economies

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Mediating Role of Firm R&D in Creating Product and Process Innovation: Empirical Evidence from Norway

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Abstract: Government funding actively engages in private R&D investment to enhance firm innovation. At the same time, firms are forced to find additional sources of competitive advantage, e.g., through cooperation based on the triple- or quadruple-helix principles. This paper analyses whether government funding and cooperation based on the triple-helix and quadruple-helix principles spur firms' product and process innovation rather directly or indirectly, taking into account the role of firms R&D. For this purpose, we collect data from the Community Innovation Survey and analyse 5045 Norwegian firms by using partial least squares structural equation modelling. Our results confirm hypotheses that public funding and both triple-helix and quadruple-helix cooperation significantly influence firms' research and development activities. Surprisingly, on the one hand, we showed that neither public funding nor triple- and quadruple-helix cooperation affect firms' product innovation directly. Moreover, the results show a negative influence of government funding and triple- and quadruple-helix cooperation on Norwegian firms' product innovation. On the other hand, process innovation is influenced positively and directly by firms' cooperation based on the triple- and quadruple-helix principles. The results of our analyses clearly show the key role of firm's R&D, which has proven to be a mediator of the effects of public funding and triple- and quadruple-helix cooperation on the product and process innovation activities of Norwegian firms.

Keywords: innovation; R& D; government funding; cooperation; triple-helix; quadruple-helix

Citation: Sein, Yee Yee, and Viktor Prokop. 2021. Mediating Role of Firm R&D in Creating Product and Process Innovation: Empirical Evidence from Norway. *Economies* 9: 56. https://doi.org/10.3390/economies9020056

Academic Editor: George R.G. Clarke

Received: 15 February 2021
Accepted: 29 March 2021
Published: 9 April 2021

1. Introduction

Nowadays, economic growth much rely more on innovation, which has also become the core of socio-economic progress in regions (Juknevičienė 2017). New knowledge generation is also important in order to develop improved products and processes (Abbas et al. 2019; Prokop and Stejskal 2019). In particular, investing in R&D is one of the most important factors for technological advancement and economic development in developed and developing countries (Romer 1990; Cin et al. 2017). Innovation needs greater collaboration between businesses and external partners and when they have variety of innovation resources, more R&D activities can be carried out (Stejskal et al. 2018; Sein and Vavra 2020). As a result, faster innovation activities can be enhanced.

In most countries, government funding for corporative R&D is a main practice to enhance innovation. This policy is to correct the market failure by enhancing incentives through the reduction of the cost of R&D activities. Therefore, a number of studies have analysed the influence of public funding and cooperation on the firm innovation performance (e.g., Kotkova Striteska and Prokop 2020). The importance of collaboration between higher education institutions and the non-academic sphere (e.g., Tetrevova and Vlckova 2020), and the efficiency of public expenditures (e.g., Halaskova et al. 2018), or the influence of innovation on the economic performance (Zhylinska et al. 2020) has been re-echoed.

However, the Norwegian innovation system is a paradox. The controversy highlights Norway's proprietary combination of low innovation and high business performance

(Gronning et al. 2006). Innovation is believed to be a key factor in explaining the economic performance of industrialized nations. Therefore, it is difficult for Norway to explain how a country with less investment in innovative activities can achieve higher incomes and economic prosperity in recent years (Castellacci 2008). In addition, public policies have played an important role in the provision of private innovation activities in Norway. Although policy makers in Norway pay too much attention to innovation development at the national and regional level, the level of investment in R&D is lower than in other Nordic and European countries (Solesvik 2017). In addition, the Norwegian economy is not within the top ten range, and it is currently still behind other Nordic countries' economies in terms of innovation development.

Following the above arguments and considering the facts that Norwegian firms have relied on collaboration (Fitjar and Rodríguez-Pose 2014) and have tended to pursue collaborative innovation strategies (decreasing investments in internal R&D) and interacting more with external partners than firms in most other European economies (Fagerberg et al. 2009; Fitjar and Rodríguez-Pose 2013), we aim to analyse how government funding and cooperation influence R&D activities and the innovation of firms in Norway. Following arguments of Solesvik (2017), there is a need to shift towards development of new generation of innovation models, specifically quadruple-helix. For these purposes, we analyse the influence of governmental funding on firms' product and process innovation and on R&D activities. Moreover, taking into account the fact that previous research focused primarily on the issue of triple-helix cooperation in Norway (Strand et al. 2017; Larsen et al. 2018), we consider the influence of cooperation based on both the triple-helix and quadruple-helix principles on firms' R&D and product and process innovation. Therefore, this research contributes to the current state of the knowledge on the influence of cooperation based on the triple- and quadruple-helix principles on firms' R&D and product and process innovation in the case of Norway, whereas we are considering the mediating role of research and development activities. In addition, this research also provides several practical implications.

The paper is organized into five sections. Section 2 presents the theoretical framework and hypothesis development. Section 3 expresses the methodology including data analysis and samples. Section 4 is dedicated to presenting the empirical findings. Section 5 presents the discussion. The last section contains the conclusions.

