R&D prior to the adoption of the tax credit scheme: indeed, the size of the effect was hard to assess with any precision, but the scheme was claimed to induce about two kroner additional R&D per krone spent as tax subsidy. The SkatteFUNN has been one of the main topics studied in depth by the Norwegian literature about research and development: Cappelen (2010) wrote a review on the Norway's tax credit stating that: "it works as intended. The scheme is cost-effective and it is used by a large number of firms. It stimulates these firms to invest more in R&D, and in particular, the effect is positive for small firms with little R&D experience" (Cappelen et al., 2010, p. 107). Always Cappelen (2012) focused on the effects of the SkatteFUNN on the likelihood of innovating and patenting: by performing empirical analyses based on three different versions of binary regression, it was proven that projects receiving tax credits ended to develop new production processes and, to some extent, also brand-new products for the company; it was also demonstrated that collaborations with other enterprises had positive effects on the introduction of innovation activities. However, the tax credit scheme did not appear to contribute to innovations in the form of new products for the market or patenting. Isaksen, Henning Normann and Spilling (2017) examined the regional distribution of support from the Norwegian SkatteFUNN scheme: performing regression analysis, they observed that regional innovation system (RIS) variables were important to understand and explain the region's capacity to attract funding from the SkatteFUNN. According to the authors, SkatteFUNN projects are quite evenly spread across labour market regions, which are grouped into a geographical centre–

periphery pattern. That is, being in a peripheral location is not a disadvantage. However, at a more detailed regional level, the scheme tends to favour firms in specific industries and in regions with a relatively developed regional innovation system.

In 2018, the Norwegian Ministry of Finance performed analysed the SkatteFUNN to determine if it is able to boost R&D investment in the private sector, especially among SMEs: the results show that the goal of the scheme has been considered well-defined and able to provide incentives for R&D investments in the private sector. Generally speaking, the programme is capable to fulfil the operational target of higher research and development investment in the private sector and -especially- in SMEs projects. According to theoretical beliefs, R&D investment in the private sector enhances labour productivity: gathered data proved that the projects promoted by the SkatteFUNN strengthened competitiveness and the dissemination of competence through staff mobility and cooperation. Input additionality generated by the tax-credit scheme was evaluated through two different approach: the first one evaluated the effect of an increase in the project cost cap in 2009 and it confirmed that only firms with R&D spending below the project cost cap are stimulated to increase efforts in research and development. The second approach is less specific and studies how different changes in the scheme have affected firms' R&D investment: it proved that SkatteFUNN has high input additionality, but effects can vary according to the type of change and the type of user-generation. As far as SMEs are concerned, half of the companies helped by the SkatteFUNN count less than 10 employees: the share of firms with 10 workers or less is significantly larger than in other R&D supporting schemes (Røtnes, Flatval, & Bjøru, 2017), and it is stable over time, but the percentage of small production units that constantly seeks for the SkatteFUNN's help has decreased over time probably because the size of an enterprise tends to increase with the passing of years. More than 80% of all applicants, however, are firms with less than 50 employees. The probability of the scheme to contribute to a net negative impact on trade and competition is low both for domestic and international reasons: inside Norwegian borders, the fact that the SkatteFUNN favours SMEs with a more favourable tax rate and the cost cap has a positive impact on the competitive environment as it reduces entry barriers and counteracts the bias towards large firms inherent in other avail-able R&D schemes. From an international point of view, a small share of the exporting recipients receives monetary support above the limit of the minimis aid: usually, the users of the SkatteFUNN import more from foreign firms, which might be a positive externality for Norway's trading partners. Focusing on social costs, the authors who performed the analysis stated that firms which rely on the SkatteFUNN invest 2 kroner more in research and development per 1 krone of tax credit they receive: this means that NOK 1 billion of tax credit results in NOK 2 billion of extra R&D investment -one billion private investment and another one through SkatteFUNN-. On the other hand, the scheme is financed through taxes, implying that the social costs associated with the public funding exceed the government's direct costs. The authors remind that it is common to assume that the social cost is 20% higher than the cost of the scheme in order to adjust for the efficiency loss of tax financing activities: it seems that the companies' gains accumulated during the years cover only private investments, while public investment essentially is a subsidy for expected positive spillovers from research and development activities. Therefore, the conclusion as to whether SkatteFUNN is socially profitable depends on whether there are positive externalities attributable to R&D investment: so, the answer will be "yes" if R&D is able to generate strong positive spillovers and new pieces of knowledge tend to depreciate slowly (Winger Eggen, Norberg-Schulz, Rybalk, Røtnes et al., 2018).

