Aalto-yliopisto
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Bachelor's Programme in Economics and Business Administration

The importance of public funding on new firms, innovation, and R&D

Does public funding have a positive effect on private R&D investments?

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Abstract

This thesis examines the role of public funding on private investment in research and development (R&D) and tries to answer if public funding can increase private investment in R&D to foster innovation and progress.

This thesis includes a literature review of the existing evidence as well as an empirical analysis that is based on OECD data from 1981 to 2021. The main findings include that public funding can increase private investment but the relationship between them is non-linear. Moreover, the effectiveness seems to change depending on the region and time period.

The findings highlight that policymakers must apply proper policy tools depending on their own needs to maximize the benefits of public funding on private R&D investment and innovation.

Keywords public funding, R&D, innovation, crowding in effect, crowding out effect, OECD

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Työn nimi Julkisen rahoituksen merkitys uusille yrityksille, innovaatioille ja tutkimus- ja kehitystoiminnalle

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Tiivistelmä

Tämä työ tutkii julkisen rahoituksen roolia yksityisessä tutkimus- ja kehitysinvestoinnissa (T&K) ja pyrkii vastaamaan siihen, voiko julkinen rahoitus lisätä yksityisten investointien määrää T&K-toiminnassa innovaatioiden ja kehityksen edistämiseksi.

Työhön kuuluu kirjallisuuskatsaus sekä empiirinen analyysi, joka perustuu OECD:n dataan vuosilta 1981–2021. Tärkeimmät löydökset osoittavat, että julkinen rahoitus voi lisätä yksityisiä investointeja, mutta niiden välinen suhde ei ole lineaarinen. Tukien vaikutus vaikuttaa myös vaihtelevan alueen ja ajanjakson perusteella.

Tulokset korostavat, että päättäjien on sovellettava asianmukaisia työkaluja omien tarpeidensa mukaisesti, jotta julkisesta rahoituksesta saadaan mahdollisimman suuri lisäävä vaikutus yksityiseen T&K-investointiin ja innovaatioihin.

Avainsanat julkinen rahoitus, tutkimus & kehitys, innovaatio, houkutteleva vaikutus, karkottava vaikutus, OECD

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Preface and acknowledgements

I want to thank Professor Mitri Kitti and my peers for their comments, critique, good advice and guidance.

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Otaniemi, Thursday 19th September 2024
Emil Pekkinen

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1 Introduction

Innovation is a key driver for economic growth, thus supporting actions that boost innovation, such as investing in R&D and in new innovative companies, are important measures for ensuring economic growth in the future. Thus, almost all OECD countries are involved in providing some sort of governmental support into R&D activity. The positive effects of R&D and innovation on economic growth and productivity are supported greatly in literature (Howitt, 1998; Maradana et al., 2017; Solow, 1957). The opportunity to innovate is intriguing to both individuals and firms. Given that the R&D process is successful and an innovation is made, the payoffs for the innovators can be substantial, simultaneously making the entire society better off in the long term. (Croitoru, 2017; Munier, 2013) This potential for generating high financial profits due to innovation has arguably been one of the biggest reasons why private equity and especially venture capital have evolved into such notable sectors in the field of finance (Zider, 1998).

The funding of R&D and innovation are mainly achieved with either private investor money or public money. Currently, the major public policies taking place in aiding R&D and innovation are categorised into 1) Tax benefits and direct subsidies into companies, 2) Support of the university research system and high education to produce high-skilled labour and 3) Support of formal R&D across various institutions. (Becker, 2015).

The optimal government policies that boost innovation and R&D should be such that the public and private funding would be complementary to each other. Yet, the effectiveness of these policies that should boost private R&D can be criticised on three main aspects: crowding out through prices, substitution effects and allocative distortions. (Guellec & Potterie, 2000)

This thesis examines the effects of public funding on new firms, innovations and R&D by answering the research question: Does public funding have a positive effect on private R&D investments? Specifically, this thesis explores the relationship between government lead public funding and private investment, to see if public funding has positive outcomes for R&D on the country level, and especially tries to examine if public funding works as a signalling effect for possible further private funding to determine what policies should be in place to optimise the investments to boost innovation and economic growth.

The thesis proceeds as follows. Section 2 consists of the literature review, where the relevant literature is reviewed and summarized. In section 3, the data for an empirical analysis is introduced and explained thoroughly alongside with the empirical strategy. Section 4 will follow up with the results of the analysis and discuss the meaning of the results. Section 5 will consist of the conclusion, which is followed by the references and other miscellaneous items.

2 Literature review

2.1 Evolution of public funding

Public funding can be explained by a few key ideas. There exists economic theory that can explain the rationale behind public funding in R&D and innovation. First, public funding can be used to combat capital market inefficiencies which may be caused by the nature of investing in innovative firms and supporting their risky endeavours. Investors face asymmetric information problems about the firms progress and public funding can act as a signalling effect to outside investors, reducing the information asymmetries, thus making the costs of both external and internal funds smaller. Second, a key belief that new innovations have positive spillover effects explain why governments are willing to invest in R&D (Hyytinen & Toivanen, 2005). The spillover effects of new innovations create positive externalities, for example, new technologies make the labour force more productive, thus creating endogenous growth within the economy i.e. making the economy better as a whole, as demonstrated in equation (1). (Solow, 1956; Swan, 1956)

$$Y(t) = K(t)^{\alpha}\big(A(t)L(t)\big)^{1-\alpha}, \tag{1}$$

where $Y(t)$ is the aggregate output i.e. gross domestic product, $K(t)$ is the capital stock, $L(t)$ is the labour input and $A(t)$ is the level of technology or technological progress during period t. It is good to note that the product between technology and labour, $A(t)L(t)$, represents the 'effective' labour force, thus intuitively when the level of technology increases, the labour becomes more productive. α is a parameter between 0 and 1 and represents the ratio between capital K and output Y, formally called the output elasticity of

capital. Lastly $1 - \alpha$ represents the output elasticity of labour, in other words, $1 - \alpha$ indicates how greatly the output Y changes in respect to labour $L(t)$.

