

# **The Ministry of Education of Azerbaijan Republic**

## **The impact of financial institutions and financial markets on real economy**



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## **Abstract**

**This study is specifically concerned with the role of Research and Development in Technology sector. Large companies in all around the world have spent billions of dollars on Research and Development to enhance their capabilities in order to compete with their rivals, but how important is it. In order to determine that in this study we are going to research about the amount of money that the countries invest in Research and Development compared to their overall exports of high technology products and try to analyze those details for understanding the reasons. We will also dig into the companies that have large amount of impact to those figures and their revenue share of Research and Development investments and try to understand if there's any perfect value of percentage that should be implemented by the companies by the statistics of how much have they really invested in Research and Development in the previous years.**

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# **1.Introduction**

## **The Analysis of Role of Research and Development in Technology Sector.**

The growth of a Technology company is based on the rate of its improvements, the shifts of the overall market and how the company adapts in the process of the shifting in the market. The most important thing for a company here is to take the right steps in this shifting process and take place in this shifting process from the positive side. In order to take place in this changing market the technology companies should innovate and develop their company. But for doing a development the company should also do research which is the first step of Research and Development. Using different samples of statistic datasets of companies and governments alongside the analysis of different books of remarkable writers this paper bears the answers to the questions and gives additional information that comes out of the research.

### **1.1 Research Questions:**

1. Does investing in Research and Development has any effect on exports of high-tech products in a country?
2. Can a technology company operate without any research and development?
3. How do the companies choose if they should outsource or use in-house Research and Development?
4. What portion of the revenue should a technology company invest into Research and Development?
5. Which one increases the amount of high-tech exports outcomes? Research and Development done by Government or Business?

## **1.2 Background of Study**

Research and development is a process that is done by a person or a company with the purpose of improving the current situation with changes or new creations. Within the process the company or the person either creates a new product with a new and improved idea that will serve the community in a better way or it will improve a different process in the company. That's why it has been referred to as an internal process. It can also be used to upgrade an existing product with different additional innovative components. But the part is mainly emphasized here is the development part. Research part on the other hand is using the knowledge before the development part which is also important as it's the core element for being able to do the development. In this study I will analyze the Research and Development from the standpoint of government and companies in different sections to break them down for answering our questions. Although developing a new product can be seen as one time process, in reality it's a part of an ongoing process in Research and Development. It's simply along the way of product life time to improve it continuously until the retirement of the product from the lifecycle.

## **1.3 Purpose of the study**

There are two different aspects to this study that are: research and development from the perspective of the country, and the research and development from the perspective of a company. From the perspective of the whole country the things are more general and thus simpler which is stimulating research and development as it brings more advanced technology, increases the overall intelligence level and also increases the exports of the country as it may bring some sales to it. But still like all other sectors you can't use all your resources on this direction as you will be left off with nothing in other sectors. Therefore it's very important to how much resource should be allocated on this direction. For this purpose in this study we will take the datasets of how much is being invested by the countries to research and development sector with respect to their overall exports and also how much is being allocated in respect to their overall GDP. The reason of the latter experiment is mostly conducted because the staff of the research and development of wealthier countries take more investment compared to the others which will be pointed out on the tables of the first experiment.

From the perspective of the companies however things are different. The research and development sector is very unique part of the company as it is important but also risky. Almost all of the large technology companies have research and development sectors. The only ways that you can evade having research and development sector in your company is going to happen in three

conditions: Merge and Acquisition, Partnering with a different company, or using the other companies' achievements which is simply not innovating by yourself. The reason why some companies evade from the research and development is simply one of the most famous problems of the whole world. Because they are expensive. Not only that but research and development is such a unique part of the company that it may even bring failure despite the fact that the company paid millions of dollars to it. Therefore you simply can't flood 80% of your revenue into the research and development laboratories of yours with a high expectation of coming up with a product that will pay even the half of the investment that was put into it. Of course the company may create a ground breaking product that will be sold so much that the competitors will be left off in the dust, but it's highly unlikely and also the other companies will understand the new technology to abate your leadership in the industry before you make half of the investment back. Therefore the companies should be very smart with how much they will invest into research and development. Thus this study will also bear the analysis of the leading companies and their revenue share on the research and development sector to determine the logical points on if the company should decrease its percentage share of revenue on research and development.

## **1.4 Limitation of the Study**

The main limitation of the study is that the numbers that are used in the study are skewed by the fact that the living standards in one country may vastly differ from the other. Therefore a staff of a research and development laboratory in the United States will most surely require more reward to be satisfied compared to a laboratory in China. This example was actually maybe the largest skewed part of the data as they were competing in technology sector for decades with having completely opposite side of advantage. As United States had so much advantage with having a country already developed and almost being number one in most of the sectors they tried to push their companies to next level with research and development, but China in the other hand knew that they had an advantage to enter the technology sector from the lower end of price point. Because of the reason that they paid few times lower to their staff members to satisfy them, they could easily bring their price down and get the whole industry in their hands. Thus, in order to alleviate that we are going to look at the data that represents the GDP or different calculations based on the data per capita of the countries as well This way will give us a different way of looking at the situation and hopefully a more accurate statistical results.