4. EVALUATION OF NORWEGIAN POLICY SUPPORT TO R&D

The main goal of this chapter is to assess whether Norwegian tax incentives boost firms' research and development expenditure (input additionality) and if they also contribute to increase the firms' ability to introduce new products and processes (output additionality): this is possible by relying on individual firm data and by performing the Propensity Score Matching (PSM) method to estimate the average treatment effect of the treated. The chapter provides the methodology of the analysis along with the dataset's features and some descriptive statistics, then, the results of the matching procedure and their discussion.

4.1 DATA AND METHODOLOGY

The dataset used to perform this evaluation exercise is taken from the Community Innovation Survey (CIS). The CIS has been developed through the joined efforts of Eurostat and EU Member States' national institutions of statistics: its aim is to gather information about the firms' innovation processes, expenses for research and development and the impact of innovative outcomes on economic performances. Apart from that, other general features of the involved firms – e.g., group membership, cooperation with other institutions, total number of employees, main sector of activity, etc. – are also provided.

As for Norway, the micro data provided by Eurostat are from CIS 2014, which refers to the three-year period 2012-2014. The total number of firms involved in the Norwegian 2014 CIS sample is 5045; however, we have initially focused on 1899 firms considered as innovative since they had positive research and development expenditure during 2014 (considering both internal and/or external R&D). For each firm, the CIS provides information on whether a firm has received any kind of public support for innovation from different levels of government: national, regional or European Union (EU). Unfortunately, in the CIS data, tax incentives cannot be distinguished from direct subsidies and thus, their effect cannot be assessed separately. However, since R&D tax credits, by definition, are provided at national level, the analysis carried out has focused on firms that obtained public support from the central government only. Hence, the scope of the study has been to evaluate the impact of public support provided at the national level (i.e. by central government) by means of tax credits and/or direct subsidies.

From the methodological point of view this has been done employing a non-parametric method named Propensity Score Matching (PSM) (Caliendo and Kopeinig, 2008). This procedure allows to match and compare innovative firms benefiting of public support (considered as "treated") with similar innovative firms that did not receive any kind of public support (control group). Each pair is identified on the basis of the propensity scores yielded by a probit regression which predicts the probability of receiving public support conditional on a set of observable characteristics, formally:

$$E(Y|X) = P(Y = 1|X) = \Phi(\beta_0 + \beta_1 X)$$

with $\Phi(.)$ representing the cumulative standard normal distribution function.

Once the propensity scores are computed, the next step is choosing the most suitable matching algorithm. Its quality can be evaluated through a T-test, checking for significant differences in covariate means, and by comparing the standardised bias[20] before and after the matching (Caliendo and Kopeinig, 2008).

The Treatment Effect can be defined as:

$$E(_{ATT}) = E(Y^T |S = 1) - E(Y^C |S = 1)$$

where S is an indicator of the recipient under the treatment (it is equal to 1 for observations joining the treatment and 0 for the untreated ones), Y^T is the outcome variable and Y^C stands for the potential outcome which would have been realized if the treatment group (S = 1) had not been treated (Czarnitzki et al., 2011).

The propensity score is defined as the probability of treatment assignment conditional on observed baseline characteristics (Austin, 2011). Assuming the conditional independence assumption (CIA) to solve the selection problem -

[20] The standardised bias is defined by Caliendo and Kopeinig (2008) for each covariate as "the difference of sample means in the treated and matched control subsamples as a percentage of the square root of the average of sample variances in both groups" (pp. 48).

participation and potential outcomes are independent for enterprises having the same set of exogenous characteristics, defined as X (Rubin, 1977) - we obtain:

$$E(_{ATT}) = E(Y^T |S = 1,X=x) - E(Y^C |S = 0,X=x)$$

the latter is the Average Treatment Effect on the Treated (ATT), which is able to measure the difference between the outcome variable and Y^C, assessing the results of having been submitted to the treatment (in our case, having received public financial support from the central government) with respect to belonging to the control group (having been prevented from any form of financial support for R&D activities) (Czarnitzki et al., 2011; Cerulli and Potì, 2012; Marzucchi and Montresor, 2013).

4.2 TREATMENT AND CONTROL GROUPS' IDENTIFICATION

As already mentioned (cf. par. 4.1), the companies that obtained public support only at the national level are considered as "treated". Such firms can be opposed to those that did not receive any public support ("control group"): therefore, firms that received public support at other levels of government (i.e. regional and/or EU), exclusively or together with those incentives provided at the national level, have been removed from the sample. The final target sample used for the PSM analysis is, thus, of 1479 firms: 670 "treated" opposed to 809 "untreated" firms.