The positive externalities created by innovations make the government subsidies more rational as it is seen in studies that most often the social rate of return is greater than the private rate of return which means that the public funds do not only support the Schumpeterian entrepreneur[1] and rather act as a factor of economic growth. (Griliches, 1979, 1992) Public R&D is also justified because it helps in maintaining economic activity, especially, during the downturns of the business cycle and ensuring that new ideas and innovations are made even if there is a lack of private funding. (Mazzucato & Semieniuk, 2017) Intuitively, it seems clear that ensuring the creation of new firms, innovations, and productive ventures also creates new job opportunities.

Becker (2015) reviews existing economic papers related to empirical research on public research and development policies and their impact on private R&D investment. In this body of work, it is discussed that economists have previously been sceptical about public investment and subsidies in R&D especially due to the problems caused by the crowding out effect but focuses on highlighting the recent findings that indicate that public subsidies tend to stimulate private R&D investments.

Earlier literature, for example (Wallsten, 2000), suggests that public funding eliminates or reduces the amount of private investment in R&D rather than complements it, thus the subsidy would not create any new R&D efforts. This crowding out hypothesis is based on the idea that when a company receives government funding, they would substitute their private R&D investment to

[1] Schumpeter defines the 'entrepreneur' as a person or a group, such as a company, that create innovations, and new markets see e.g. (Munier, 2013).

the public investment. The crowding out effect would lead to a situation where private companies' R&D projects are funded by the government instead of the company itself or its private investors. The worst-case scenario from the crowding out effect would create situations where the government subsidies decrease risk from the entrepreneur and shift it to the government. The companies receiving subsidies would become reliant on subsidies rather than on investor money and would signal to the commercial investors that they are not needed. (Reichert et al., 2021) This would be an unwanted and inefficient effect of the government policies, as one of the main reasons for the policies is to fix market problems, not create them.

Contrary to earlier literature, the more recent papers show that instead of crowding out private money, subsidies tend to crowd in investor money, and the finding from recent papers indicate that government subsidies on R&D tend to have additionality effects. (Aerts & Schmidt, 2008; Carboni, 2011; Cerulli & Poti, 2012) The changes in findings are discussed by (Becker, 2015) as changes in econometric techniques that allow for better control of selection bias. The earlier works are often criticized because they ignore the problem of sample selection-bias which arise from the trend that R&D intensive firms are most likely to apply for subsidies, and when they receive those subsidies, they tend to substitute their own R&D budget from private to public money. The shift from crowding out to crowding in is also discussed by (Klette & Møen, 2011) who studied Norwegian firms and their R&D investment responses to subsidies based on data from two different time periods, pre-2000 and post-2000. They found that post-2000 R&D subsidies seemed to have significant additionality effects whereas pre-2000 did not, which indicates that the effectiveness of the government policies have improved over time.

2.2 Tax credits and direct subsidies

As briefly covered in the introduction section, the most prominent policy tools for supporting R&D include tax benefits and direct subsidies into companies, supporting the university research system and high education to produce high-skilled labour as well as supporting formal R&D across various institutions. The potential effects of each policy tool are demonstrated in Figure 1.

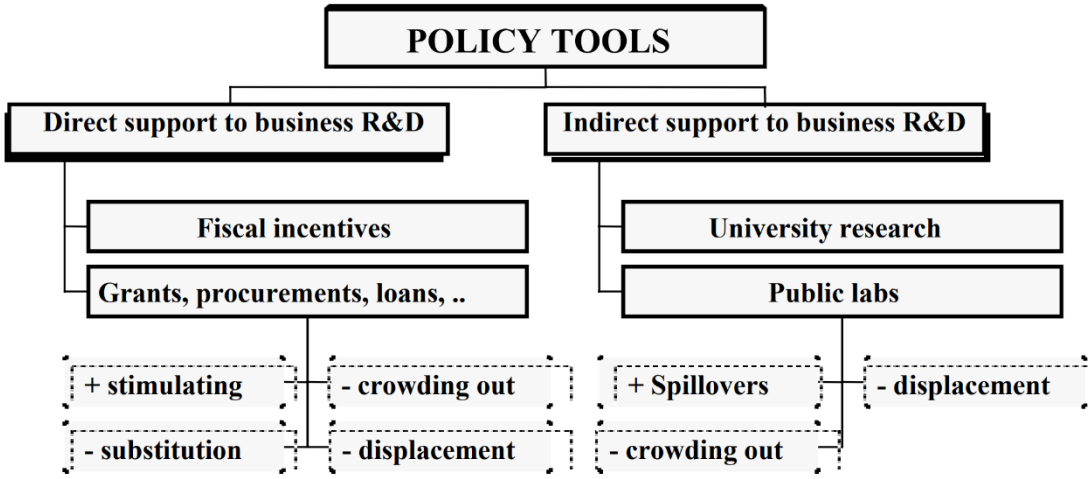

Figure 1. Policy tools and their potential effects (dotted lines) on private R&D outlays (Guellec & Potterie, 2000).

