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Bachelor Thesis Economics and Business Economics

The impact of government R&D Funding on private R&D investments and innovation outcomes

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Abstract

This bachelor thesis investigates the impact of government R&D funding on private R&D investments and innovation outcomes. The data used for this research is a panel dataset from Eurostat and the European Patent Office, containing data for 13 European countries over the years 2012-2019. Empirical analyses were performed based on existing literature and empirical studies to emphasize the extent to which government support is important for stimulating R&D activities and promoting innovation. This study finds a significant effect of government R&D funding on private R&D investments and innovation outcomes. However, different effects are found for the effect of government R&D funding on private R&D investments between Eastern and Western European countries. This research can help policymakers in shaping R&D policy, optimizing government investments in innovation and stimulating cooperation between the public and private R&D investments.

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1. Introduction

In today's high-income capitalism, economies are based on innovation and are characterized by new and higher-quality goods and production methods. More and more countries around the world are becoming developed, which increases world trade. This growth allows less developed countries to grow their economies at a rapid pace. The increasing number of high-income countries makes innovation more important than ever and requires good innovation policies from governments to be successful (Joffe, 2011).

Innovation plays an important role in stimulating economic growth. In addition, it promotes competitiveness and tackles societal challenges in this globalizing world. The source of innovation lies in research and development (R&D), which is a driver of product development and technological progress (Edquist, 2001). In this context, government R&D funding plays a crucial role. It can be a catalyst for innovation by providing financial support and incentives to stimulate R&D activities in various sectors (Hall & Lerner, 2010). The role of the private sector in R&D is also crucial, as firms invest in their own R&D initiatives to create new products and gain competitive advantages (Hall & Mairesse, 1995).

Globally, governments are increasingly recognizing the importance of investing in R&D. This is done with the purpose to create technological progress, higher productivity, and a favourable environment for innovation-driven entrepreneurship. By allocating resources to R&D initiatives, governments seek to support the development of advanced technologies and stimulate sustainable economic development (OECD, 2015). Understanding the impact of government funding of R&D on private R&D investment and innovation performance is essential for policymakers, researchers, and stakeholders in specific industries (UNCTAD, 2018).

This thesis is scientifically relevant because it examines the effect of government R&D funding on both private R&D investments and innovation outcomes. Most studies within this research field examine the effect of government R&D funding on only private R&D investments or innovation outcomes. Furthermore, this study delves deeper into how the relationship between government R&D and innovation outcomes is influenced by private R&D investments.

This research seeks to uncover how governmental support for R&D initiatives influences private R&D investments and innovation outcomes. This leads to the following research question of this thesis: How does government R&D funding influence private R&D investment, and what is their impact on innovation outcomes?

This research question is answered by delving deeper into the underlying theory on this topic in the theoretical framework and by making hypotheses based on this. Wallsten (2000) finds evidence that R&D grants from the government crowd out firm-financed R&D. This is in contrast to Levy & Terleckyj (1983), who found evidence for positive effects of government R&D funding on private R&D investments. In order to test what findings the dataset of this study corresponds to, hypothesis 1 is tested that Government R&D funding has a positive effect on private R&D investments. The majority of the papers in this research field show a positive correlation between Government R&D funding and innovation outcomes. To see whether the same applies to this study, the second hypothesis is tested that government R&D funding has a positive effect on innovation outcomes. The results in the study of Garcia & Mohnen (2010) also show positive effects of government R&D funding on innovation outcomes. But they suggest that the effects of government subsidies may be driven through the increased private R&D expenditures. To test for this the third hypothesis is formulated that the effect of government R&D funding on innovation outcomes is partly driven by private R&D investments. Pilinkiene (2015) states that in Eastern European countries, investments in R&D lag behind and innovation is lower than in the rest of Europe. The last hypothesis will be tested to see if there are any different effects of Government R&D funding in East-Europe than. This hypothesis says that in West Europe, Government R&D funding has a positively stronger effect on private R&D investments and on innovation outcomes than in East-Europe.

These hypotheses will be tested using different regression models. The regressions will be performed on a database from Eurostat. This panel dataset contains data for 13 different countries in the European Union (EU) for the years 2012 to 2019. For government and private sector investments in R&D, the government budget allocations on R&D (GBARD) and the business enterprise R&D expenditure (BERD) reported by Eurostat are used. In this research, innovation outcomes are measured by the number of patent applications to the

European Patent Office (EPO). To test whether there are different effects between Eastern and Western Europe, a distinction is made for which countries are West European and which countries are not. The Netherlands, France, Germany and Belgium are seen as West European in this study. This study uses several controls in the regression models performed. Firstly, there will be controls for the amount of employment and enterprises in high-tech sectors in all models. In addition, the number of people aged 25 to 34 with a tertiary education is controlled for. Finally, all models control for a country's current account balance and the real gross domestic product (GDP) per capita. Because this study uses a panel dataset, the fixed effects regressions performed will control for the year-fixed effects. In addition, country-fixed effects are also included in all models to control for unobserved country differences. A Breusch-Pagan test was performed for all models to control for heteroskedasticity. Because this is present in all models, robust standard errors are used.

The results of the first model show that there is a positive and significant effect of government R&D funding on private R&D investments. This supports the first hypothesis. The second model shows a positive and significant effect of government R&D funding on innovation outcomes. This is in line with the second hypothesis. The results of the third model show a positive and significant effect of private R&D investments on innovation outcomes. Because the results of the first model show a positive effect of government R&D funding on private R&D investments, this third model supports the third hypothesis, that the effect of government R&D funding on innovation outcomes is partly driven by private R&D investments. The results of the fourth model show a positive and significant effect of the interaction term of government R&D funding and the dummy variable for Western European countries on private R&D investments. Due to the previously indicated positive effect of government R&D funding on private R&D investment, these results support the fourth hypothesis.

In the context of this study, the presence of unobserved variables or omitted variable bias may pose a challenge. If these are present, it affects the accuracy of the estimated effects.

The second and following section of this paper discuss previous theory and research on this topic. Based on this theory, hypotheses were formed to answer the research question. The third section discusses the data and relevant variables of this research. The fourth section discusses the models and methodology that are studied. The fifth section presents and discusses the results of the models. The sixth section contains the conclusion and discussion of this research. This is followed up by the references and the appendix.

2. Theoretical framework

In order to answer the research question of this thesis, the existing literature is reviewed and hypotheses are made based on this. A lot of research has been done on the effects of government R&D funding on private R&D investments and its effect on innovation outcomes. Some papers only look at the effect of government R&D funding on private R&D investments, while other papers focus more on the effect on innovation outcomes. The first section of this literature review will discuss the papers that focus only on the effect of government R&D funding on Private R&D investments. The second part discusses the papers that focus on the effects of Government R&D funding on innovation outcomes. The third section will discuss the paper that focus on the effect of government R&D funding on both private R&D investments and innovation outcomes. There is also quite a bit of literature on this subject that focuses on certain areas in Europe and especially Eastern Europe. This is because the effects of government spending are sometimes different between Eastern and Western Europe. Because, as mentioned before, this research focuses on different countries in the European Union, this literature will also be discussed. The fourth and last section of the literature review will consist of this.