2. Theoretical Background and Hypotheses

2.1. The Role of Government Subsidies in Enhancing Firms' R&D Activities and Innovation Performance

Government funding could be seen as a free transfer of government grants to firms for specific purposes (Kong et al. 2013). It is not only part of the government's fiscal expenditure but also an important means of direct intervention in the market. Government subsidies can provide many benefits to firms, specifically those with limited financial resources (Amezcua et al. 2013; Söderblom et al. 2015). On the one hand, according to Czarnitzki and Hussinger (2004), government grants can enhance firms R&D and increase intangible assets indirectly. On the other hand, Prokop et al. (2018a) showed in the case of the Czech, Slovak, Estonian, Lithuanian, Romanian, Croatian, Slovenian, and Hungarian firms that the effects of financial sourcing and cooperation could differ across the countries. Therefore, there is a number of analyses dealing with this topic. Bronzini and Piselli (2016), for example, analysed the impact of an R&D subsidy program on innovation in the northern Italy region in the early 2000s. They found that subsidies had a significant effect on the number of patent applications, obviously in the case of smaller firms. Aerts and Schmidt (2008) found that government funded firms are more significantly active in R&D than non-funded firms in Flanders and Germany. Government subsidies have a significant positive impact on the R&D intensity of Chinese energy vehicles firms, in the study of Jiang et al. (2018). In addition, Luo et al. (2016) found that direct government funding stimulates private R&D investment.

In another way, government funding represents alternative source of funding instead of replacing private R&D investment. Government subsidies help in attracting both human and financial capital to increase the firm performance, which can be seen as a sign of legitimacy and quality (Söderblom et al. 2015). According to Zhang and Bai (2017), government subsidies will increase investment in R&D to improve product quality, so government subsidies can have a positive effect on the quality of firms' products. Moreover, government subsidies can minimize the prices and risk of R&D activities, create financial leverage and spill-over effects, also encourage private investment by firms in basic research and development that have a positive impact on product development of the firm and extension of new goods (Hewitt-Dundas and Roper 2010). Moreover, government funding affects scientific and technological cooperation positively (Zhang et al. 2020).

However, some studies have shown that government subsidies have a crowding-out effect on R&D expenditure, for example in the case of selected firms within EU and US countries (Wallsten 2000; Zúñiga-Vicente et al. 2014). According to rent-seeking assessment, giving subsidies is not dependent on the potential or social commitment of a firm, thus subsidies are not advantageous to the performance of firms. Many researchers describe that government subsidies do not influence firm's performance (McKenzie and Walls 2013). Under the R&D tax credit regime, crowding-out effects tend to be greater. Bergström (2000) stated that government subsidies result in low business growth and a decrease in return to scale. In the empirical study of Hud and Hussinger (2015), they found the overall positive impact of R&D subsidies on the R&D investment of SMEs' firms, but there is an evidence of a crowding out effect on German firms in the crisis year 2009.

It is clear from the above-mentioned that governments encourage innovation and economic development by supporting potential R&D projects (Feldman and Kelley 2006). Government funding can fully contribute to enhancing innovation performance indirectly through R&D because R&D activities can have a positive effect on innovation. Government funding can also serve as the additional resources for firms, which allows firms to allocate adequate resources to internal R&D (Dimos and Pugh 2016). Firms' investment in R&D will not only improve their own innovation capacity, but also the level of innovation of society as a whole due to the impact of technology spill-over. R&D investments also fulfil the expectations of government funding. In the findings of Afcha and Lucena (2020), they showed that government funding does not directly affect a firm's innovation, but rather shifts the firm's R&D efforts and transparency to the technology market by using panel data from Spanish manufacturing firms. Likewise, government funding has a positive direct and indirect impact on the firm's innovation mediated by internal R&D and collaboration of firms (Kang and Park 2012).

Regarding the above arguments, we developed the following hypotheses:

Hypothesis 1 (H1). *Government funding has a positive direct influence on firms' R&D activities.*

Hypothesis 2a (H2a). *Government funding has a positive direct influence on firms' product innovation.*

Hypothesis 2b (H2b). *Government funding has a positive direct influence on firms' process innovation.*

Hypothesis 3a (H3a). *Government funding has a positive indirect influence on product innovation mediated by R&D.*

Hypothesis 3b (H3b). *Government funding has a positive indirect influence on process innovation mediated by R&D.*