But for the purpose of this thesis, we will focus on the more direct support, i.e., on the tax credits and direct subsidies, and describe the underlying mechanisms that make these policy tools viable and rational for supporting innovation and R&D.

Empirical evidence shows that direct subsidies to companies tend to boost the private expenditure to R&D with a one-to-two-year lag, whereas tax credits are noticed to have an almost instantaneous effect on companies' R&D expenditure. By nature, direct subsidies are more selective and have positive and meaningful effects with a delay, because the government must review different project proposals and applications for the subsidies. Often the

projects selected require fundamental and long-term research that should eventually lead to a breakthrough or innovation. Thus, after the initial funding is done, the wanted result is achieved and the company starts to benefit from the innovation, the company will ultimately be encouraged to use investor or their own private funds to finance their new venture. Therefore, the impact of direct public funding as a catalyst to private funding may not be apparent in the data immediately after receiving the subsidy. (Guellec & Potterie, 2000)

Guellec & Potterie (2000) discuss the optimality of the public subsidies and have found that the effect of public subsidies on private R&D investment is not at all linear and rather resembles a downwards opening parabola similar to the Laffer curve[2]. In other words, the relationship appears to be an inverted U-shape meaning that after a certain level of subsidization the firms start to substitute their private money with the subsidy, but before the threshold level, government subsidies ought to crowd in funding from the business sector. This is illustrated below in Figure 2.

[2] Laffer curve is also an inverted U-shaped curve, and it demonstrates that after a certain tax level, the tax revenue of a country starts to decrease. See e.g. Miravete, E. J., Seim, K., & Thurk, J. (2018). MARKET POWER AND THE LAFFER CURVE. *Econometrica*, *86*(5), 1651-1687. http://www.jstor.org/stable/44955255

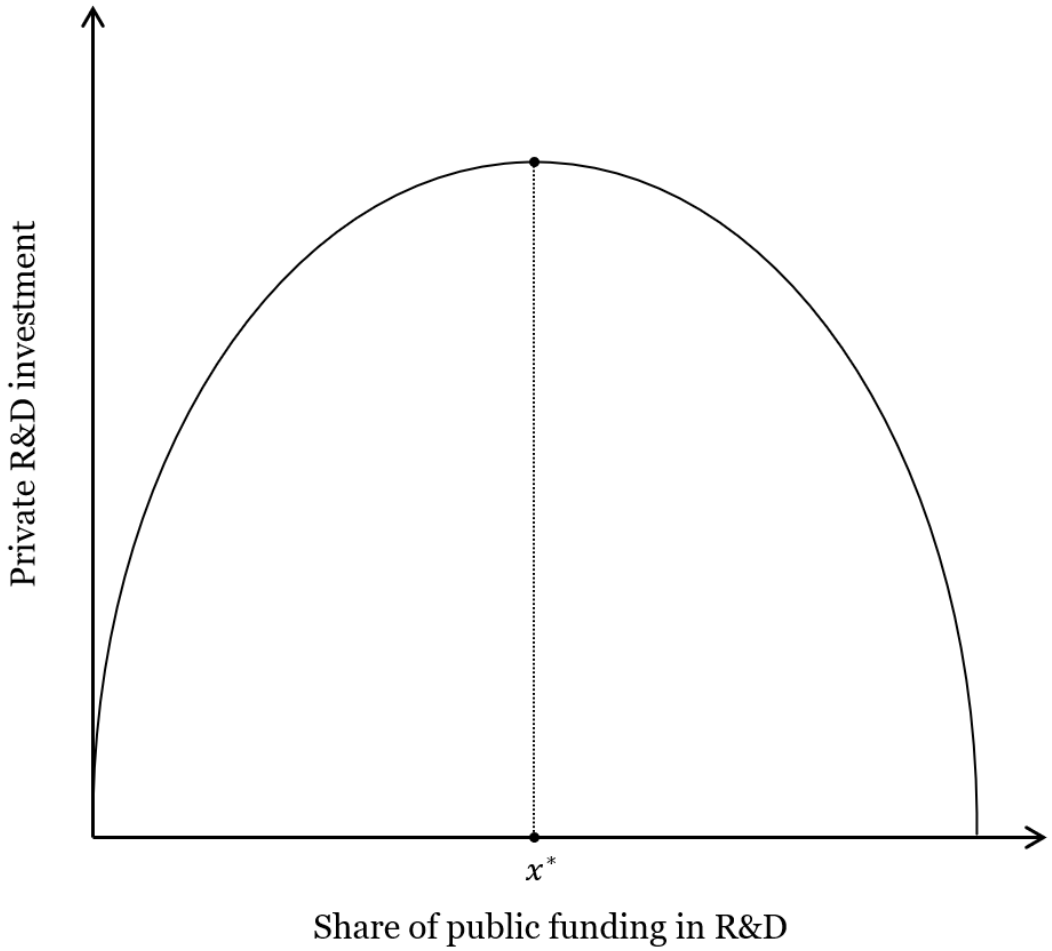

Figure 2: Illustration of the downwards opening parabola describing the relationship of public funding and private R&D investment, where x^* denotes the optimal level of subsidization

Tax credits on the other hand have a quick effect on private R&D spending in the short term because it affects all business spending. Instead of having to spend private funds on only one project, the company can finish earlier projects with a cheaper price tag because of the reduction in taxes. Tax reliefs do not have to conform to government requirements, and firms take that opportunity to accelerate the completion of current projects or invest more to enhance the quality of the outcomes of the projects (Guellec & Potterie, 2000; van Pottelsberghe & Guellec, 1997).