2.1 The effects of Government R&D funding on private R&D investments

The government's intentions to invest in commercial research and development (R&D) have often been the subject of extensive research. These interventions are often justified by market failures that result in underinvestment in innovation. One of those market failures is that firms cannot capture the full economic benefits of their investments in R&D. While most studies conduct empirical research, Leyden & Link (1991) create a theoretical framework to investigate the effect of government R&D funding on private R&D investments. They do so by proposing a framework that emphasizes the importance of infrastructure technology in facilitating R&D processes. Infrastructure technology refers to the technologies that support essential services in sectors such as energy and IT. Their results show that government R&D is not only complementary to private R&D, but also ensures the spread of technical knowledge.

Government R&D funding can have complex effects on private R&D investment. On the one hand, it can stimulate private R&D investment, on the other hand, it can replace private R&D investment, known as the crowding-out effect. Private R&D investment can be stimulated by reducing the financial risk for firms by sharing the costs of R&D projects. Crowding-out effects may arise because firms get the idea that they can count on government funding for their R&D activities. As a result, they can reduce their own R&D expenditure and replace it by government fundings (Arora & Gambardella, 1994). Some empirical studies on the effectiveness of government R&D funding find that it crowds out private R&D investments. An early paper on the topic is Mamuneas & Nadiri (1996), who do research on both government R&D funding and tax incentives. They try to estimate the impact of publicly financed R&D on R&D investments utilizing an econometric approach, specifically a cost function dual to a production function using data of Twelve two-digit US manufacturing firms over the period 1981-1988. The results show that publicly financed R&D leads to cost savings, but crowds out privately financed R&D investments. Wallsten (2000) finds evidence that R&D grants from the government crowd out firm-financed R&D. He does so by performing a multi equation model using firm-level US data between 1990 and 1992. Similar results of crowding out effects are found in the paper of Montmartin & Herrera (2015). In addition to the research of Wallsten (2000), different sorts of government R&D policies are researched. They investigate the effects of R&D subsidies and tax incentives on R&D financed by firms using data from 25 OECD countries from 1990 to 2009. This is done using spatial dynamic panel data methods. The results show that R&D subsidies decrease business-funded R&D intensity. This would also mean that government R&D funding does not result in an increase in total R&D.

In contrast to these studies, papers do find evidence of positive effects of Government R&D funding on private R&D investments. Levy & Terleckyj (1983) first find evidence for this. They make use of contract R&D data, as reported by industry performers in the National Science Foundation (NSF) surveys between 1949 and 1981, to estimate the impact of government R&D expenditure on private R&D investment and productivity. The study finds that government contract R&D has a positive effect on stimulating additional private R&D expenditure. They estimate that $1 of government contract R&D performed in industry induced 20-30 of private R&D expenditure. Guellec et al. (1997) also find evidence of positive effects of government R&D funding on private R&D expenditure. In their paper they examine the impact of different types of government support on private R&D in 17 OECD countries from 1981 to 1996. The analysis includes more country and welfare policy aspects compared to previous studies, using a dynamic R&D investment model. According to the study, direct subsidies have a positive effect on private R&D and are more beneficial in the long run than fiscal incentives. Similar results are found in the research done by Coccia (2010) who uses data from Eurostat at an aggregated level. He performs econometric linear regression models to investigate the relationship between public and private R&D investments in different countries. The results show that public expenditure on R&D is complementary to private investments in R&D. It is also indicated that countries with a high level of development (high GDP per capita) have a trend of higher private R&D investments (as a percentage of GDP) compared to public investments.

Small businesses often have the problem that they would like to innovate but lack the budget for this. It is important for these businesses to attract external funding to be able to carry out innovation processes. Not only Government R&D funding helps these small businesses, attracting external funding in the form of venture capital is also import for this process. (Hall & Lerner, 2010). Government R&D funding can play a role in this by making companies attractive for external funding. This topic is investigated by Wu (2017). His research shows that government R&D subsidies promote the signalling effect for companies in China. The signalling effect concerns the extent to which companies are seen as attractive to external investors. A positive signalling effect of government R&D funding may motivate firms to increase their own R&D investments. Firms that benefit from a strong signalling effect are be more likely to pursue innovative projects. This can result in accelerated innovation outcomes, as firms strive to maintain their attractiveness to external investors.

2.2 The effect of government R&D funding on innovation outcomes

This section will discuss the papers that investigate the effect of government R&D funding on innovation outcomes.

Contrary to the literature discussed in the first section, Bronzini & Piselli (2016) examine the effect of R&D subsidies on innovation outputs rather than on innovation inputs, with firm innovation being measured by patent application. In this way they try to investigate the impact of an R&D subsidy program on firm innovation in Northern Italy. Using a regression discontinuity design, they compare the patenting activity of subsidized and non-subsidized firms near the program threshold. The results show a positive effect of the subsidy program on the number of patent applications, especially for small and medium-sized enterprises. In the study of Guo et al. (2016), patents are also used as a measure of innovation outcome. On top of that they also look at exports and sales of products to measure innovation. Their research investigates the impact of the Innovation Fund for Small and Medium Technology-based Firms (Innofund) using fixed effect panel data on Chinese manufacturing firms from 1998 to 2007. The findings show that firms supported by Innofund exhibit higher levels of innovation output and are consistent with many existing studies, who argue that government funding stimulates firms R&D activities. Similar results are found in the study of Zhang & Guan (2018). They investigate the time-varying effects of Government R&D subsidies and tax incentives on firms innovation performance, by measuring innovation outcomes as the performance of new products. The study focuses on high-tech firms in Beijing Zhongguancun Science Park from 2005 to 2014. They emphasize the importance of considering both short-term and long-term effects for direct subsidies and indirect tax credits from the government. The results show that direct subsidies have a positive impact on innovation performance in the short run, but a negative impact in the long run.

2.3 The effect of government R&D funding on private R&D investments and on innovation outcomes

This section will discuss the papers that, like this study, investigate the effect of government R&D funding on private R&D investments and on innovation outcomes.

The research by Garcia and Mohnen (2010) delves into the impact of government support on R&D and innovation based on micro data from the third wave of Community Innovation Survey (CIS) during the years 1998-2000. This impact is estimated using a structural model explaining the various sources of government support and their effects on R&D and innovation output. Innovation output is measured by the share of total sales due to new or substantially modified products. The study shows a correlation between government subsidies and increased R&D expenditures of firms, which leads to improved innovation outcomes. They suggest that the effects of Government subsidies may be driven through the increased R&D expenditures.

The paper by Hu (2001) gives some more evidence on the suggestion of Garcia & Mohnen (2010) that the effects of Government subsidies may be driven through the increase of private R&D expenditures. Hu (2001) examines the impact of R&D expenditure on productivity in Chinese enterprises, focusing on the roles of private and government R&D. A system of three equations, including the production function, private R&D and government R&D, is analysed. The study reveals a strong relationship between private R&D investment and enterprise productivity. Although its direct contribution to enterprise productivity is insignificant, government R&D contributes to productivity indirectly by promoting private R&D.

Unlike previous papers, Lerner (1996) measures innovation outcomes by looking at growth in employment in addition to growth in sales. In his paper he uses a quantitative approach to study the long-term effects of the Small Business Innovation Research (SBIR) program on the growth of firms. This program allows the government to act as a venture capitalist initiative to stimulate innovation in small businesses. The study concludes that SBIR winners experience significant growth in sales and employment compared to firms who were not awarded with the SBIR program.