2.2. The Effects of Triple- and Quadruple-Helix Cooperation on Firms' R&D Activities and Innovation Performance

Collaboration is an important factor in innovation, making it faster and easier (Triguero et al. 2018; Prokop et al. 2019). It is also an important matter in order to achieve sustainable development goals by sharing knowledge and access to innovation (Walsh et al. 2020). Generally, R&D collaboration is recognized as the driving force behind firms' innovation (Un et al. 2010). In the resource-based theory, R&D collaboration is seen as a crucial source that enhances value and competitiveness of firms by integrating local resources with external partners (Miotti and Sachwald 2003). R&D collaboration serves as an organizational tool in sharing and developing new knowledge between partners and helps to overcome the problems caused by spill-over effects (Un and Rodríguez 2018). Internal technology development resources are not enough to deal with environmental complexity and rapid technological changes. As a result, some scholars (Van Beers and Zand 2014; Hottenrott and Lopes-Bento 2016) mentioned that collaboration provides access to external resources and knowledge, enables the internalization of knowledge spill-overs, and improves learning at the organizational level and technology transfer as well, which allows for cost and risk sharing. Therefore, firms can ultimately increase their innovation ability by leveraging the transfer of external and internal knowledge and technologies to acquire the necessary resources and capabilities (Hannigan et al. 2015).

According to triple-helix approach, university-industry-government collaboration is a key important factor to promote innovation (Etzkowitz and Leydesdorff 1995). R&D collaboration with other firms and institutions is a key way to leverage external resources. It is an effective transfer of knowledge. Some empirical studies revealed that there is a positive effect of R&D collaboration on firm innovation (Faems et al. 2005; Koski 2015). Veugelers (1997) identifies significant positive effects of R&D collaboration at the R&D investment level in the Flemish manufacturing sector. However, firms need to build up their capacity such as full-time R&D departments. Evidence in German manufacturing showed that R&D collaborations with universities increased the potential of R&D and R&D investment of firms (Becker and Peters 2000). Firms that collaborate with universities invest more in product development and improvement than firms that do not. Firms that cooperate with public research institutes on R&D have a positive influence on the firm's economic success of innovation (Aschhoff and Schmidt 2008). Belderbos et al. (2015) showed that R&D collaboration can produce significant innovation premium if they are stimulated repeatedly.

Cooperation for innovation is often inspired by a desire to get entry into new or foreign markets and to share risks and costs related to R&D and innovation activities (Mention 2011). According to Miotti and Sachwald (2003), cooperation with research institutes positively impacts the intermediate outcomes of the innovation process (patents). Cooperation with universities has a positive influence on innovative performance of Swedish manufacturing firms (Lööf and Broström 2008). Another indication of university partnership showed the positive impact on the possibility of developing new product in German firms (Aschhoff and Schmidt 2008). However, researchers at research centers and universities tend to focus on academic outcomes and ignore commercial outcomes, which can have a negative effect on university collaboration (Partha and David 1994). Pavitt (2003) emphasizes that universities' response times can be longer, as expected by the businesses sector. In the findings of the Temel et al. (2013), university partnership did not immediately yield the expected benefits, but it takes a certain edge of the university's commitment to better performance.

Moreover, we also focus on the quadruple-helix cooperation model, which is a modification of the triple-helix cooperation model. Quadruple-helix cooperation not only concentrates on the actors from academia, government, and industry, but also allows the enlarged role played by civil society, including media, users, agencies, and culture (Leydesdorff 2012). The idea of quadruple-helix is not well established hence, used broadly in innovation research and innovation policies. Some call this the fourth pillar, or medium, an organization that provides innovation (Liljemark 2004) because they act as a network between triple-helix organizations. According to Carayannis and Campbell (2012), the quadruple-helix model is innovative and especially emphasized the need to focus on cooperation in normally interconnected processes. Cunningham et al. (2018) take the perspective of users and view the fourth helix as the key stakeholder group in the innovation systems. Innovation research and policy present user-driven innovation as an essential factor for success for both firms and the public sector (Eriksson et al. 2005). For these reasons, consistent with Gouvea et al. (2013) and Yun and Liu (2019), we include also the fourth helix represented by the users (customers or client from private sector) to reveal the influence of the cooperation based on the quadruple-helix principles on firms' research and development and both product and process innovation. In this regard, we test hypotheses H1, H2, and H3a&b within the conditions of cooperation based on the triple- and quadruple-helix principles.

Based on the above arguments, we developed the following hypotheses:

Hypothesis 4a (H4a). *Cooperation based on the triple-helix principles has a positive direct influence on firms' R&D activities.*

Hypothesis 4b (H4b). *Cooperation based on the quadruple-helix principles has a positive direct influence on firms' R&D activities.*

Hypothesis 5a (H5a). *Cooperation based on the triple-helix principles has a positive direct influence on firm' product innovation.*

Hypothesis 5b (H5b). *Cooperation based on the triple-helix principles has a positive direct influence on firm' process innovation.*

Hypothesis 5c (H5c). *Cooperation based on the quadruple-helix principles has a positive direct influence on firms' product innovation.*

Hypothesis 5d (H5d). *Cooperation based on the quadruple-helix principles has a positive direct influence on firms' process innovation.*

Hypothesis 6a (H6a). *Cooperation based on the triple-helix principles has a positive indirect influence on firms' product innovation through R&D activities.*

Hypothesis 6b (H6b). *Cooperation based on the triple-helix principles has a positive indirect influence on firms' process innovation through R&D activities.*

Hypothesis 6c (H6c). *Cooperation based on the quadruple-helix principles has a positive indirect influence on firms' product innovation through R&D activities.*

Hypothesis 6d (H6d). *Cooperation based on the quadruple-helix principles has a positive indirect influence on firms' process innovation through R&D activities.*

Figure 1 shows the proposed conceptual framework of this research. We will subsequently perform four analyses. For the first and second, we will analyze the influence of public funding and cooperation based on the triple-helix principles on both product and process innovation. For the third and fourth, we will analyze the influence of public funding and cooperation based on the quadruple-helix principles on both product and process innovation. Within these models, we also plan to reveal the role of R&D activities.