The existing research shows that both direct policy tools can be effective in boosting R&D activity if performed in a coordinated and clever manner. The tax credits are the more effective short-term option, whereas the direct subsidies are more effective in the medium to long run.

2.3 Critique of public funding

Giving out public funding to boost R&D activity in an economy is often criticized. A common critique is that governments tend to prefer to grant the R&D subsidies to larger firms, because they are most likely to meet the subsidy standards set by the government. This inequality in the distribution of the subsidies may contribute to a higher concentration of R&D to firms that already have plenty of market power. By subsidizing industry leaders, the barrier to entry for others is raised and in the long term competition is reduced, which may lead to monopolistic conditions. (Czarnitzki & Ebersberger, 2010)

Another critique is related to the phenomenon that by giving out the direct subsidies to companies, some projects may be funded and carried out, but in the lack of the subsidy it would not have been, due to it being, for example, too risky or non-profitable. (Görg & Strobl, 2007)

2.4 Challenges in research

Görg and Strobl (2007) bring out the challenges related to measuring the true effects of public funding on private R&D. One great issue in the empirical literature has been the lack of the counterfactual to truly determine the effects of treatment.[3] It is impossible to determine how much a firm would have practised privately financed R&D if they would have not received the government subsidy. Because the expenditure of a subsidized firm is unobservable in the case that it did not receive the treatment, researchers must use those firms that did not receive a subsidy as a control group. This is not ideal because most often governments do not provide the subsidy treatment to firms randomly, and the research related to this topic is made difficult because of selection bias.

Thus, the true effect of the treatment is hard to identify, and to identify it properly, researchers should conduct research with a proper counterfactual to eliminate potential selection bias.

[3] The treatment in this context being the amount and type of subsidy that a firm receives.

3 Empirical Analysis

3.1 Data

The data that is used in this empirical analysis is sourced from the OECD Data Explorer. The dataset is called "Gross domestic expenditure on R&D by sector of performance and source of funds" and includes data from the 38 OECD countries with additional non-OECD countries such as China, Russia and Singapore. The expenditure is measured in millions of current US dollars i.e. the values are inflation-adjusted.

The dataset provides panel data spanning from 1981 to 2021, describing R&D funding from both the business enterprise sector as well as data from the government sector. This means that it is possible to analyse the relationships of private and public funding in the field of research and development. Moreover, the diverse geographical coverage and the broad time frame enhance robustness of the analysis and reduces potential biases in the empirical analysis of private and public funding. This dataset is merged with GDP data provided by the World Bank.

Unlike many other empirical papers, this paper takes a more macroeconomic approach as this data is from the country-level instead of the more common firm level data. As discussed by (Guellec & Potterie, 2000), the benefits are that this approach allows the indirect policy effects to be captured within the model and at the macroeconomic level, "government funding of R&D can be considered as exogeneous with respect to privately funded R&D." At the firm level, the assumption that the public funding is exogeneous is questionable, because governments do not provide the subsidies to R&D at random. By comparing countries to each other, we can highlight macro trends and patterns that may not be noticeable at the firm level, reducing the effects of

variables such as firm size, market power or industry. Moreover, this approach enables for the capture of the impact caused by the subsidies alongside the other national policies and institutional factors that might affect R&D in general.

To slightly simplify the empirical analysis, the data is aggregated further to the continent level. In other words, the amount of both business spending and government funding have been summed up by year and continent, to get the aggregate amounts of the two funding options for each continent i.e. Africa, Asia, Europe, North and South America as well as Oceania.

To examine the data, see Appendix A to see the trend how government funding has evolved over the last 40 years in Asia, Europe and North America and see Appendix B for the descriptive statistics of the data set.

3.2 Data preparation, Processing and Variables

The data had to be cleaned from unnecessary variables, and the format of the table had to be transformed to allow for easy panel data analysis. Moreover, the countries had to be properly assigned with their continent. Strings such as “ASI”, “EUR” and “NA” had to be assigned to each country.

Also, since the data did not include the GDP figures for the countries, the OECD data set had to be merged one-to-one with a data set containing GDP data for the corresponding countries.

In addition, the GDP data had to be cleaned from unnecessary variables and countries. Both the funding and the GDP data were modified where there were missing values. Each missing value was replaced with zero.

The variables are introduced and reviewed more thoroughly in Figure 5, Appendix C.

3.3 Empirical Strategy

We conduct the analysis by doing an OLS regression and estimate the effect of public funding on private funding by doing a regression on government funding with continent dummies to account for the possible differences between the regions as well as including the aggregate GDP of each continent. This approach is similar to the empirical research method described in (Oxford Economics, 2020). Additionality, we apply lagged values for the public funding and estimate the model with lags from $t-1$ to $t-5$, because direct subsidies tend to have credible effects in the long run and the treatment effects are most likely to appear in the data with a delay. We formulate the linear regression equation as follows:

$$Y_{i,t} = \beta_0 + \beta_1 GDP_{i,t} + \delta_2 NA_i X_{i,t-k} + \delta_3 AFR_i X_{i,t-k} + \delta_4 SA_i X_{i,t-k} + \delta_5 ASI_i X_{i,t-k} + \delta_6 OCE_i X_{i,t-k} + \delta_7 EUR_i X_{i,t-k} + \epsilon_{i,t-k}, \quad (2)$$