2.4 Differences between East and West Europe

Eastern Europe experienced tremendous economic growth after the fall of the Soviet Union. This was because economies became more open and there was a lot of investment in the form of Foreign Direct Investment (FDI). The main reason for this investment was the low labour costs in Eastern Europe (Popescu, 2014). This growth started to stagnate after the crisis of 2008 because Eastern European countries received less foreign investment. A solution for this could be to change the growth models in Eastern Europe from a model based on foreign direct investment to a model based on innovation. This can ensure that the current development ceiling in Eastern European countries is broken. (European Investment Bank, 2018). This development ceiling, which arose from the crisis, is further demonstrated in the research of Pilinkiene (2015). He examines the relationship between R&D investments and competitiveness in the Baltic States over the years 2007-2013 and tries to compare it with averages in the EU. The findings show a positive effect of R&D investments on efficiency. However, it is noted that R&D investments in the Baltic States are growing slowly and lagging behind the EU average and that the economies in the Baltic States mainly consist of low-tech industries. Estonia manages to distinguish itself from the Baltic States in terms of competitiveness and innovation capacity by approaching the EU average R&D expenditure.

The findings show that a significant part of R&D funding comes from the state budget and is allocated to the higher education sector. This is in contrast to countries with much higher innovation where most R&D expenditures come from the business enterprise sector. In the study of Coccia (2010), it is indicated that countries with a high level of development (high GDP per capita) have a trend of higher private R&D investments (as a percentage of GDP) compared to public investments. These findings could mean something for the differences between Eastern and Western Europe.

A major problem that stagnates innovation in Eastern Europe is brain drain. This means that many highly educated people leave Eastern Europe for Western Europe, because of better chances. There are too few jobs for highly educated workers, because the economies in many Eastern European countries are based on low-tech industries. This makes innovation a less important factor for economic growth in these countries (Lugones & Suarez, 2010). Empirical evidence on this is given by Pece et al. (2015), who investigate the determinants of R&D expenditure, patents and their impact on economic growth in CEE countries. They focus on the countries: Poland, the Czech Republic and Hungary. The results show that tax incentives and public support for R&D and patents promote private sector innovation, but have no direct impact on aggregate productivity growth. It is emphasized that economic growth is mainly driven by resource allocation to R&D rather than innovation. The study further emphasizes the importance of education and research investments in promoting economic development and improving living standards in CEE countries. This topic is also researched in the study of Petrariu et al. (2013). They investigate the link between innovation and economic growth in the countries of Central and Eastern Europe (CEE). They consider different proxies to measure innovation, such as R&D expenditure and patents. The results show a negative effect of R&D as a percentage of GDP and the number of patents on economic growth. It is indicated that this is typical for the catching-up process that these countries went through. These countries experienced rapid growth, because many inventions were imported from more developed countries. This caused less interest in domestic research. Furthermore, it is concluded that the gap between the Western and Eastern economies can be reduced by investing in innovation.

2.5 Hypotheses

In this section, the hypotheses will be formulated based on the previous information from the theoretical framework.

First, it was stated that Wallsten (2000) found evidence that R&D grants from the government crowd out firm-financed R&D. These findings were supported by the studies of Montmartin & Herrera (2015) and Mamuneas & Nadiri (1996). In contrast, earlier in time, Levy & Terleckyj (1983) found evidence for positive effects of government R&D funding on private R&D investments. They indicate that $1 of government contract R&D performed in industry induced 20-30 of private R&D expenditure. This is in line with most studies that have looked into this topic and show that government R&D funding promotes private R&D investments. In order to test which findings the dataset in this study corresponds to, hypothesis 1 is tested that Government R&D funding has a positive effect on private R&D investments.

The majority of the papers discussed in the second section of the theoretical framework show a positive correlation between Government R&D funding and innovation outcomes. Bronzini & Piselli (2016) for example state that every extra government funding between 200,000 and 300,000 euros results in one extra patent application. To see whether the same findings apply to the dataset of this study, the second hypothesis will be tested that government R&D funding has a positive effect on innovation outcomes.

The results in the study of Garcia & Mohnen (2010) show positive effects of government R&D subsidies on innovation outcomes. But they suggest that the effects of government subsidies may be driven through the increased business enterprise R&D expenditures. HU (2001) elaborates on this by showing that there is no direct significant effect of government R&D funding on the productivity of firms. He does indicate that government R&D funding contributes to productivity indirectly by promoting private R&D. To test whether this is the case in this study, the third hypothesis will be tested that the effect of government R&D funding on innovation outcomes is driven by private R&D investments.

The fourth section of the theoretical framework states that in Eastern European countries, investments in R&D lag behind and innovation is lower than in the rest of Europe (Pilinkiene, 2015). Moreover, investments in innovation in Eastern European countries cannot be fully utilized because there are too few jobs for highly educated people. This causes a brain drain in Eastern European countries (Lugones & Suarez, 2010). In order to investigate whether there are different effects of Government R&D funding in Europe, the last hypothesis will be tested that in West Europe, Government R&D funding has a positively stronger effect on private R&D investments and on innovation outcomes than in East Europe.

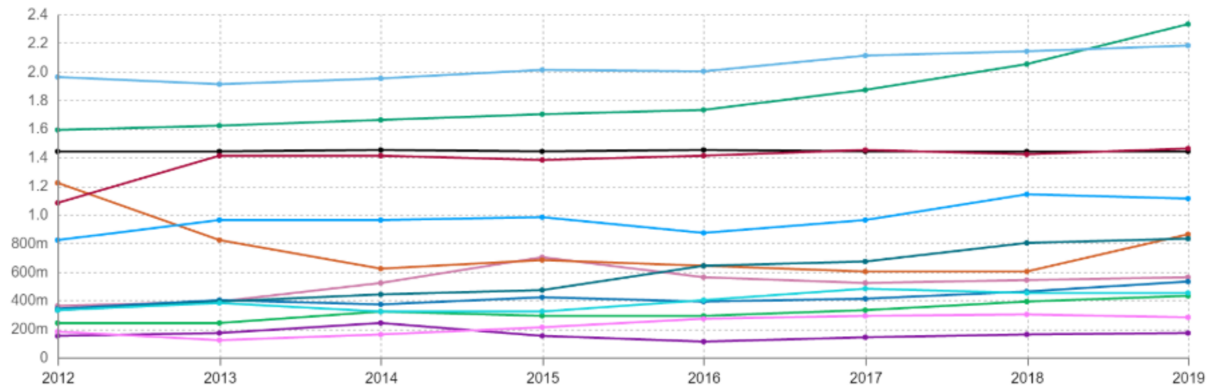
3. Data

The dataset used for this study comes from Eurostat, this is the statistical office of the European Union. Eurostat contains data from all countries in the EU and sometimes also from countries outside the EU. The researched period for this dataset is from to 2012 to 2019. This period is chosen because for many variables the available data starts from 2012 and ends in 2019. The dataset contains data for 13 countries from the European union, those countries are: Belgium, Bulgaria, Germany, Estonia, France, Hungary, Croatia, Latvia. Lithuania, Netherlands, Poland, Romania and Slovakia. The reason that only these countries were selected is because for several variables a lot of data was missing for most countries in the EU. Especially the data concerning government R&D funding and private R&D investments, was missing for many EU countries. Descriptive statistics for all variables used can be found in appendix A.