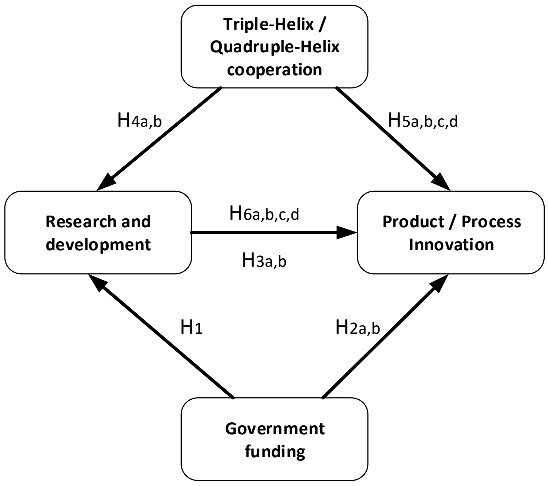

Figure 1. Conceptual framework.

3. Data and Methodology

3.1. Research Design

In this paper, a quantitative approach was conducted and partial least squares structural equation modelling (PLS-SEM) analysis was employed to verify proposed hypotheses according to previous similar studies (Aloini and Martini 2013; Obeidat et al. 2017; Gyamfi and Stejskal 2020). PLS-SEM is one of the most popular techniques in the social sciences. In addition, it is a suitable tool for testing hypotheses in an exploratory manner, particularly for complex path models (Nitzl et al. 2016). SEM is a modern method, which enables the researchers to find various relationships by performing confirmatory factor analysis and integrating both known and unknown variables (Hair et al. 2019). One of the main advantages is that the method can measure the influence of each item in explaining the variance and the relationship between concept of interest at the second order level which regression analysis cannot do (Henseler et al. 2009; Hair et al. 2019). It can estimate using small sample size issues while measuring very complex models with many latent and manifest variables. There are four latent variables and nine manifest variables in our analysis. The description of the variables is shown in Table 1.

In the paper, first, confirmatory factor analysis (CFA) is used to assess the reliability and validity of the model. After that, PLS-SEM is conducted to measure the hypothesis relationships. PLS-SEM is a permissible multivariate statistical system, which allows a comparison between multiple response variables and multiple descriptive variables. Partial least square is designed to cope with problems in data specifically, small datasets, missing values and multicollinearity (Pirouz 2006). Bootstrapping techniques were used to estimate the path models by applying the path-weighting scheme. Bootstrapping assigns measures of accuracy (bias, variance, confidence intervals, prediction error, etc.) to sample estimates. The bootstrap is a way of estimating the properties of predictors based on samples obtained from original findings. Bootstrap is also useful for creating confidence intervals. The simplest nonparametric bootstrap confidence interval is known as the percentile interval. The $(1-\alpha)$ percentile interval for a statistic is the interval that captures the inner 100 $(1-\alpha)$ percent of the bootstrap distribution (Efron 1987). All analyses were performed in SmartPLS software.

Additionally, the previous studies also pointed out that the subsidy becomes an endogenous variable in the analyses focusing on the issue of innovation the public supports (Aerts and Schmidt 2008; Clausen 2009; Dimos and Pugh 2016). We therefore also tested whether our results are not biased. We tested different numbers of subgroups of data (segments) to identify unobserved heterogeneity (in total, 1 to 5 segments). The results confirmed one-segment solution.

Table 1. Variables description.

Latent Variables	Manifest Variables	Descriptions	References
Innovation	INPDGD	A product innovation is the market introduction of a new or significantly improved good or service with respect to its capabili-ties, user friendliness, components or sub-systems.	New products and processes are gaining new markets and market share and support to secure against competitive pressures. Moreover, it seeks to reduce time for marketing, try to get new technologies in producing process and produce better products (Owens 2004).
	INPSPD	A process innovation is the implementation of a new or significantly improved production process, distribution method or supporting activity.	
R&D activities	RMAC	Acquisition of advanced machinery, equipment, software, and buildings to be used for new or significantly improved products or processes.	Generally, R&D supports firms to generate new knowledge, solve technical difficulties and enhances firms' innovation, knowledge stock, technology and productivity (Prokop et al. 2018b).
	RMAR	In-house or contracted out activities for the market introduction of new or significantly improved goods or services, including market research and launch advertising.	
	RRDIN	Research and development activities undertaken by enterprise to create new knowledge or to solve scientific or technical problems (include software development in-house that meets this requirement).	
Funding	FUNGMT	Central government funding which includes grants and subsidies loans etc (including central government agencies or ministries)	Firms has successfully received from government to develop innovation activities (Garcia and Mohnen 2010).
Cooperation	COUNI	Cooperation with universities or other higher education institutes for R&D activities.	Firms that cooperate with external parties introduce innovation more often (Sachpazidu-Wójcicka 2018).
	COGOV	Cooperation with government, public or private research institutes for R&D support.	
	COCUS	Cooperation with customers or client from private sector	

Adopted from the Community Innovation Survey.