where Y_{it} is the amount of private funding paid by the business enterprise sector in continent i during year t. β_0 is the constant term or the y-intercept that represents the baseline amount of private funding paid in a continent on average in the lack of any government funding. δ_i is the government sector coefficient that describes how much, on average, the amount of private funding increases, when one unit of government funding increases. $X_{i,t}$ is the amount government funding paid in continent i during year t. The error term $\epsilon_{i,t}$ describes the unobserved factors that affect Y_{it}, the unobservable factors could include variables such as overall market conditions that affect the amount of funding available and the characteristics of the investors and firms

in different regions. $GDP_{i,t}$ is the aggregate gross domestic product of continent i in year t, that controls for the economic atmosphere during year t. Each continent has its own dummy variable such as NA_i, EUR_i which are either 0 or 1 depending on the continent.

We formulate the regression in this manner because it allows us to study the mechanisms between private and public funding across different regions and allows to control for the overall economic environment. Including the aggregate GDP of each continent allows us to control for the broader economic conditions that might influence both the private and public funds, this also reduces the omitted variable bias as the state of the overall economy is likely to affect private funding.

4 Results

4.1 Regression Analysis Results

Regression Results

VARIABLE	(1) OLS	(2) One lagged period	(3) Two lagged periods	(4) Three lagged periods	(5) Four lagged periods	(6) Five lagged periods
gdp	0.00749***	0.00864***	0.00901***	0.0101***	0.00959***	0.00976***
	(0.00160)	(0.00139)	(0.00142)	(0.00130)	(0.00124)	(0.00108)
govsector_AFR	10.54***					
	(3.834)					
govsector_ASI	2.445***					
	(0.203)					
govsector_EUR	0.918***					
	(0.232)					
govsector_NA	1.408***					
	(0.220)					
govsector_OCE	7.702***					
	(2.625)					
govsector_SA	5.757**					
	(2.513)					
govsector_AFR_L1		8.194**				
		(3.811)				
govsector_ASI_L1		2.398***				
		(0.184)				
govsector_EUR_L1		0.735***				
		(0.210)				
govsector_NA_L1		1.248***				
		(0.195)				
govsector_OCE_L1		5.313**				
		(2.511)				
govsector_SA_L1		4.150*				
		(2.451)				
govsector_AFR_L2			7.957**			
			(4.014)			
govsector_ASI_L2			2.510***			
			(0.199)			
govsector_EUR_L2			0.700***			
			(0.222)			
govsector_NA_L2			1.223***			
			(0.203)			
govsector_OCE_L2			6.496**			
			(2.879)			
govsector_SA_L2			3.867			

			(2.571)			
govsector_AFR_L3				6.787		
				(4.187)		
govsector_ASI_L3				2.511***		
				(0.194)		
govsector_EUR_L3				0.525**		
				(0.213)		
govsector_NA_L3				1.080***		
				(0.190)		
govsector_OCE_L3				4.308*		
				(2.514)		
govsector_SA_L3				3.104		
				(2.697)		
govsector_AFR_L4					6.212	
					(4.324)	
govsector_ASI_L4					2.746***	
					(0.196)	
govsector_EUR_L4					0.613***	
					(0.210)	
govsector_NA_L4					1.174***	
					(0.185)	
govsector_OCE_L4					5.665*	
					(3.203)	
govsector_SA_L4					2.940	
					(2.850)	
govsector_AFR_L5						5.216
						(4.424)
govsector_ASI_L5						2.886***
						(0.181)
govsector_EUR_L5						0.579***
						(0.189)
govsector_NA_L5						1.166***
						(0.165)
govsector_OCE_L5						3.158
						(2.364)
govsector_SA_L5						2.538
						(3.161)
Constant	-24,458***	-19,654***	-18,562***	-16,194***	-14,422***	-12,118***
	(4,210)	(3,916)	(4,001)	(3,925)	(3,877)	(3,694)
Observations	201	201	201	201	201	201
R-squared	0.962	0.964	0.964	0.964	0.966	0.968
F-statistic	696					

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 1: Regression Analysis Results

4.2 Interpretation and discussion of the results

The same period OLS regression, Model (1) in the table, shows that the effect of government sector funding is positive and significant on the 5% significance level in each of the six different regions. The effect is not uniform in all regions, and it seems to be the strongest in Africa, Oceania and South America, where 1 dollar of public funding seems to increase public funding by $10.54, $7.70 and $5.76 respectively. Potential interpretation for this effect could be explained by lower levels of baseline private funding. Thus, especially in Africa and Oceania, the signalling effect of the public funding truly attracts and crowds in private money to be used in R&D. Other interpretation for the performance of Africa and Oceania, is that public funding is given to significant projects such as renewable energy, or other infrastructure projects that are also supported via private funds.

The effect is less noticeable in Asia, North America and Europe where one dollar of public money increases private expenditures by $2.45, $1.41 and $0.92 respectively. These results indicate that in Europe the crowding out effect seems to be most powerful. To interpret this further, the European subsidies seem to be non-effective in crowding in more private investment, and thus the European amount public funding might be on a too high level exceeding the optimal level. Other interpretation for the small effect in Europe could be that the R&D projects in Europe are deemed to be bad and non-profitable by private agents reducing their willingness to invest in European ventures.