3.1 Private R&D investments and patent data

The first dependent variable of this study concerns private R&D investments in a country. For this purpose, the study looks at the business enterprise R&D expenditure (BERD) reported by Eurostat per country. Graph 1 shows the amount of BERD as a percentage of the GDP for the same countries. It can be seen that over the years Germany and Belgium with some distance have the highest relative BERD followed by the Netherlands and France. Among them are the Eastern European countries of this study, where Hungary with its relative BERD comes closest to the Western European countries. It is striking that in 2012 Estonia had a higher BERD as a percentage of their GDP than the Netherlands, but this has decreased sharply for Estonia in the years after.

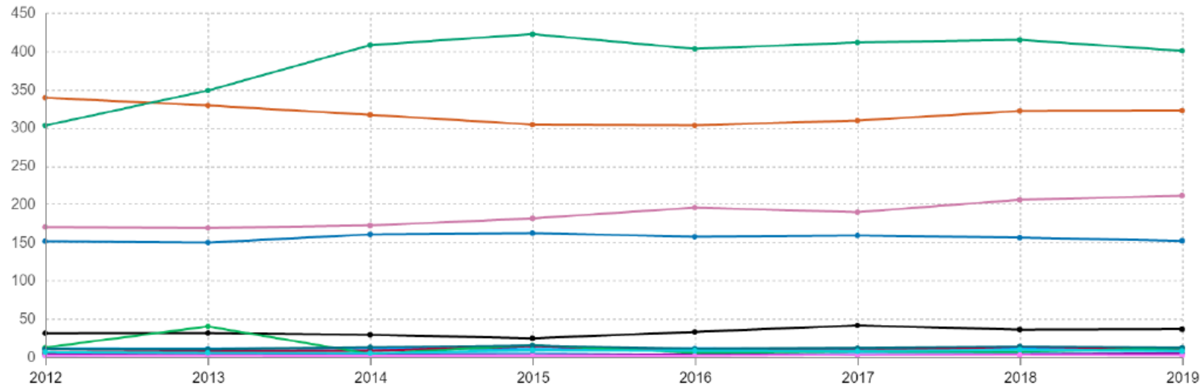
Graph 1



Graph 1: BERD as a percentage of the GDP for the researched countries of this study during the years 2012-2019.

The second dependent variable of this study is about the innovation outcomes of a country. The variable patents is used for this, which concerns the number of patent applications to the EPO. Using patent applications to measure innovation outcomes is in line with the studies of Bronzini & Piselli (2016) and Guo et al. (2016). Patents are most likely the most definitive measure of innovation compared to other proxies measured through surveys. Examples include the number of new products or processes introduced by firms. In contrast, patents are less exposed to personal or subjective considerations (Bronzini & Piselli, 2016). In previous literature on innovation, Griliches (1990) proposes to use patent activity as an indicator of economically valuable knowledge. According to him, this would thus be a good way to measure inventive activity, even if only a part of the inventions is patented. Furthermore, Hagedoorn and Cloodt (2003) conclude that in the context of enterprises, patents are a good indicator of innovation at the firm level. Graph 2 shows the amount of patent applications to the EPO per million inhabitants for all the researched countries over the years 2012-2019. It can be seen that the Netherlands and Germany by far have the most patent applications, followed by France and Belgium. There is a huge difference in the number of patent applications between the Eastern European countries and the western European countries. This graph is in line with the statements of Lugones & Suarez (2010) about the stagnating innovation in Eastern Europe.

Graph 2



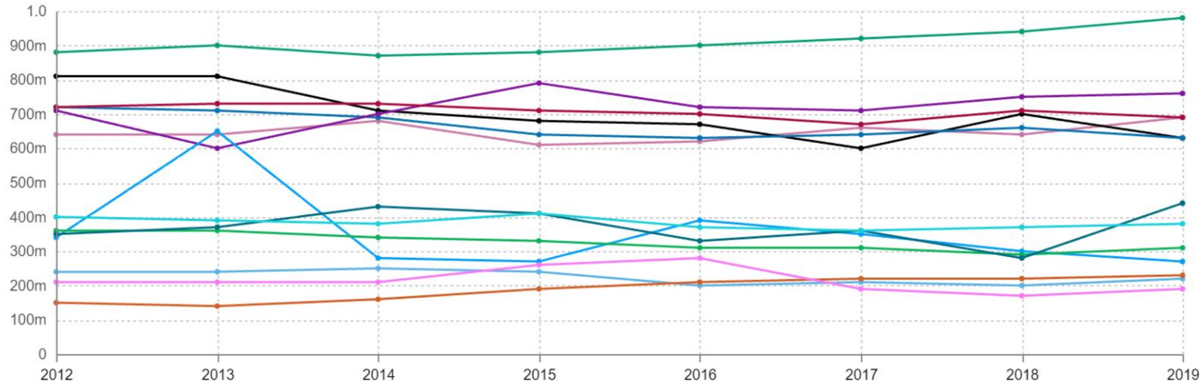
Graph 2: Patent applications to the EPO per million inhabitants for the researched countries of this study during the years 2012-2019.

To look for a difference in effects between countries in West Europe and East Europe, a dummy variable is created that takes the value 1 if a country is located in West Europe. This applies to the countries Netherlands, Belgium, France and Germany. This does not apply for the countries in East Europe, these are: Bulgaria, Estonia, Hungary, Croatia, Latvia, Lithuania, Poland, Romania and Slovakia.

3.2 Government R&D funding

The first independent variable of this study will concern the total amount of government R&D funding in a country. The study will look at the total government budget allocations on R&D (GBARD) in a country reported by Eurostat. Graph 3 shows the total GBARD as a percentage of the GDP. It can be seen that certain countries like Croatia and Estonia come closer to the GBARD ratios of Western European countries, while this is not the case for the BERD ratios in Graph 1. In graph 4, a considerable difference can be seen between the values of the real GDP per capita in Eastern and Western European countries. The top four lines are those of the Netherlands, Germany, Belgium and France. Graphs 1, 3 and 4 therefore partly show an image of the findings of Coccia (2010), who indicated that countries with a high level of development (high GDP per capita) have a trend of higher private R&D investments (as a percentage of GDP) compared to public investments.

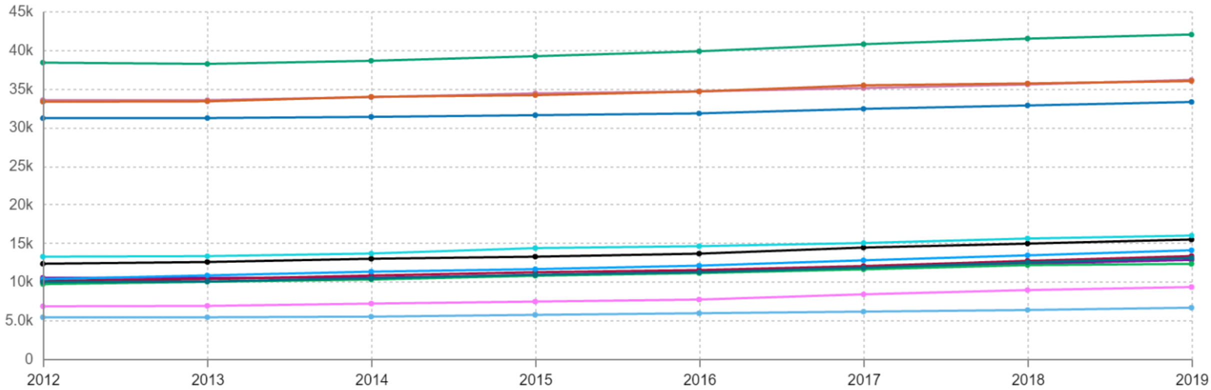
Graph 3



Graph 3: GBARD as a percentage of the GDP for the researched countries of this study during the years 2012-2019.