3.2. Data Collection

According to previous studies concerning the policy effects (Madaleno et al. 2020; Costa 2021), we are using the Community Innovation Survey (CIS) 2012–2014 in the paper. In total, we analysed 5045 firms in Norway, operating in services and manufacturing sectors. The survey follows all the methodological recommendations of Eurostat for conducting the CIS, which also permits comprehending which features and barriers influence innovation outcomes (Alquézar Sabadie and Kwiatkowski 2017).

Table 1 shows selected variables whereas, according to the CIS, all the variables were binary.

4. Experimental Results

4.1. Confirmatory Factor Analysis

Table 2 shows that all outer loading values are greater than 0.4, whereas, according to Hair et al. (2019), outer loading above 0.4 can be considered acceptable. Moreover, collinearity validity, measured by the Variance Inflation Factor (VIF), shows that the VIF values are lower than 5. Hence, the model shows no collinearity problem in all values shown in Table 2.

Table 2. Outer loading & Collinearity Validity (VIF).

Variables	Product Innovation				Process Innovation			
	Quadruple-Helix		Triple-Helix		Quadruple-Helix		Triple-Helix	
	VIF	Outerloadings	VIF	Outerloadings	VIF	Outerloadings	VIF	Outerloadings
COCUS	1.303	0.742	-	-	1.303	0.735	-	-
COUNI	1.872	0.700	1.756	0.812	1.872	0.705	1.756	0.813
COGOV	1.825	0.695	1.756	0.808	1.825	0.699	1.756	0.807
RMAC	1.712	0.678	1.712	0.677	1.712	0.716	1.712	0.719
RMAR	1.457	0.661	1.457	0.655	1.457	0.622	1.457	0.612
RRDIN	1.838	0.875	1.838	0.881	1.838	0.876	1.838	0.883

Table 3 shows the overall fit of the model. The Saturated model measures relationship between all constructs, whereas the estimated model accesses a total effect of the system. SRMR values which are less than 0.08 (Hu 1998) can be assumed as good functioning of the model. NFI that exceeds 0.90 is acceptable (Byrne 1994) and is greater than 0.95 are indicative of good fitting models (Hu and Bentler 1999).

Table 3. Model fit.

Criterion	Product Innovation				Process Innovation			
	Quadruple-Helix		Triple-Helix		Quadruple-Helix		Triple-Helix	
	Sat.	Est.	Sat.	Est.	Sat.	Est.	Sat.	Est.
SRMR	0.040	0.040	0.019	0.019	0.039	0.039	0.018	0.018
Chi-square	955.965	955.965	212.052	212.052	879.530	879.530	174.836	174.836
NFI	0.938	0.938	0.984	0.984	0.938	0.938	0.986	0.986

Legend: Sat. = saturated, Est. = estimated, SRMR—standardized root mean squared residual, and NFI—normed fit index.

Table 4 below shows the reliability of variables operationalized to measure constructs used in the model.

Table 4. Reliability and validity.

Product Innovation							
Quadruple-Helix				Triple-Helix			
CA	RA	CR	AVE	CA	RA	CR	AVE
0.780	0.804	0.785	0.554	0.780	0.806	0.786	0.555
0.758	0.757	0.756	0.508	0.792	0.792	0.792	0.656
Process Innovation							
Quadruple-Helix				Triple-Helix			
CA	RA	CR	AVE	CA	RA	CR	AVE
0.780	0.807	0.786	0.556	0.780	0.810	0.787	0.557
0.758	0.757	0.756	0.509	0.792	0.792	0.792	0.656

CA = Cronbach's Alpha; RA = Rho_Alpha; CR = Composite Reliability; AVE = Average Variance Extracted.

The Heterotrait-Monotrait (HTMT) ratio of the correlations are used to access the discriminant validity of the model. Discriminant validity has been established between two reflective constructs in the model because all values in Table 5 are lower than 0.85 suggested by (Franke and Sarstedt 2019).

Table 5. Discriminant validity (Heterotrait-Monotrait Ratio).