Table 1: Firms doing research and development and receiving public support.

	TOTAL	%
Total firms	*5045*	*100*
Innovative firms (doing R&D)	**1899**	**37.641**
Innovative firms with national public support **(treated)**	***670***	***35.282***
Innovative firms without any public support **(control)**	***809***	***42.601***
Innovative firms with regional and/or european support **(excluded)**	130	6.846
Innovative firms with national, regional and/or european support **(excluded)**	290	15.271

Source: Author's elaborations on Norwegian CIS 2014 data (Eurostat).

Table 1 reports the total amount of firms in the Norwegian CIS 2014 sample (5045), the number of firms with research and development expenditures in 2014 (1899) and, then, the number of treated (670) and untreated firms (809) used to perform the PSM analysis. As can be seen, 420 firms have been excluded from the analysis: 130 of the latter are innovative companies which received financial support from the regional or the European level, while the other 290 were offered R&D public support from both the central government and the region and/or the EU. Innovative firms represent almost 38% of the total amount of the surveyed firms. The group of the treated firms, which received public financial support only at the national level, is made of 35% of innovative companies (i.e. with R&D expenses), while the untreated firms correspond to 43% of innovative firms.

4.3 PROBIT ANALYSIS

After having identified the different groups of treated and control firms, a probit regression has been performed for estimating the probability of receiving public financial support at national level, i.e., the propensity scores that will be used for matching the supported and un-supported firms with similar observable characteristics. The dependent variable employed is thus a dummy equal to 1 if a firm received public support for innovation (i.e. tax credits or direct subsidies) from the central government and 0 otherwise.

4.3.1 Explanatory variables

With regard to the set of covariates to include in the probit estimation, several factors have been considered, which have been identified drawing on recent empirical literature that uses a similar methodology (see among others Cerulli and Potì, 2012; Marzucchi and Montresor, 2015; Aristei, Sterlacchini and Venturini, 2017; Sterlacchini and Venturini, 2019): therefore, the chosen explanatory variables concern firms' size, business groups membership and the country of origin of their head offices, collaborations with other institutions, propensity to export, introduction of organisational innovations and propensity to hire employees with a university degree.

In order to identify the size of a firm, the CIS data include the number of the firms' employees: so, according to the standards adopted in the European Union, a firm can be considered of small size if it has less than 50 employees; of medium-size if its number of employees stands between 50 and 249 units, whereas it is classified as large if it comprises more than 250 employees. Accordingly, three binary variables have been constructed in order to identify the firm size, that is "size_S" equal to 1 if the considered firms have a small size and 0 otherwise; "size_ M" equal to 1 for medium-sized companies and 0 otherwise, with "size_L" equal to 1 for large companies taken as reference category. Small firms should be more likely to receive R&D incentives from Norwegian government: as a matter of fact, not only the SkatteFUNN was initially set up to help companies with less than 50 employees (see Chapter 3), but also large enterprises are claimed to be more capable of spending in private research and development expenditures because of their complex organisational structure and their disposable income.

Table 2: Firms' size distribution of the target sample.

	Size_S	Size_M	Size_L	*TOTAL*
Target sample	**731**	**582**	**166**	**1479**
Treated firms	360	244	66	670
Control sample	371	338	100	809
	%			
Treated firms on target sample	49.25	41.92	39.76	45.30
Control sample on target sample	50.75	58.08	60.24	54.70

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

Table 2 shows the size distribution of the target sample, constituted by 1479 firms: 49% of the target sample is represented by small firms, while the percentages of medium-sized and large companies are -respectively- 39% and 11%. Almost half of small companies composing the target sample received tax incentives from Norwegian government, along with 42% of medium-sized firms and 40% of large firms; the control sample comprises 51% of small companies belonging to the target sample, 58% of medium-sized firms and 60% of large companies.

In the CIS dataset there is also information about firms' membership to a group and the country of the head office: this allows to construct two further binary variables signalling those firms' belong to a group, namely "gp", including them in "gp_hno" if belonging to a group with head office in Norway and in "gp_hfor" if belonging to a group with a head office in another country. According to previous literature, firms belonging to a group, especially if with headquarter in the same country, have a higher probability to receive R&D tax incentives (Cerulli and Potì, 2012): firstly, because being part of a business group, in general, can boost the propensity and capability of individual group members to innovate thanks to shared resources and information; secondly due to the fact that, governments tend to favour more national innovative firms; accordingly, foreign groups are less likely to receive R&D incentives from the government (Sterlacchini and Venturini, 2019).