Belgium Bulgaria Germany
Estonia France Croatia
Hungary Lithuania Latvia
Netherlands Poland Romania
Slovakia

Graph 4



Graph 4: The Real GDP per capita for the researched countries of this study during the years 2012-2019 determined on the basis of a price index compared to the base year 2010

Belgium Bulgaria Germany
Estonia France Croatia
Hungary Lithuania Latvia
Netherlands Poland Romania
Slovakia

3.3 Control Variables

In many of the previously discussed papers, research is done at the firm level, where this research is done at the country level. This study uses firm-level controls from previous studies as an inspiration for the country-level controls. Zhang & Guan (2018) do research at firm-level where they control for variables that relate to whether a company is high-tech and how many employees companies have with a PhD degree. Feldman & Kelley (2006) conduct research at the firm level where they control for variables that relate to how much biotech, electronics and advanced materials are used by companies. In both these studies it is stated that to what extent companies can be seen as high-tech and whether they employ highly educated employees, influences innovation outcomes. That is why this study will control for similar variables. Exactly equal variables cannot be used in this study because it takes place at country level instead of firm level. Therefore, the total amount of employment and companies in high-tech sectors in a country will be controlled for. Two variables are controlled for, which concern enterprises and employment in high-tech sectors. In addition, enterprises and employment in medium high-tech sectors are also controlled for. These four variables are based on the statistical classification of economic activities in the European Community (NACE). Appendix A shows exactly which industries these variables consist of. As mentioned, Zhang and Guan (2018) control for the number of employees with a PHD diploma that companies employ, because they indicate that it influences innovation outcomes. So in addition, this study will also control for the amount of people between the age of 25 to 34 with a tertiary education classified by the International Standard Classification of Education (ISCED) as levels 5 to 8. These levels consist of: Short-cycle tertiary education, Bachelor's or equivalent level, Master's or equivalent level, Doctoral or equivalent level.

In the study by Zhang & Guan (2018), the level of a company's export is controlled for. In order to create a similar control variable for this study, the total export of a country should be considered. This can say something about the level of innovation in a country, on the other hand, import can also say something about this. When innovation in a country is low, more products will have to be imported. That is why this study controls for a country's current account balance. This variable shows a country's current account balance as a percentage of the country's real GDP. The current account balance is measured by subtracting the total import from the total export. This variable is measured as percentage of the total population. According to Coccia (2010), the GDP per capita has important direct effects on both private and public R&D expenditures and can also influence innovation outcomes. For that reason this research will also control for the real GDP per capita. The real GDP per capita is measured in euros and determined on the basis of a price index compared to the base year 2010. Real GDP is used because it better reflects the different price levels of the countries that are studied

4. Methodology

This section will discuss the models that were created to give answers to the hypotheses of this research. In all models the subscripts stand for country i in year t. Fixed effects method is used because this study uses panel data. Fixed effects is preferred over random effects, because random effects makes the assumption that the independent variable is uncorrelated with the error term. It is unlikely that there are no unobserved country-specific factors that influence both government R&D funding (independent variable) and private sector R&D investments (dependent variable). So therefore fixed effects method is the method used for this study.

To test the hypothesis that Government R&D funding is positively related with private sector R&D investments, model 1 is performed.

Model 1:

$$Y_{i,t}=\beta 0+ \beta 1GBARD_{i,t}+ \beta 2Enterprisehightech_{i,t}+ \beta 3Enterprisemedhightech_{i,t}+ \beta 4Employmenthightech_{i,t}+ \beta 5Employmentmedhightech_{i,t} \beta 6Educationlev_{i,t}+\beta 7Internationaltrade_{i,t}+ \beta 8GDPpc_{i,t}+\mu_t+\pi_i+ \varepsilon_{i,t}$$

Model 1 will also be used to give an answer to the second hypothesis, that government R&D funding has a positive effect on innovation outcomes. To test hypothesis 1, $Y_{i,y}$ will be the variable *BERD,* which is the business enterprise expenditure on R&D, used to measure the amount of private R&D investment. *BERD* is measured in millions of euros. To test hypothesis 2, $Y_{i,y}$ will be the variable *Patents,* which concerns the number of patent applications to the EPO. The variable *GBARD* concerns the government budget allocations on R&D, used to measure the amount of government R&D funding. *GBARD* is measured in millions of euros. The first control variable that will be used is *Enterprisehightech*. This variable indicates the number of enterprises in industries of high-technology manufacturing and knowledge-intensive high-technology services. The second control variable is *Enterprisemedhightech.* This variable is about the amount of enterprises in medium high-technology manufacturing industries. In addition, the variables *Employmenthightech* and *Employmentmedhightech* are controlled for. These variables indicate the number of employees in a country in the industries mentioned earlier. Eurostat has distinguished three types of sectors, low high-tech, medium high-tech and high-tech. The results of the four aforementioned variables show their effect in relation to the low-high tech sector. The variable *Educationlev* will control for the amount of people between the age of 25 to 34 with a tertiary education. *Internationaltrade* controls for a country's current account balance as a percentage of the country's real GDP. At last, *GDPpc* controls for the real GDP per capita, measured in euros and determined on the basis of a price index compared to the base year 2010.

All 3 created models are run as a fixed effects regression with year fixed effects μ_t and country fixed effects π_i. Year dummies are included to control for time variation effects. Country variation effects are already controlled for because fixed effects regressions are performed. In the main results these year dummies are not shown. In appendix B the tables with the results and the year dummies can be seen. For all the models a Breusch-Pagan test is performed to check for heteroskedasticity. Because this was present in all models, robust standard errors are used.

To test the third hypothesis, that the effect of government R&D funding on innovation outcomes is partly driven by private R&D investments, model 2 is created.

Model 2:

$$Patents_{i,t}=\beta 0+ \beta 1BERD_{i,t}+ \beta 2Enterprisehightech_{i,t}+ \beta 3Enterprisemedhightech_{i,t}+$$
$$\beta 4Employmenthightech_{i,t}+ \beta 5Employmentmedhightech_{i,t}$$
$$\beta 6Educationlev_{i,t}+\beta 7Internationaltrade_{i,t}+ \beta 8GDPpc_{i,t}+\mu_t+\pi_i+ \varepsilon_{i,t}$$

Model 1 tests whether there is an effect of government R&D funding on business enterprise R&D investments. If this is the case, it could mean that the effect of government R&D funding is driven by an increase in business enterprise R&D investments. So this is tested in model 2. This the model is the same as model 1, only that the variable GBARD is replaced by the variable BERD and $Patents_{i,y}$ is the only dependent variable. The control variables remain the same as in model 1 and year fixed effects μ_t and country fixed effects π_i are also included.