Product Innovation								
Variables	Quadruple-Helix				Triple-Helix			
	Innov.	R&D Activ.	Coop.	Funding	Innov.	R&D Activ.	Coop.	Funding
Innov.	-	-	-	-	-	-	-	-
R&D Activ.	0.701	-	-	-	0.701	-	-	-
Coop.	0.379	0.606	-	-	0.315	0.508	-	-
Funding	0.444	0.657	0.532	-	0.444	0.657	0.482	-
Process Innovation								
Variables	Quadruple-Helix				Triple-Helix			
	Innov.	R&D Activ.	Coop.	Funding	Innov.	R&D Activ.	Coop.	Funding
Innov.	-	-	-	-	-	-	-	-
R&D Activ.	0.551	-	-	-	0.551	-	-	-
Coop.	0.397	0.606	-	-	0.339	0.508	-	-
Funding	0.344	0.657	0.532	-	0.344	0.657	0.482	-

4.2. Hypotheses Testing

We present the hypotheses testing results in the following Tables 6–9. First, Table 6 shows results for the model considering the influence of government funding and triple-helix cooperation on firms' product innovation in Norway.

Table 6. Path Coefficients—Influence of government funding and triple-helix cooperation on firms' product innovation.

Paths	OS	SM	StDev.	T-Stat.	P-Val.
Gov. funding → R&D	0.542	0.542	0.015	35.756	0.000 ***
Gov. funding → Product Innovation	−0.012	−0.012	0.025	0.488	0.603
Gov. funding → R&D → Product Innovation	0.349	0.349	0.019	18.700	0.000 ***
T-H Cooperation → R&D	0.246	0.245	0.017	14.114	0.000 ***
T-H Cooperation → Product Innovation	−0.048	−0.048	0.022	2.197	0.028 **
T-H Cooperation → R&D → Product Innovation	0.179	0.178	0.014	12.366	0.000 ***

*** significant at $p < 0.01$; ** significant at $p < 0.05$; T-H = triple-helix; OS = Original Sample; SM = Sample Mean.

Second, Table 7 shows results for the model considering the influence of government funding and triple-helix cooperation on firms' process innovation in Norway.

Table 7. Path Coefficients—Influence of government funding and triple-helix cooperation on firms' process innovation.

Paths	OS	SM	StDev.	T-Stat.	P-Val.
Gov. funding → R&D	0.541	0.541	0.014	37.740	0.000 ***
Gov. funding → Process Innovation	−0.059	−0.060	0.026	2.270	0.023 **
Gov. funding → R&D → Process Innovation	0.243	0.243	0.017	14.029	0.000 ***
T-H Cooperation → R&D	0.244	0.244	0.016	15.030	0.000 ***
T-H Cooperation → Process Innovation	0.096	0.097	0.025	3.857	0.000 ***
T-H Cooperation → R&D → Process Innovation	0.130	0.130	0.011	12.103	0.000 ***

*** significant at $p < 0.01$; ** significant at $p < 0.05$; T-H = triple-helix; OS = Sample; SM = Sample Mean.

Third, Table 8 shows results for the model considering the influence of government funding and quadruple-helix cooperation on firms' product innovation in Norway.

Table 8. Path Coefficients—Influence of government funding and quadruple-helix cooperation on firms' product innovation.

Paths	OS	SM	StDev.	T-Stat.	P-Val.
Gov. funding → R&D	0.471	0.471	0.017	27.659	0.000 ***
Gov. funding → Product Innovation	−0.012	−0.012	0.025	0.488	0.626
Gov. funding → R&D → Product Innovation	0.349	0.349	0.019	18.700	0.000 ***
Q-H Cooperation → R&D	0.355	0.357	0.018	19.289	0.000 ***
Q-H Cooperation → Product Innovation	−0.062	−0.061	0.026	2.377	0.018 **
Q-H Cooperation → R&D → Product Innovation	0.263	0.264	0.018	14.538	0.000 ***

*** significant at $p < 0.01$; ** significant at $p < 0.05$; Q-H = quadruple-helix; OS = Original Sample; SM = Sample Mean.

Fourth, Table 9 shows results for the model considering the influence of government funding and quadruple-helix cooperation on firms' process innovation in Norway.

Table 9. Path Coefficients—Influence of government funding and quadruple-helix cooperation on firms' process innovation.

Paths	OS	SM	StDev.	T-Stat.	P-Val.
Gov. funding → R&D	0.472	0.471	0.018	26.182	0.000 ***
Gov. funding → Process Innovation	−0.059	−0.060	0.026	2.270	0.023 **
Gov. funding → R&D → Process Innovation	0.243	0.243	0.017	14.029	0.000 ***
Q-H Cooperation → R&D	0.352	0.353	0.019	18.055	0.000 ***
Q-H Cooperation → Process Innovation	0.120	0.120	0.029	4.081	0.000 ***
Q-H Cooperation → R&D → Process Innovation	0.181	0.182	0.015	12.241	0.000 ***

*** significant at $p < 0.01$; ** significant at $p < 0.05$; Q-H = quadruple-helix; OS = Original Sample; SM = Sample Mean.