The inclusion of the GDP variable, controls for the overall economic environment in the different regions, and the effect of GDP seems to be uniform in all regions. On average, the amount of business enterprise sector investment is not heavily influenced by the aggregate GDP of a continent because the

values for the coefficients are equal or less than 0.0101, i.e. small effects, according to every model. The GDP coefficients are significant on the 1% significance level.
Unlike in other literature, these results indicate that, the effect of the lagged government funding on private R&D expenditure seems to linearly decrease year-over-year. The values of the coefficients are smaller and smaller as more lag is introduced in the model. For example, the coefficient for public funding in Africa decreases linearly from t to $t - 5$, from 10.54 to 5.22.

Moreover, the credibility of the model seems to suffer when lag is introduced, as most of the results are not anymore significant even on the 10% significance level. This could be caused by the fact that every unobserved value in the dataset was replaced by zero. This modification might have distorted the relationships between the variables and the results maybe be misleading. This modification is problematic for the analysis, because the datasets were somewhat unbalanced, and observations were missing from some countries in multiple years, which means that the time series aspect of this analysis is not the most robust that it could have been.

The interpretation of the constant term is problematic because every model approximates the constant to be significant but negative. Thus, in the lack of government funding the average private investment of each region into R&D would be negative 24,458 to negative 12,118. This could suggest that private R&D investment requires some level of initial public funding. In reality, the negative amount of funding is not possible and should probably be a positive value as it can be expected that there is some level of private expenditure into R&D even in the lack of public subsidies. This problem is likely to be caused by the fact that there are missing values that are replaced by zero and thus the true relationships of GDP, government funding, and business enterprise

expenditure are inaccurate and distorted, so that the baseline appears to be more negative than it should be.

The results indicate that each of the models accurately explain the change in the dependent variable as the R^2 value is approximately 0.96 with each model, i.e., each model explains approximately 96% of the variance in the dependent variable. Criticizing the results more, the selection bias in these models might be prevalent as discussed previously in the literature. The positive effects of each coefficient might signal something about the possible selection bias. Naturally, if the public subsidies are given to innovative and R&D heavy firms, they will have higher expenditure in private R&D as well. In data, this positively correlated relationship would appear as the positive coefficients.

5 Conclusions

This thesis explored the potential effects of public R&D funding on private R&D investment and focused on determining if public policies can truly aid in crowding in private money to potentially innovative firms and projects. To study this phenomenon the analysis included both a literature review as well as an empirical study that was performed using a dataset from OECD that included country-level government and business enterprise sector R&D expenditure data from various countries over a significant period.

Past literature indicates that public funding can stimulate and crowd in private investment in R&D but with some limitations. For example, public funding must be offered in optimal levels so that firms do not substitute their own expenditure with the public investment. When the amount of public funding exceeds the optimal level, it seems to have a crowding out effect, whereas sufficiently sized subsidies seem to crowd in more money from the private side, indicating that the effect is non-linear. Moreover, the literature shows that direct subsidies tend to have a significant effect in the long run, whereas the public policy tool that increases private R&D in the short-term is tax credits.

The literature also discusses that the effectiveness of the public funding tools has improved over time. In the past, government aid in R&D seemed to decrease the amount of private R&D investment i.e. in the past public funding seemed to have a crowding out effect. In more recent papers, public funding is observed to have a crowding in effect. This shift in the effectiveness can be explained by improved econometric tools that have improved the quality of empirical studies around this topic as well as improvements in the allocation of public funding and in the use of these tools. In other words, policymakers and governments have improved in providing public funding.

The empirical results demonstrate that public funding can have a positive effect on private R&D investment. The findings show positive and significant results, they also show that the crowding in effect is the strongest in Africa and Oceania. This supports the literature which emphasizes that public funding reduces information asymmetries and can work as a signalling effect for private investment. This effect is especially relevant in these aforementioned smaller economies where private investment might otherwise be lacking and on a non-sufficient level. Smallest effects can be seen in Europe, indicating that the crowding out hypothesis might hold true in certain conditions. Perhaps the amount of public funding exceeds the optimal level in Europe, decreasing the amount of private investment.

Government funding is highly bureaucratic, competitive, and strict by nature. The firms applying for these funds must meet exact criteria to receive any public funding. This means that studying the effect of public funding on private investment always includes some level of selection bias, leading to inaccurate results unless proper measures are used to control for the bias.

Although the data used in the empirical analysis was thorough and included observations from many countries over a long period, it has its limitations. Certain countries have multiple missing data points. These missing observations were simply replaced with the value 0 as the software used for the analysis could not conduct a time series regression analysis with missing values. The introduction of zero values distorts the results downwards and the missing values should be imputed from the data to better control for the missing values.

In future research, the data set should be more complete to gain more robust results for the analysis. The empirical analysis could provide more accurate

results if it was conducted using funding data from a certain industry or sector, such as the pharmaceutical industry. By analysing a specific sector rather than the aggregate level, the analysis would allow for a more apples-to-apples comparison as the firms in a certain field are somewhat similar to each other, thus reducing the effects of non-observables on the results of the analysis.

Also, since the relationship between public R&D funding and private investment is non-linear according to the literature, the regression analysis should perhaps be polynomial rather than linear. Future research would probably benefit from conducting this analysis for two different time periods, because research shows that the effectiveness has improved over time. The current results include observations from the past and thus could decrease the values for the coefficient.