The last model is created to give an answer to the third and last hypothesis, that in West Europe, Government R&D funding has a positively stronger effect on private R&D investments and on innovation outcomes than in East Europe.

Model 3:

$Y_{i,t}= \beta 0+ \beta 1GBARD_{i,t}+ \beta 2Westeur_{i,t}+\beta 3Westeur_{i,t}*GBARDgov_{i,t} +\beta 4Enterprisehightech_{i,t}+ \beta 5Enterprisemedhightech_{i,t}+ \beta 6Employmenthightech_{i,t}+ \beta 7Employmentmedhightech_{i,t}+ \beta 8Internationaltrade_{i,t}+ \beta 9GDPpc_{i,t}+ \beta 10Educationlev_{i,t}+\mu_t+\pi_i+ \varepsilon_{i,t}$

To see if the effects of government R&D funding are different in North-West Europe, the dummy variable *Westeur* is created that takes a value of 1 if a country is located in West Europe. An interaction variable is made of this with *GBARD*. Same as in model 1, $Y_{i,t}$ will be either *Patents* or *BERD.* The control variables remain the same as in the previous models and year fixed effects μ_t and country fixed effects π_i are again included.

5. Results

The results of the first model with $BERD_{i,y}$ as the dependent variable provides an insight on the first hypothesis. This hypothesis says that Government expenditure on R&D has a positive effect on enterprise R&D investments. The results are shown in table 1.

Table 1

VARIABLES	(1) BERD	(2) BERD	(3) BERD
GBARD	2.253***	1.932***	1.960***
	(0.077)	(0.178)	(0.140)
Enterprisehightech		0.069***	0.059**
		(0.011)	(0.020)
Enterprisemedhightech		-0.852***	-0.640***
		(0.207)	(0.144)
Employmenthightech		11.426	13.102*
		(6.672)	(7.151)

Employmentmedhightech		-0.267	-2.753
		(4.310)	(3.878)
Internationaltrade			0.024
			(0.014)
GDPpc			-0.520
			(0.437)
Educationlev			-27.484
			(45.537)
Constant	-843.488***	-472.095	8,462.918
	(152.549)	(1,653.626)	(8,243.370)
Observations	104	102	102
R-squared	0.917	0.945	0.950
Number of countryid	13	13	13

Table 1: Fixed effects regression of Government budget allocations on R&D (GBARD) on business enterprise expenditure on R&D (BERD).

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In the first column of Table 1, all control variables are still left out. The coefficient that belongs to the government spendings on R&D is positive and statistically significant. In the second column, the control variables are added that concern enterprises and employment in high-technology sectors and in medium high-technology manufacturing. After adding these variables, it can be seen that the coefficient of GBARD becomes slightly smaller and remains just as significant. After adding the other control variables, the coefficient of GBARD remains approximately the same. This coefficient can be interpret as follows: an increase in the government R&D funding by 1 million euro increases the private R&D investments with 1.960 million euro. These results show a positive relationship between the dependent and independent variable. This shows support for the first hypothesis.

In Table 2 the results from model 1 with Patents as the dependent variable are displayed. These results can be used to draw conclusions about the second hypothesis. This hypothesis says that government spendings on R&D have a positive effect on innovation outcomes. The innovation outcome is measured by the number of patent applications as earlier mentioned in the methodology. Table 3 shows the results from model 2. These results can give us an insight on how the effect of GBARD on Patents is partly driven by BERD.

Table 2

VARIABLES	(1) Patents	(2) Patents	(3) Patents
GBARD	0.008	0.127	0.116***
	(0.014)	(0.073)	(0.032)
Enterprisehightech		0.000	0.025
		(0.026)	(0.018)
Enterprisemedhightech		0.129	-0.153
		(0.232)	(0.126)
Employmenthightech		4.970	1.877
		(5.422)	(2.607)
Employmentmedhightech		-4.635*	-2.499
		(2.414)	(1.677)
Internationaltrade			-0.031***
			(0.009)
GDPpc			0.075
			(0.107)
Educationlev			12.088
			(24.012)
Constant	3,412.971***	2,582.849	2,397.000
	(180.796)	(2,201.884)	(2,403.503)
Observations	104	102	102
R-squared	0.052	0.224	0.467
Number of countryid	13	13	13

Table 2: Fixed effects regression of Government budget allocations on R&D (GBARD) on total patent applications.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3

VARIABLES	(1) Patents
BERD	0.083***
	(0.013)
Enterprisehightech	0.019
	(0.017)
Enterprisemedhightech	-0.067
	(0.129)
Employmenthightech	0.482
	(2.585)
Employmentmedhightech	-3.023*
	(1.498)
Internationaltrade	-0.033***

	(0.008)
GDPpc	0.112
	(0.128)
Educationlev	8.224
	(22.823)
Constant	2,100.752
	(2,541.801)
Observations	102
Number of countryid	13
R-squared	0.518

Table 3: Fixed effects regression of Fixed effects regression of Government budget allocations on R&D (GBARD) on total patent applications including the business enterprise R&D expenditure (BERD).

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In the first column of Table 2, all control variables are left out and the coefficient of GBARD is insignificant. This is still the case in column 2 after adding the control variables that concern enterprises and employment in high-technology sectors and in medium high-technology manufacturing. In column 3 the full model with all control variables is displayed. The results of this column show that the coefficient of government spending on R&D is positive and statistically significant. This coefficient can be interpret as follows: an increase in government R&D funding of 1 million euros increases the amount of patent applications with 0.116. This gives support for the second hypothesis that Government R&D funding has a positive effect on innovation outcomes

In Table 3 the estimates of model 2 is displayed and it can be seen that the coefficient of BERD is positive and statistically significant. When the amount of private R&D investments increases by 1 million, it increases the amount of patent applications by 0.083. The results of the first model showed that GBARD has a positive effect on BERD. The results from the first and third model could mean that the effect of GBARD on the number of patents applied for is partly driven by BERD. This shows support for the third hypothesis the effect of government R&D funding on innovation outcomes is driven by private R&D investments.

For the last model, an interaction term of countries in West Europe and government spendings on R&D was created. The results of this model can give us an insight on the third and last hypothesis. That for countries in West Europe, government spendings on R&D have a positively stronger effect on innovation outcomes than for countries in East Europe. These results are shown in Table 3.