Then, other binary variables have been inserted to account for firms' cooperation linkages for innovation: collaborations with the government and research institutes (public and private) are represented as "coop_gov", whether collaborations with universities as "coop_uni". Vertical collaborations involve upstream and downstream partnerships referring to all the joined activities with suppliers, equipment's suppliers, private and public clients: they are identified as "coop_clsupp". On the other hand, horizontal collaborations stand for all the partnerships with consultants, commercial labs, competitors and other enterprises: they are defined by the variable "coop_comp". Taking into account previous contributions, Marzucchi and Montresor (2012) analysed the impact of collaborations with other private and public institutions on of input additionality (R&D) in Spain and output additionality in Italy: in both cases, cooperation with universities, with government agencies and with research institutes seemed to assure positive results.

Another variable has been included to account for the implementation of organisational innovations by firms, "org_inn". Among the types of organisational innovations detected by the CIS there are new business practices for organising procedures, new methods of organising work responsibilities and decision making and new techniques of organising external relations: these three categories have been grouped into a single indicator built as a dummy equal to 1 if at least one of the cited organisational innovations has been introduced by the surveyed enterprises. Only 33% of the 5045 companies belonging to the total sample confirmed the introduction of a minimum of one organisational innovation in the reference year: 60% of these enterprises are innovative, proving that introducing more sophisticated processes regarding the organisational matter is a good predictor of having found a company that invested in R&D in 2014.

Exporting companies are more likely to be innovative and to receive monetary help at national level (Czarnitzki et al., 2011; Sterlacchini and Venturini, 2019): another binary indicator that has been considered is "export", which is equal to 1 for exporting enterprises and equal to 0 for those firms that do not export.

In the dataset, there is information about the presence of employees with a university degree. Based on this, a categorical indicator for the firms' percentage class of graduated employees has been included as a proxy of the firms' human capital ("empud"). This indicator takes values from 0 to 6, as reported in the following table:

Table 3: Target sample's distribution according to the n° of employees with a university degree.

Value	Percentage	Treated	Untreated	Target
0	*0%*	2	17	19
1	*1% - 4%*	9	12	21
2	*5% - 9%*	28	69	97
3	*10% - 24%*	160	254	414
4	*25% - 49%*	165	166	331
5	*50% - 74%*	179	173	352
6	*75% - 100%*	126	113	239

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

Table 3 reports the percentages of employees with a university degree associated to every value of "empud", along with the distribution of the target sample according to the variable and the number of treated and untreated firms. A high number of employees with a university degree could be considered a good predictor of receiving R&D incentives from the government (Cerulli and Potì, 2012) because it usually characterises companies with a certain degree of innovation.

Finally, 10 sectorial dummies have been included: they have been defined following aggregations of the manufacturing and service sectors included in the CIS based on the two-digit NACE[21] (statistical classification of economic activities).

Table 4: Target sample's distribution according to sectors.

Variables	Sectors	Target	Treated/Untreated	
primary_sec	agriculture, forest ,fishing, mining and quarrying	*60*	*T*	26
			U	34
manufacture_sec	food products beverages and tobacco products, manufacture of textiles apparel leather and related products, wood and paper products and printing	*177*	*T*	79
			U	98
pharmachemical_sec	manufacture of coke and refined petroleum products, chemicals and chemical products, pharmaceuticals medicinal chemical and botanical products, rubber and plastics products and other non-metallic mineral products, basic metals and fabricated metal products except machinery and equipment	*146*	*T*	81
			U	65
electronic_sec	manufacture of computer electronic and optical products, electrical equipment, machinery and equipment, transport equipment, other manufacturing and repair and installation of machinery and equipment	*218*	*T*	120
			U	98
construction_sec	construction	*61*	*T*	11
			U	50
retailmotor_sec	wholesale and retail trade, repair of motor vehicles and motorcycles	*106*	*T*	50
			U	56
transtorage_sec	transportation and storage	*84*	*T*	17
			U	67
telecomedia_sec	telecommunications, publishing audiovisual and broadcasting activities, IT and other information services	*314*	*T*	172
			U	142
servicesrd_sec	financial and insurance activities, real estate activities, legal accounting management architecture engineering technical testing and analysis activities, scientific research and development,other professional scientific and technical activities	*242*	*T*	96
			U	146
energyairwater_sec	electricity gas steam and air-conditioning supply, water supply sewerage waste management and remediation	*71*	*T*	18
			U	53

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

As reported in Table 4, more than the half of the target sample is composed by firms belonging to those sectors represented by the variables "telecomedia_sec",

[21] European Commission (2008). NACE Rev. 2 – Statistical classification of economic activities in the European Community, Luxembourg: Office for Official Publications of the European Communities, pp. 43 – 44

"servicesrd_sec" and "electronic_sec", while the other 50% comprises companies from all the other sectors; the three abovementioned variables also represent the sectors with the highest number of firms which received R&D grants from Norwegian government in the reference period, whereas "energyairwater_sec" and "transtorage_sec" constitute a proxy for the sectors with the lowest amount of treated companies.