The results in Tables 6 and 7 show that government funding spurs firms R&D activities during the innovation processes, both product and process innovation. However, we revealed the negative direct influence of government funding on both types of innovation. Firms' cooperation based on the triple-helix principles significantly influence firms' R&D. On the other hand, only process innovation creation was influenced positively by triple-helix cooperation. Creation of product innovation was influenced negatively by the triple-helix cooperation. These results pointed out the crucial role of firms' R&D as a mediator of government funding and triple-helix cooperation in the processes of the creation of product and process innovation in Norway. These results are consistent with the studies from Jiang et al. (2018), Anzola-Román et al. (2018); Zhang et al. (2020).

Results in Tables 8 and 9 show that the models including the fourth helix represented by the users (clients and customers from the private sector) provided similar results. In the case of Norwegian firms between 2012–2014, the effects of triple- and quadruple-helix cooperation could be considered consistent. The decisions of hypotheses are shown in Table 10.

Table 10. Validation of hypotheses.

Hypothesis	Decision
H1. *Government funding has a positive direct influence on firms' R&D activities.*	Accepted *
H2a. *Government funding has a positive direct influence on firms' product innovation.*	Rejected *
H2b. *Government funding has a positive direct influence on firms' process innovation.*	Rejected *
H3a. *Government funding has a positive indirect influence on product innovation mediated by R&D.*	Accepted *
H3b. *Government funding has a positive indirect influence on process innovation mediated by R&D.*	Accepted *
H4a. *Cooperation based on the triple-helix principles has a positive direct influence on firms' R&D activities.*	Accepted **
H4b. *Cooperation based on the quadruple-helix principles has a positive direct influence on firms' R&D activities.*	Accepted **
H5a. *Cooperation based on the triple-helix principles has a positive direct influence on firms' product innovation.*	Rejected
H5b. *Cooperation based on the triple-helix principles has a positive direct influence on firms' process innovation.*	Accepted
H5c. *Cooperation based on the quadruple-helix principles has a positive direct influence on firms' product innovation.*	Rejected
H5d. *Cooperation based on the quadruple-helix principles has a positive direct influence on firms' process innovation.*	Accepted

Table 10. *Cont.*

Hypothesis	Decision
H6a. *Cooperation based on the triple-helix principles has a positive indirect influence on firms' product innovation through R&D activities.*	Accepted
H6b. *Cooperation based on the triple-helix principles has a positive indirect influence on firms' process innovation through R&D activities.*	Accepted
H6c. *Cooperation based on the quadruple-helix principles has a positive indirect influence on firms' product innovation through R&D activities.*	Accepted
H6d. *Cooperation based on the quadruple-helix principles has a positive indirect influence on firms' process innovation through R&D activities.*	Accepted

* consistent for all presented models; ** consistent for both product and process innovation.

5. Discussion

From our hypotheses' tests, we can see that government funding has a significant positive influence on the R&D activities of Norwegian firms. Our finding supports the previous empirical results, which showed that government funding has a positive effect, and directly enhances R&D of firms (Lee and Cin 2010; Jiang et al. 2018). Moreover, Luo et al. (2016) deliberated on the impact and effectiveness of government policies, which showed that investment in R&D, which is provided by government policies, is critical to radical innovation of firms. Unexpectedly, government funding has a negative direct effect on both product and process innovation in Norway. Hence, this result does not meet our hypothesis H_2. Therefore, we reject this hypothesis for all cases. On the other hand, we showed that government funding could enhance firms' innovation through research and development. Our result corroborates that of Zhang et al. (2020), which revealed that government funding has an indirect influence on the firm process and product innovation. However, the results do not support the finding of Kang and Park (2012), which showed that the government funding directly and indirectly promotes innovation by stimulating R&D of firms and domestic cooperation.

Next, we analysed the influence of cooperation based on the triple-helix principles. This kind of cooperation has a positive significant direct influence on R&D activities of firms in Norway. Similarly to the government funding, we show that cooperation with government and universities has a significant positive indirect influence on both firm product and process innovation in Norway, mediated by research and development. Our findings are consistent for example with following authors Miotti and Sachwald (2003), and Lööf and Broström (2008). They showed that cooperative R&D activities contribute to the improvement of technological abilities in order to develop new products for the firms. Moreover, this triple-helix cooperation maintains a significant positive direct influence on process innovation, but a significant negative indirect influence on product innovation in Norway. Additionally, we also focused on the role of the fourth helix and analysed the effects of quadruple-helix cooperation on firms' research and development and on the product and process innovation. Similarly to the models considering cooperation based on the triple-helix principles, we show that, in the case of Norway, R&D activities play a crucial role. This kind of cooperation keeps a positive direct influence on process innovation, whereas it has a significant negative indirect influence on product innovation. This cooperation also has a significant positive influence on firm's R&D activities in Norway.