Table 4

VARIABLES	(1) Patents	(2) BERD
GBARD	-0.060	-1.222***
	(0.205)	(0.373)
Westeur*GBARD	0.174	3.152***
	(0.217)	(0.375)
Enterprisehightech	0.025	0.058**
	(0.019)	(0.021)
Enterprisemedhightech	-0.143	-0.455**
	(0.118)	(0.159)
Employmenthightech	2.170	18.428***
	(2.747)	(4.517)
Employmentmedhightech	-2.526	-3.243
	(1.694)	(3.474)
Internationaltrade	-0.031***	0.031**
	(0.009)	(0.014)
GDPpc	0.072	-0.567
	(0.102)	(0.478)
Educationlev	11.804	-32.636
	(23.728)	(39.946)
Constant	2,344.167	7,504.468
	(2,394.637)	(8,964.958)
Observations	102	102
R-squared	0.469	0.962
Number of countryid	13	13

Table 4: First column shows the fixed effects regression with the interaction effect of Government budget allocations on R&D (GBARD) and countries in West-Europe. Second column shows the fixed effects regression of the interaction effect of GBARD and countries in West-Europe.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The first column of Table 4shows the effect of the interaction term of the West European dummy variable and GBARD on Patents. The coefficient of the interaction term is insignificant so no conclusion can be drawn about it. The second column shows the effect of the interaction term on BERD. Here, the coefficient of the interaction term takes on a positive and significant value. In addition, it can be seen that GBARD takes on a negative and significant value. This means that in the countries outside West Europe, government R&D funding has a negative effect on private R&D investments, while this effect is positive for the countries in West Europe. For the countries outside of West Europe, an increase in government R&D funding, decreases the private R&D investments by -1.222 million euros. For the West European countries relative to East European countries, an increase in government R&D funding by 1 million increases the amount of private R&D investments by 3.152 million euros. As mentioned earlier in the results section, evidence is found that the effect of GBARD on Patents is partly driven by BERD. This could therefore mean for the results in Table 4 that the negative effect of GBARD on BERD, for the countries outside West Europe, indirectly leads to fewer patent applications. In this way, the results in Table 4 provide support for the last hypothesis that Government R&D funding has a positively stronger effect on private R&D investments and on innovation outcomes than in East Europe.

6. Conclusion and discussion

6.1 Conclusion

This bachelor thesis investigates the effects of government R&D funding on private R&D investments and innovation outcomes. For this purpose, a panel data set is used that contains data for 13 countries in the EU from 2012 to 2019. This research is conducted on the basis of four hypotheses, in the first part of this section conclusions are drawn about these four hypotheses. Based on this, an answer to the research question will be formulated. Finally, the limitations of this research and suggestions for future research are discussed.

The results of the first regression performed, which can be seen in Table 1, suggest that there is a positive effect of government R&D funding on private R&D investments. This is in line with the first hypothesis of this study. According to these results, it would therefore be beneficial to increase government R&D funding in order to increase private R&D investments. This is in line with one of the earlier studies on this topic by Levy & Terleckyj (1983), but also with the more recent study by Coocia (2010). These findings contradict the results of Wallsten (2000), Montmartin & Herrera (2015) and Mamuneas & Nadiri (1996) who all suggest crowding out-effects of government R&D funding. There may be several reasons for these different findings. The studies focus on different countries and time periods, which may lead to different outcomes on how government funding of R&D affects private sector investment. In addition, variations in the econometric models and control variables may contribute to contrasting findings on crowding out effects.

The results in Table 2 show a positive effect of government R&D funding on the number of patent applications and thus confirm the second hypothesis. Namely that government R&D funding has a positive effect on innovation outcomes, because this study measures innovation outcomes based on the number of patent applications. This is in line with most studies discussed earlier. Only the results of the study by Zhang & Guan (2018) show something different, namely they see a positive effect in the short term but a negative effect in the long term. In addition, there is the study by Hu (2001) which indicates that government R&D funding has a positive effect on innovation outcomes by increasing private R&D investments. This is tested using the third hypothesis of this study. The results in Table 3 indicate that there is a positive effect of private R&D investments on innovation outcomes. Since government R&D funding has a positive effect on private R&D investments, the third hypothesis is partly confirmed. There is not enough evidence to assume that the effect of government R&D funding on innovation outcomes is entirely driven by private R&D investments. In contrast to Hu (2001), this study does find a positive significant effect of government R&D funding on innovation outcomes.

In Table 4, the results of the last model are displayed. These results do not show a different significant effect of government R&D funding on innovation outcomes in Western European countries. However, it can be seen that for Eastern European countries the effect of government spending on private R&D investments is negative. This indicates that in the Eastern European countries researched, there is a crowding-out effect of government R&D funding on private R&D investments. Since evidence has been given earlier for a positive effect of private R&D investments on innovation outcomes, the last hypothesis can be confirmed. These differences between Eastern and Western Europe can perhaps be explained by the findings of van Leyden & Links (1991), who emphasize the importance of infrastructure technology in facilitating R&D processes. Pilinkiene (2015) and Lugones &

Suarez (2010) indicated about this topic that the economies in Eastern European countries are based on low-tech industries.

The research question of this thesis is: "How does government funding in R&D influence private R&D investment, and what is their impact on innovation outcomes?". Four hypotheses are tested using different regression models. After evaluating these hypotheses, it can be concluded that the effect of government R&D funding on private R&D investments and innovation outcomes differs for different countries and regions. It seems that in countries and regions with higher levels of development (high GDP per capita), government R&D funding has a positively stronger effect on private R&D investments and innovation outcomes.

6.2 Limitations and suggestions for future research

This thesis has several limitations. First, in this research, innovation outcomes are measured by the number of patent applications. A problem here may be that the number of patent applications does not necessarily say anything about the economic value of the innovation. Furthermore, there may be a delay between the actual innovation and the filing of the patent application, which may affect the timeliness of measurements. Also, not all innovations need to be patented. There are several other ways for companies to protect their innovation, such as secrecy or exploiting lead time advantages. It is therefore a challenge for future research to measure innovation outcomes by means of mechanisms that are not affected by these problems.

Another limitation of this study is the reliance on panel data from a specific time period (2012-2019) and a limited set of European countries. The study therefore has low external validity, which limits the generalizability of the findings to other countries and areas. Future research could benefit from expanding the dataset to include more countries and extending the analysis to include a longer time span.

Furthermore, in the context of this study, the presence of unobserved variables or omitted variable bias may pose a challenge. Omitted variables related to sector characteristics, such as competition levels and market structure, may influence government decisions on R&D funding and private sector investment in R&D. This can make the estimates of the causal effects of government R&D funding on private R&D investment and innovation outcomes less accurate. Also, there is a chance that endogeneity arises if there are unobserved factors that simultaneously affect government R&D funding, private R&D investment and innovation outcomes. Unobserved firm-specific factors may influence the relationship between government R&D funding and private sector investment in R&D. These may include firm size, financial resources and innovativeness. Future research may consider using more advanced econometric methods to reduce possible endogeneity issues and improve the robustness of the research results. The possible presence of endogeneity and omitted variables bias in this study may affect the accuracy of the estimated effects.

For future research, the fourth hypothesis of this study can be further investigated. It would be interesting to investigate what the different effects of government R&D funding are between different countries and areas. It could also be further investigated why these differences arise and which factors play a role in this. Based on the previously discussed literature of Pilinkiene (2015) and Lugones & Suarez (2010), it would be especially good to investigate the role of the presence or absence of high-tech industries.

What can also be further investigated are the long-term effects of Government R&D funding. This research finds positive effects of this on innovation outcomes, but the long-term effects have not been investigated. Zhang & Guan (2018) find evidence that Government R&D funding also has a positive effect on innovation outcomes in the short term, but a negative effect in the long term. When studying the long-term effects of government R&D funding, the focus will be on how the impact of this funding evolves over time, beyond the immediate or short-term results. In the short term, government R&D funding can lead to direct impulses in R&D activities and innovation outputs. In the long term, other factors such as changing market conditions or shifts in policy priorities, can influence the effectiveness of government R&D funding.