Table 5: Descriptive statistics of explanatory variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
size_S	1479	0.494	0.500	0	1
size_M	1479	0.394	0.489	0	1
size_L	1479	0.112	0.316	0	1
gp_hno	1479	0.586	0.493	0	1
gp_hfor	1479	0.208	0.406	0	1
coop_gov	1479	0.175	0.380	0	1
coop_uni	1479	0.190	0.392	0	1
coop_comp	1479	0.352	0.478	0	1
coop_clsupp	1479	0.429	0.495	0	1
export	1479	0.642	0.479	0	1
org_inn	1479	0.513	0.500	0	1
empud	1473	4.056	1.329	0	6
primary_sec	1479	0.048	0.214	0	1
manufacture_sec	1479	0.120	0.325	0	1
pharmachemical_sec	1479	0.099	0.298	0	1
electronic_sec	1479	0.147	0.355	0	1
construction_sec	1479	0.041	0.199	0	1
retailmotor_sec	1479	0.072	0.258	0	1
transtorage_sec	1479	0.057	0.232	0	1
telecomedia_sec	1479	0.212	0.409	0	1
servicesrd_sec	1479	0.164	0.370	0	1
energyairwater_sec	1479	0.048	0.214	0	1

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

Table 5 summarizes the main descriptive statistics of the chosen set of covariates: as we can see, apart from that representing the percentage of employees with a university degree ("empud"), all the other variables are dummies. As we have already said, the values of "empud" go from 0 to 6, with a mean equal to 4, corresponding to an average level of employees having a university degree between 25% and 49%; also, the latter is the only variable having 1473 observations, whether the others comprise 1479 observations.

Half of the companies belonging to the target sample introduced organisational innovations in 2014, while more than 60% of them exported their products or services; 59% of firms among the considered ones were part of a Norwegian business group, while 21% of them belonged to a foreign group. Regarding sectors, the most popular one is that labelled "telecomedia_sec" which includes telecommunications, publishing, audiovisual and broadcasting activities, IT and other information services: this aggregate sector accounts for 21% of the companies belonging to the target sample. Even though fishery and other maritime activities constitute a significant part of the Norwegian GDP, only less than 5% of firms were represented by the variable "primary_sec".

4.3.2 Results of the Probit regression

Table 6: Probit estimation for the probability of receiving national public support.

variable	coefficient		S.E
size_S	0.305	**	[0.130]
size_M	0.143		[0.127]
gp_hno	0.054		[0.112]
gp_hfor	-0.230	**	[0.112]
coop_gov	0.402	***	[0.113]
coop_uni	0.303	***	[0.114]
coop_comp	0.012		[0.999]
coop_clsupp	0.165	*	[0.092]
export	0.657	***	[0.079]
org_inn	0.021		[0.071]
empud	0.087	**	[0.037]
manufacture_sec	0.344		[0.218]
pharmachemical_sec	0.330		[0.218]
electronic_sec	0.282		[0.210]
construction_sec	-0.112		[0.272]
retailmotor_sec	0.221		[0.229]
transtorage_sec	-0.494	**	[0.251]
telecomedia_sec	0.377	*	[0.212]
servicesrd_sec	-0.153		[0.214]
energyairwater_sec	-0.298		[0.261]
Constant	-1.459	***	[0.277]
N° of observations	*1473*		
Pseudo R^2	*0.1278*		

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

The dummy variables representing large firms ("size_L") and the sectors of agriculture, forest, fishing, mining and quarrying ("primary_sec") have been omitted since they are taken as reference categories. Overall, the results shown in Table 6 don't differ too much from the hypotheses made before running the regression. Regarding the role of firm size, small firms are confirmed to be more likely to obtain public support from the central government: indeed, the relative coefficient is positive and significant at 5% level of confidence.