This study also provides some practical implications. We can state that governmental funding, triple and quadruple-helix based cooperation are vital for firms' product and process innovation; however, there is the need for continual support of firms' research and development. Therefore, we propose that firms focus primarily on internal R&D and absorptive capacity. Following Kafouros et al. (2020), there is a relationship between firms' ability to absorb external knowledge and R&D intensity, whereas support of different dimensions of firms' absorptive capacity (for example employee skills and organizational practices for exchanging and transferring knowledge across and within the firm) seems to be necessary. Moreover, according to Aldieri et al. (2018), it is crucial to build firms' adaptive capacity to avoid firms' potential lock-in when firms' strategy may make the firm incapacitated in coping with external shocks. In these cases, we also propose firms to focus on R&D trainings and on building internal and external social capital, which play a major role in forming knowledge sharing intentions and behaviours (Akhavan and Hosseini 2016). According to Solesvik (2017), it would be also important to stimulate international cooperation and attraction of foreign experts into R&D for firms in Norway.

Next, we propose that government supports firms' R&D activities (primarily) as well as to aiding in the creation of pro-innovative environment. This includes, for example, reducing the administrative burden on firms, but also finding common goals for firms and universities. Firms should also make more use of contract research with universities, especially in the early stages of product development. As we have shown, such R&D collaboration can be much more effective. Firms could also cooperate with other firms to acquire additional external knowledge sources, in order to boost their internal R&D activities for development of firm innovation. Our results also showed that governmental funding influences positively firms' research and development. Therefore, we propose that public authorities primarily focus on specific firms' needs regarding their research and development. For instance, following the example of Oslo City's introduction of the Programme for Regional R&D and Innovation, it improved in the position of innovation leader; hence, there is the need to continue with systematic support of research and development. Moreover, according to Solesvik (2017), as the innovation models are not static, it is necessary to follow the new trends in the modern economy, which lead to the development of new generation of innovation models, specifically quadruple-helix model including civil society.

Finally, we set additional policy recommendations as follows. Government should emphasize the role of innovation to foster sustainable economy and should increase public funding for supporting R&D activities because the national R&D investment's level in Norway is lower than other Nordic countries. Concurrently, the government should set the clear mission of funding in order to encourage firms to conduct R&D activities very actively. Moreover, the government should set targeted policies that can drive firms to technological change and the policies that can improve their technical capabilities. Apart from that, government should focus on the policies in the development of infrastructure and commercial platforms, increasing the quality of workforce and creating well-established business environment for firms.

6. Conclusions and Limitations

In conclusion, the aim of this paper was to analyse how government funding and triple-helix and quadruple-helix cooperation influence on R&D activities and both product and process innovation of firms in Norway. In the result, government funding has a positive significant direct effect on R&D, but an indirect effect on innovation mediated by R&D in Norway. This kind of funding keeps a significant negative direct effect on process innovation in Norway. Government funding cannot directly support firm innovation without stimulating R&D of firms. It goes through R&D activities to enhance innovation. Similarly, triple and quadruple helix collaborations directly affect the R&D of firms; nonetheless, both have a significant negative direct effect on product innovation and a significant positive direct impact on a firm's process and product innovation in Norway. In addition, the two types of cooperation maintain significant a positive indirect influence on process and product innovation of firms in Norway. This is because firm innovation cannot be improved without cooperation on R&D with external partners (like universities, government and customers). The results of this study show the irreplaceable role of corporate research and development, which, as we have shown, can help firms absorb external financial resources as well as external knowledge. Moreover, it could enable firms to create new additional knowledge, new to the market (radical) innovation, and a high value added (Klímová 2018). The mediation role of research and development is therefore crucial in supporting firm innovation, as we have shown in the example of Norwegian companies.

This study also has some limitations. The major limitation of this study is that we used relatively old data. However, CIS provides unique information about firm's cooperation with various partners as well as information about different financial sources and firms R&D. Compared to other databases that do not contain this information (e.g., OECD, Eurostat, World Bank), despite the age of the data, we consider the Community Innovation Survey to be a relevant source of data for this study. Moreover, we assume that these results could serve as inspiration for future research, which could verify whether the mediation role of firm R&D is valid in other countries. For example, these results could be verified in the case of countries from Central and Eastern Europe where it is possible to see, in many cases, less developed infrastructure, lower development of social capital and trust and the resulting lower efficiency of cooperation on triple- and quadruple-helix principles. Moreover, we also propose that future research could reveal the influence of firms' cooperation based on triple- and quadruple-helix principles on the radical and incremental innovation. It would be also fruitful to include other subjects representing quadruple-helix cooperation in future research. Finally, CIS encompasses European Funds, Local Funds and other funds as well; therefore, we also propose to analyse the influence of other financial sources on firms' innovation and research and development.

Author Contributions: Conceptualization, V.P. and Y.Y.S.; methodology, V.P. and Y.Y.S.; software, Y.Y.S.; validation, V.P.; formal analysis, V.P. and Y.Y.S.; investigation, V.P.; data curation, V.P. and Y.Y.S.; writing—original draft preparation, Y.Y.S.; writing—review and editing, V.P.; visualization, V.P.; supervision, V.P.; project administration, V.P. All authors have read and agreed to the published version of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not Applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

Conflicts of Interest: The authors declare no conflict of interest.

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