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8. Appendix

8.1 Appendix A

Table 5: descriptive statistics of all variables used

	(1)	(2)	(3)	(4)	(5)
VARIABLES	obs	mean	std.dev.	min	max
BERD	104	9,102	18,024	27	75,830
GBARD	104	4,184	8,061	32.46	33,995
Enterprisehightech	103	44,310	45,659	2,612	144,825
Enterprisemedhightech	102	6,374	7,750	450	30,020
Employmenthightech	104	352.5	474.2	22.10	1,762

Employmentmedhightech	104	496.4	862.7	9.700	3,507
Unemployment	104	676.0	803.9	31	3,073
Internationaltrade	104	20,900	57,284	-27,071	231,605
GDPpc	104	18,438	11,576	5,390	41,980
Educationlev	104	38.05	8.227	23.60	55.60
Patents	104	3,529	7,224	8	27,249
Number of countryid	13	13	13	13	13

Sectors that are seen as high-technology:

(1)Sectors with the manufacturing of basic pharmaceutical products and pharmaceutical preparations.

(2) Sectors with the manufacturing of computers, electronics and optical products.

Sectors that are seen as medium high-technology:

(1) Sectors with the manufacturing of chemicals and chemical products.

(2) Sectors with the manufacturing of electrical equipment, machinery and equipment.

(3) Sectors with the manufacturing of motor vehicles, trailers, semi-trailers and other transport equipment.

8.2 Appendix B

Table 5

VARIABLES	(1) fixed effect	(2) fixed effect	(3) fixed effect
GBARD	2.253***	1.932***	1.960***
	(0.077)	(0.178)	(0.140)
Enterprisehightech		0.069***	0.059**
		(0.011)	(0.020)
Enterprisemedhightech		-0.852***	-0.640***
		(0.207)	(0.144)
Employmenthightech		11.426	13.102*
		(6.672)	(7.151)
Employmentmedhightech		-0.267	-2.753
		(4.310)	(3.878)
Internationaltrade			0.024

			(0.014)
GDPpc			-0.520
			(0.437)
Educationlev			-27.484
			(45.537)
2013.year	-50.961	-134.969	-46.756
	(327.216)	(252.746)	(257.804)
2014.year	273.972	-23.798	249.675
	(214.973)	(208.094)	(330.931)
2015.year	630.051*	109.077	582.925
	(348.810)	(293.271)	(581.675)
2016.year	653.481	21.661	667.690
	(442.757)	(373.830)	(793.552)
2017.year	830.861*	-22.410	997.800
	(394.775)	(315.504)	(1,036.827)
2018.year	897.049**	50.460	1,397.589
	(381.383)	(319.910)	(1,299.181)
2019.year	914.329	-218.277	1,342.132
	(530.538)	(348.823)	(1,481.388)
Constant	-843.488***	-472.095	8,462.918
	(152.549)	(1,653.626)	(8,243.370)
Observations	104	102	102
R-squared	0.917	0.945	0.950
Number of countryid	13	13	13

Table 5: Fixed effects regression of Government budget allocations on R&D (GBARD) on business enterprise expenditure on R&D (BERD) including year dummies.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6

VARIABLES	(1) Patents	(2) Patents	(3) Patents
GBARD	0.008	0.127	0.116***
	(0.014)	(0.073)	(0.032)
Enterprisehightech		0.000	0.025
		(0.026)	(0.018)
Enterprisemedhightech		0.129	-0.153
		(0.232)	(0.126)
Employmenthightech		4.970	1.877
		(5.422)	(2.607)
Employmentmedhightech		-4.635*	-2.499
		(2.414)	(1.677)
Internationaltrade			-0.031***
			(0.009)
GDPpc			0.075

			(0.107)
Educationlev			12.088
			(24.012)
2013.year	0.336	13.048	-49.459
	(90.184)	(18.377)	(81.356)
2014.year	78.769	130.645	21.691
	(210.167)	(84.473)	(107.380)
2015.year	64.991	163.955	46.833
	(278.067)	(128.958)	(200.555)
2016.year	28.540	135.116	25.605
	(252.117)	(113.278)	(203.111)
2017.year	99.188	183.418	-58.001
	(227.632)	(135.572)	(276.249)
2018.year	203.583	196.121	-146.864
	(182.665)	(132.098)	(342.619)
2019.year	174.641	36.732	-321.683
	(164.534)	(111.127)	(421.787)
Constant	3,412.971***	2,582.849	2,397.000
	(180.796)	(2,201.884)	(2,403.503)
Observations	104	102	102
R-squared	0.052	0.224	0.467
Number of countryid	13	13	13

Table 6: Fixed effects regression of Fixed effects regression of Government budget allocations on R&D (GBARD) on total patent applications including year dummies.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7

VARIABLES	(1) Patents
BERD	0.083***
	(0.013)
Enterprisehightech	0.019
	(0.017)
Enterprisemedhightech	-0.067
	(0.129)
Employmenthightech	0.482
	(2.585)
Employmentmedhightech	-3.023*
	(1.498)
Internationaltrade	-0.033***
	(0.008)
GDPpc	0.112
	(0.128)

Educationlev	8.224
	(22.823)
2013.year	-42.621
	(83.197)
2014.year	20.957
	(114.988)
2015.year	40.790
	(209.440)
2016.year	23.697
	(205.525)
2017.year	-77.977
	(296.176)
2018.year	-199.881
	(375.503)
2019.year	-370.450
	(464.488)
Constant	2,100.752
	(2,541.801)
Observations	102
Number of countryid	13
R-squared	0.518

Table 7: Fixed effects regression of Fixed effects regression of Government budget allocations on R&D (GBARD) on total patent applications including the business enterprise R&D expenditure (BERD) and year dummies.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9

VARIABLES	(1) Patents	(2) BERD
GBARD	-0.060	-1.222***
	(0.205)	(0.373)
1.NorthWesteur#c.GBARD	0.174	3.152***
	(0.217)	(0.375)
Enterprisehightech	0.025	0.058**
	(0.019)	(0.021)
Enterprisemedhightech	-0.143	-0.455**
	(0.118)	(0.159)
Employmenthightech	2.170	18.428***
	(2.747)	(4.517)
Employmentmedhightech	-2.526	-3.243
	(1.694)	(3.474)

Internationaltrade	-0.031***	0.031**
	(0.009)	(0.014)
GDPpc	0.072	-0.567
	(0.102)	(0.478)
Educationlev	11.804	-32.636
	(23.728)	(39.946)
2013.year	-42.841	73.301
	(76.635)	(235.132)
2014.year	27.710	358.864
	(103.879)	(328.476)
2015.year	55.224	735.136
	(190.085)	(612.787)
2016.year	28.775	725.184
	(197.847)	(817.525)
2017.year	-51.585	1,114.188
	(266.807)	(1,106.655)
2018.year	-147.382	1,388.197
	(338.219)	(1,345.937)
2019.year	-311.578	1,525.437
	(407.056)	(1,574.037)
Constant	2,344.167	7,504.468
	(2,394.637)	(8,964.958)
Observations	102	102
R-squared	0.469	0.962
Number of countryid	13	13

Table 8: First column shows the fixed effects regression with the interaction effect of Government budget allocations on R&D (GBARD) and countries in West-Europe. Second column shows the fixed effects regression of the interaction effect of GBARD and countries in West-Europe.

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1