In conclusion, public funding plays a crucial role in fostering innovation and supporting R&D activities, but its effectiveness varies by region and over time. To ensure that public policies optimally support private sector investment in R&D, policymakers must consider the unique conditions of different regions and industries, while also being mindful of the potential risks associated with over-reliance on subsidies.

References

Aerts, K., & Schmidt, T. (2008). Two for the price of one?: Additionality effects of R&D subsidies: A comparison between Flanders and Germany. *Research Policy*, *37*(5), 806-822. https://doi.org/https://doi.org/10.1016/j.respol.2008.01.011

Becker, B. (2015). Public R&D policies and private R&D investment: A survey of the empirical evidence. *Journal of economic surveys*, *29*(5), 917-942.

Carboni, O. (2011). R&D subsidies and private R&D expenditures: evidence from Italian manufacturing data. *International Review of Applied Economics*, *25*(4), 419-439. https://EconPapers.repec.org/RePEc:taf:irapec:v:25:y:2011:i:4:p:419-439

Cerulli, G., & Poti, B. (2012). Evaluating the robustness of the effect of public subsidies on firms' R&D: an application to Italy. *Journal of Applied Economics*, *15*, 287-320. https://EconPapers.repec.org/RePEc:cem:jaecon:v:15:y:2012:n:2:p:287-320

Croitoru, A. (2017). Schumpeter, Joseph Alois, 1939, Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalist Process. *JOURNAL OF COMPARATIVE RESEARCH IN ANTHROPOLOGY AND SOCIOLOGY*, *8*, 67-80.

Czarnitzki, D., & Ebersberger, B. (2010). Do Direct R&D Subsidies Lead to The Monopolization of R&D in the Economy? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1750031

Görg, H., & Strobl, E. (2007). The Effect of R&D Subsidies on Private R&D. *Economica*, *74*(294), 215-234. https://doi.org/https://doi.org/10.1111/j.1468-0335.2006.00547.x

Griliches, Z. (1979). Issues in Assessing the Contribution of Research and Development to Productivity Growth. *The Bell Journal of Economics*, *10*(1), 92-116. https://doi.org/10.2307/3003321

Griliches, Z. (1992). The Search for R&D Spillovers. *The Scandinavian Journal of Economics*, *94*, S29-S47. https://doi.org/10.2307/3440244

Guellec, D., & Potterie, B. v. P. d. l. (2000). The Impact of Public R&D Expenditure on Business R&D. https://doi.org/doi:https://doi.org/10.1787/670385851815

Howitt, P., Aghion, P. (1998). Capital Accumulation and Innovation as Complementary Factors in Long-Run Growth. *Journal of Economic Growth*, *3*, 111-130. https://doi.org/https://doi.org/10.1023/A:1009769717601

Hyytinen, A., & Toivanen, O. (2005). Do financial constraints hold back innovation and growth?: Evidence on the role of public policy. *Research Policy*, *34*(9), 1385-1403. https://doi.org/https://doi.org/10.1016/j.respol.2005.06.004

Klette, T., & Møen, J. (2011). R&D Investment Responses to R&D Subsidies: A Theoretical Analysis and a Microeconometric Study. *World Review of Science, Technology and Sustainable Development*, *9*. https://doi.org/10.2139/ssrn.1940407

Maradana, R. P., Pradhan, R. P., Dash, S., Gaurav, K., Jayakumar, M., & Chatterjee, D. (2017). Does innovation promote economic growth?

Evidence from European countries. *Journal of Innovation and Entrepreneurship*, *6*(1), 1. https://doi.org/10.1186/s13731-016-0061-9
Mazzucato, M., & Semieniuk, G. (2017). Public financing of innovation: new questions. *Oxford Review of Economic Policy*, *33*(1), 24-48. https://doi.org/10.1093/oxrep/grw036
Miravete, E. J., Seim, K., & Thurk, J. (2018). MARKET POWER AND THE LAFFER CURVE. *Econometrica*, *86*(5), 1651-1687. http://www.jstor.org/stable/44955255
Munier, F. (2013). Schumpeterian Entrepreneur. In E. G. Carayannis (Ed.), *Encyclopedia of Creativity, Invention, Innovation and Entrepreneurship* (pp. 1571-1574). Springer New York. https://doi.org/10.1007/978-1-4614-3858-8_243
Reichert, P., Hudon, M., Szafarz, A., & Christensen, R. K. (2021). Crowding-in or Crowding-out? How Subsidies Signal the Path to Financial Independence of Social Enterprises. *Perspectives on Public Management and Governance*, *4*(3), 291-308. https://doi.org/10.1093/ppmgov/gvab014
Solow, R. A. (1956). Contribution to the theory of economic growth. *The Quarterly Journal of Economics*.
Solow, R. M. (1957). Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, *39*(3), 312-320. https://doi.org/10.2307/1926047
Swan, T. W. (1956). Economic growth and capital accumulation. *Economics Record (Wiley)*, *32*, 334-361.
van Pottelsberghe, B., & Guellec, D. (1997). Does Government Support Stimulate Private R&D? *OECD Economic Studies*, *29*.
Wallsten, S. (2000). The Effects of Government-Industry R&D Programs on Private R&D: The Case of the Small Business Innovation Research Program. *RAND Journal of Economics*, *31*, 82-100. https://doi.org/10.2307/2601030
Zider, B. (1998). How venture capital works. *Harv Bus Rev*, *76*(6), 131-139.