Focusing on group membership, being part of a Norwegian group doesn't seem to be a significant predictor of the probability of receiving public financial support for innovation, while belonging to a foreign group is negatively correlated to the likelihood of receiving public incentives: indeed, the relative variable "gp_hfor" has a negative coefficient significant at 5% significance level. This result is also in line with that already provided by Cerulli and Potì (2012): national governments are prone to giving R&D incentives or subsidies to national firms. Thus, belonging to a foreign business group reduces the probability to receive public support.

Horizontal and vertical collaborations are not significant predictors, while collaborations with universities, research institutes and Norwegian government strongly predict the possibility of being offered R&D incentives (at 1% significance level); also, being an exporting enterprise is positively correlated to the possibility of receiving support from the government at 1% significance level, as forecasted by previous literature (Czarnitzki et al., 2011). The percentage of employees with a university degree, represented by the variable "empud" is significant at 5% and has a positive coefficient.

Having introduced organisational innovations seems not to be a good predictor of the possibility to receive R&D incentives from the government: as a matter of fact, the variable "org_inn" is not statistically significant.

According to the results, most part of sectors do not influence the probability of being offered financial help from Norwegian government. Only the variable “telecomedia_sec”, which represents telecommunications, information, publishing audiovisual and IT sectors, has a positive impact on the probability of getting R&D support, though significant at 10% level of statistical significance; on the other hand, “transtorage_sec”, standing for transportation and storage sectors, shows a negative correlation with the dependent variable at a significance level of 0.05.

4.4 PROPENSITY SCORES AND MATCHING

Having obtained the propensity scores from the above regression, treated and untreated firms have been matched according to the one-to-one Nearest Neighbour (NN) matching procedure within specified propensity score calipers, according to which treated and untreated firms are matched only if the absolute difference in their propensity scores is within a prespecified maximal distance (the caliper distance set at 0.01). Most importantly, the exact match for firms belonging to the same sector and the same size class and the common support have been imposed.

A test for the balancing property before and after the matching indicates that the employed matching procedure performs quite well (Table 5):

Table 7: Test for the balancing property before and after the matching.

Variable	Unmatched/ Matched	Mean		t-test	
		Treated	Controls	t	p > |t|
size_S	U	0.530	0.454	2.870	0.004
	M	0.585	0.585	0.0(-)	1.000
size_M	U	0.370	0.422	-2.010	0.044
	M	0.376	0.376	0.0(-)	1.000
gp_hno	U	0.591	0.586	0.190	0.852
	M	0.610	0.653	-1.280	0.202
gp_hfor	U	0.192	0.219	-1.280	0.202
	M	0.174	0.148	1.030	0.306
coop_gov	U	0.250	0.108	7.270	0.000
	M	0.122	0.103	0.870	0.387
coop_uni	U	0.263	0.123	6.970	0.000
	M	0.141	0.139	0.100	0.921
coop_comp	U	0.412	0.297	4.650	0.000
	M	0.319	0.291	0.890	0.373
coop_clsupp	U	0.502	0.368	5.200	0.000
	M	0.383	0.380	0.070	0.944
export	U	0.790	0.518	11.200	0.000
	M	0.751	0.749	0.080	0.937
org_inn	U	0.522	0.511	0.430	0.664
	M	0.477	0.509	-0.960	0.338
empud	U	4.244	3.866	5.470	0.000
	M	4.279	4.301	-0.250	0.804
manufacture_sec	U	0.120	0.123	-0.140	0.889
	M	0.117	0.117	0.000	1.000
pharmachemical_sec	U	0.123	0.081	2.660	0.008
	M	0.092	0.092	0.0(-)	1.000
electronic_sec	U	0.183	0.121	3.280	0.001
	M	0.188	0.188	0.0(-)	1.000
construction_sec	U	0.017	0.063	-4.370	0.000
	M	0.012	0.012	0.000	1.000
retailmotor_sec	U	0.076	0.070	0.440	0.660
	M	0.066	0.066	0.000	1.000
transtorage_sec	U	0.026	0.084	-4.750	0.000
	M	0.026	0.026	0.0(-)	1.000
telecomedia_sec	U	0.256	0.175	3.760	0.000
	M	0.326	0.326	0.000	1.000
servicesrd_sec	U	0.132	0.175	-2.240	0.025
	M	0.143	0.143	0.0(-)	1.000
energyairwater_sec	U	0.027	0.066	-3.440	0.001
	M	0.016	0.016	0.000	1.000

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

Generally speaking, a good performance of the matching procedure is characterised by a bias equal to or smaller than 5%. Indeed, it is equal to 0% (so, its reduction is of 100%) for all the variables representing sectors and firms' size, plus the variable "export"; all the other variables, with the exception of "gp_hfor", show a bias lower than the abovementioned threshold. The t-Tests are a further confirmation of the matching procedure's validity: even in this case, the results are promising. Also, the similarity between the mean of treated firms and the one of companies that belong to the control sample confirms the quality of the match: as for the bias, the variables representing sectors and firms' size have the mean of treated firms which is equal to the mean of untreated firms.

4.5 ATT ESTIMATES

The last group of variables of interest in this analysis is the set of outcome variables that should capture the effects of public incentives in terms of innovative inputs and ouputs. In particular, in order to detect input effects, two continuous variables have been employed: "rd_exp" represents the total expenditure in research and development, obtained summing up intramural and extramural R&D expenditure in 2014; "rd_int" stands for the level of direct R&D intensity, representing the ratio between total R&D expenditure and sales turnover of 2014. Both variables are expressed in thousands of euros. Three further dummy variables have been considered in order to capture potential output effects: “newprod” adds up the introduction of new goods and/or new services in the reference years 2012-2014; “newmkt” is a dummy that signals the introduction of innovative goods and/or services that are new for the entire market in which a firm operates; “newproc” is equal to 1 if a firm has introduced new production methods, supporting activities and logistics, delivery or distribution systems.

It is interesting to point out that some of the chosen outcome variables have already been analysed in the past literature: Cerulli and Potì (2012) evaluated the effectiveness of public subsidies on Italian firms’ expenditure in R&D activities and the intensity of the latter, stating that financial support influenced R&D expenditures at 1% significance level; furthermore, Czarnitzki (2011) focused on the effect of R&D tax credits on innovation activities of Canadian manufacturing enterprises, but he couldn’t find a significant econometric proof that tax incentives had boosted the introduction of new products.

As shown by Tab. 8[22], 231 observations are off support and, thus, they don’t have to be considered in the ATT estimation:

[22] 17 observations (12 treated, 5 untreated) have been omitted because they were outliers.

Table 8: Common support.

TREATMENT ASSIGNMENT	OFF SUPPORT	ON SUPPORT	TOTAL
Untreated	0	799	799
Treated	231	426	657
Tot.	**231**	**1225**	**1456**

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

*Table 9: ATT estimation. (*** p<0.001, ** p<0.05, * p<0.1)*

OUTCOME VARIABLES						
Variable	***Sample***	*Treated*	*Control*	*Difference*		*S.E.*
rd_exp	ATT	1010209.470	503475.725	506733.745	**	205935.615
rd_int	ATT	0.109	0.048	0.061	***	0.009
newprod	ATT	0.838	0.756	0.082	**	0.042
newmkt	ATT	0.646	0.526	0.120	**	0.049
newproc	ATT	0.552	0.650	-0.099	**	0.048

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

Table 9 shows the results of the estimation of ATTs: as far as input additionality effects concern, we see that companies which received public R&D grants from the government have a higher probability of incrementing their total R&D expenditure ("rd_exp") with respect to their counterparts at 5% significance level, while we have a strong proof (statistically significant at level 0.01) that monetary help from the public sector could influence the level of R&D intensity ("rd_int") of recipient firms. Referring to output additionality effects, those companies that received R&D incentives or subsidies from Norwegian government seem to have more chances to introduce new products or services ("newprod") at 5% significance level: among the latter, recipient companies are more expected to produce innovations that are new to the market ("newmkt") than their counterparts at a significance level of 0.05. However, firms belonging to the control group have a higher probability of introducing or implementing processes ("newproc") at 5% significance level.

4.6 FURTHER ANALYSIS

An additional analysis has been made in order to prove the validity of our results: using the same propensity scores, we have matched treated and untreated firms again according to the one-to-one Nearest Neighbour (NN) matching procedure (as in par. 4.4), imposing a caliper distance of 0.001 instead of 0.01.

Table 10: Common support for PSM with 0.001 caliper.

TREATMENT ASSIGNMENT	OFF SUPPORT	ON SUPPORT	TOTAL
Untreated	0	799	799
Treated	430	233	663
Tot.	**430**	**1032**	**1462**

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

In this case[23], the treated firms which are off the support are 430 (almost 200 more than in Table 8) and, consequently, 233 recipients are on support instead of 426.

[23] 11 observations (6 treated, 5 untreated) have been omitted because they were outliers.