A. Appendix 1: Time Series Evolution of Aggregate Government Funding by Continent

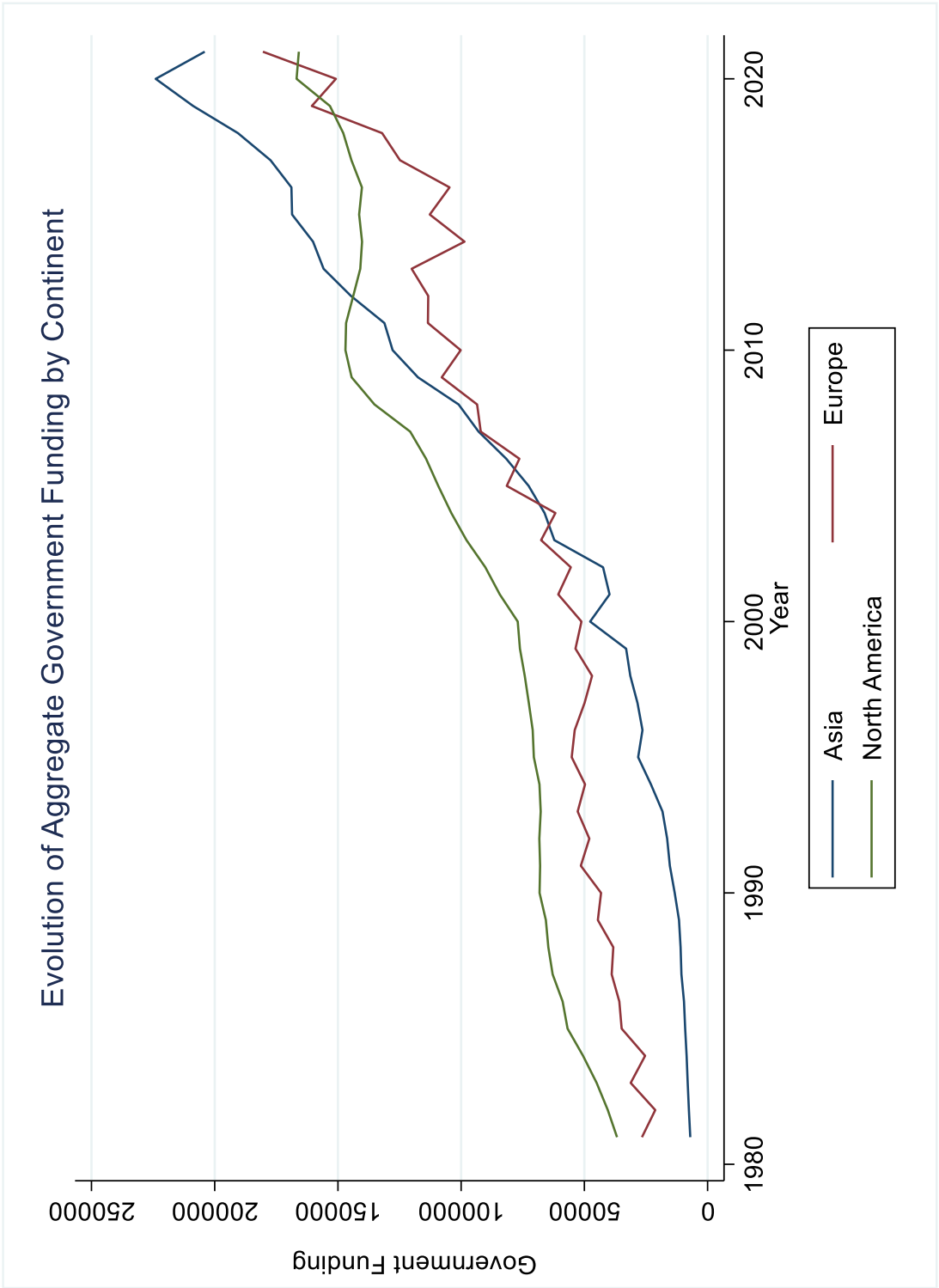

Figure 3: Evolution of Aggregate Government Funding by Continent

B. Appendix 2: Descriptive Statistics of Data

	Mean		Standard deviation		Minimum value		Maximum value	
	(sum) besector	(sum) govsector	(sum) besector	(sum) govsector	(sum) besector	(sum) govsector	(sum) besector	(sum) govsector
continent								
AFR	1904.678	2099.081	325.581	583.7168	1296.307	936.6628	2500.015	2894.932
ASI	234046.1	75679.09	236239.5	69803.32	16266.42	7037.694	837828.8	223973
EUR	121730.2	74668.35	84144.92	40013.87	22446.48	21241.66	356819.2	180454.7
NA	203618.1	98589.97	134258.9	39607.37	37535.22	36747.27	584937.1	166794.9
OCE	1909.87	1703.405	2655.484	1675.717	0	248.8997	11844.79	6619.147
SA	1262.893	2386.074	897.1843	1660.383	417.7789	798.2582	3092.707	5715.805
Total	114765.5	51561.61	160358.8	56997.14	0	248.8997	837828.8	223973

Figure 4: Descriptive Statistics of Data by Continent

C. Appendix 3: Variables Used in The Analysis

Variable	Description
$govsector\_continent$	Separates the effect of government sector funding based on the continent in question, this variable is the interaction term between a continent's govsector, and the dummy variable is either 0 or 1.
$govsector$	Funding received from the government sector, used as the independent variable.
$besector$	Funding received from the business enterprise sector, used as the dependent variable.
GDP	Aggregate GDP of continent i in year t.

Figure 5: Variables used in the analysis, and their descriptions