Tab. 11: ATT estimation for PSM with 0.001 caliper.
*(*** p<0.001, ** p<0.05, * p<0.1)*

OUTCOME VARIABLES						
Variable	***Sample***	*Treated*	*Control*	*Difference*		*S.E.*
rd_exp	ATT	941522.602	480832.654	460689.948	*	236984.564
rd_int	ATT	0.115	0.059	0.056	***	0.014
newprod	ATT	0.850	0.751	0.099	*	0.059
newmkt	ATT	0.670	0.506	0.163	**	0.067
newproc	ATT	0.524	0.661	-0.137	**	0.067

Source: Autor's elaborations on Norwegian CIS 2014 data (Eurostat).

If in Table 9 results have suggested that recipient firms have a higher probability of increasing their total R&D expenditure ("rd_exp") at 5% significance level, Tab. 11 shows us that this hypothesis is always true, but at a significance level equal to 0.01. It is also confirmed that a monetary help from Norwegian government may influence the level of R&D intensity at 1% significance level: according to previous literature, this can be true since R&D intensity is claimed to have good chances to be used as a proxy for measuring R&D and innovation performances at firm level, due to the nature of its distribution (Hughes, 1988).

Moving to variables referring to output effects, we see that there are slight discrepancies with respect to the previous analysis: "newprod" is characterised by a positive difference between the treated and control sample which is significant at 10% level, meaning that companies which were offered financial help for R&D at national level are more keen in developing new products or/and new services than firms belonging to the control sample at a significance level of 0.1; also "newmkt" shows a positive difference between treated and untreated firms at 5% significance level: hence, among those companies that introduced novelties (for which “newprod" = 1), those comprising the treated sample are more likely to offer new products and services that are also new to the market than similar firms which didn’t receive R&D incentives from Norwegian government. As in Table 9, the difference between treated and untreated firms for “newproc” is negative and significant at level 0.05.

5. CONCLUSIONS

The main goals of this analysis were to determine if Norwegian tax incentives and subsidies, offered at national level, influenced research and development expenditure (generating input effects) and if they contributed to increase firms' innovative outcomes both in terms of new products and processes (output effects). The set of covariances used in the Probit regression to identify possible indicators for recipient firms have been chosen according to results of previous literature: the size of a firm proved to be a significant indicator for the granting of R&D incentives, so did cooperation with other institutions, hiring employees with a university degree and being an exporting company. Being part of a national business group proved to be a significant predictor for receiving R&D grants, while joining a foreign business group seems to disincentive the receipt of monetary support from the public sector. Also sectors of activity could be a significant predictor for the granting of R&D incentives: one can set sectors as explanatory variables (as in the analysis performed in this thesis) or considering only companies that belong to specific sectors. Through the Probit regression, we discovered that small-sized firms and those having employees with a university degree are more likely to receive public support by Norwegian government, while belonging to a foreign group or operating in transportation and storage sectors could prevent companies from receiving public grants at national level. At the same time, operating in telecommunications, publishing audiovisual, broadcasting activities and other information services should enhance the probability of being offered R&D incentives or subsidies as well as collaborating with clients and/or suppliers. A strong positive impact on R&D support is granted by collaborations with universities and research institutes, both public and private. Also exporting firms are likely to receive monetary help from Norwegian government.

The assessment of input and output effects has been provided by analysing the ATT, evaluating the differences between "treated" firms and a control sample. In terms of input additionality, we discovered that R&D grants from Norwegian government increased the probability for recipient firms to spend more in Research and Development Moreover, innovative firms that received R&D incentives or subsidies had higher levels of R&D intensity with respect to those belonging to the control sample.

As far as output additionality concerns, public support given at national level boosted the introduction of new products and services which, in most cases, were also new to the market. Instead, companies belonging to the control sample are claimed to having introduced new processes or having implemented old ones to a higher extent than their counterparts: as a matter of fact, in this case the difference between the "untreated" firms and the "treated" ones was negative.

In order to improve its accuracy, some features of the analysis could have been different. Regarding this, some important limitations of the analysis carried out are related to the nature of the data employed that, for instance, do not allow to consider longer time periods and to distinguish tax incentives from direct subsidies. Despite these limitations, however, this study has been able to detect some positive features of the Norwegian tax-credit scheme: as an example, it seems to have been capable to support small firms to boost R&D expenditures and to promote the introduction of new products and new services.

As we have already seen in Chapter 3, Norway is considered a leader in energy (oil, gas and renewable energies) and maritime sectors. Accordingly, it could be advisable to think about a R&D policy aimed at strengthening the above-mentioned sectors by ensuring public grants (subsidies and/or tax credits) to those firms whose primary activities are fishery or energy production.

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