Another limitation of the study is that the Research and Development is an ongoing long term process which makes some of the concurrent data irrelevant for their correlation, but for its workaround for it was finding specific data of the companies in different time periods to compare them.

## 2.0 Literature Review

### 2.1 Understanding of Research and Development

Research and development was once a phrase that in the beginning of the 20th century almost nobody had any idea about, but as became a very crucial part of the economy of the companies and countries the world became to be aware of its existence from top to bottom for its implementation. Research and Development which is also known as Research and technological development is an innovative activity for improving or creating new products or services. It can be conducted by a company or a government and even though they serve mainly the same goal, but specifically research and development in a company serves to increase profit in the long term however it serves the community's welfare if it's conducted by the government. The reason why it's been conducted for long term improvement will be discussed later and although the government may pursue some revenue increasement by decreasing the costs of a procedure by innovating the service system in a field, it's simply for being able to increase the welfare of the community in general.

In some studies Research and Development to have three main activities as basic, applied and development. In this sense they are all a part of one united notion as basic research refers to acquiring knowledge with no execution of the process, the applied research refers to determination at a specific object whereas the development refers to the creating a new and improved product or a process. But in a broader sense Research and Development has two main types: basic and applied. It differs from one another with dependence of being either mainly experimental or theoretical. That means if the research and development institute is mainly based on experimental scientists they are more likely to be applied scientist or engineers. The reason for it is basically because their main objective is creating a new produce or innovate a product physically. But the theoretical type of research and development institutes are mostly working on new theories to come up with a different scientific solution that can lead to a breakthrough for applied research as well. Therefore applied research and development tends to be created inside a company because its main point is to earn profit for the company. Generally overall statistics show that only one 3<sup>rd</sup> of the Research and Development budget is being provided into the basic research side whereas the applied takes 2 out of 3. But more interestingly this numbers get even more distant from each other in developed countries where only one 5<sup>th</sup> of the Research and Development capital is serving to improve the science from the basic part.

New type of product or service is the key instrument for the survival of the company in the long term to compete with competitors, otherwise you



would be identified as obsolete and unwanted in the world that changing very fast and gives so much credit to the ones that are technologically advanced. As the technology companies give their best to improve faster and keep up with their competitors or even maybe surpass them they pay millions or even billions of dollars depending their own financial situation and reasoning. The point of the reasoning here is that there's no simple way of determining how much should be invested into research and development department of the company as it differs from one another with so many variables. The most basic one would be the scale of the company as the main belief is that the money invested into research and development should decrease in terms of percentage of the total revenue of the company while maintaining an increase of it as in numerical form. Although it will be covered up with details in our analysis part of the study, it would be reasonable to talk about the reason of why the companies don't necessarily increase their investments into it too much to surpass all of its competitors. The main reason is the risk of two components. First of these two is the adaptation and readiness of the community to the product's new development. For example if Samsung company created its foldable phones five years ago although that would be a technological leap the readiness of the community would be so much less because the timing would be horrible as nobody would be interested in it. Adding the technological incapability of readiness in that time would not even let the product to look like how it looks and performs now. Therefore as in the terms of the innovation development the timing is almost more important the innovation itself. Because that may not even be the future of the mobile phones or whatever the technology product is being developed. The second type of risk however is that the thoughts do not apply to the real world product. For example if a company tries to make a new version of a car that uses a different fuel type and energy with a different type of engine the company should implement it to be 100% sure about the idea. That means even if your idea may hold up as a theory but you may end up having a problem that is basically impossible to come up with a solution. In this case when the company conducts an experimental research in its research and development laboratory it may end up with failure. To be realistic actually most of the ideas of the research and development theories don't hold up making it end up with being a failure that only needed huge amount of money for the experimental.

## **2.2 R&D and Accounting**

Unlike taxes, there's no guarantee of getting any hope out of a Research and Development outcome. From the standpoint of Accounting the outcomes of research and development can't be measured in any way. For example if a company creates a new way of doing something or a product you simply can't

measure its outcome just because it's new and nobody has ever seen this type of product's results. Thus, even though sometimes Research and Development is referred to as an investment, from the perspective of accounting standards the research and development is accounted as an incurred expense rather than asset. Because you can gauge the level of impact that the development of the new product did to the company unlike its outcomes. As you can't sell it either you can't account it as an asset as well.

There are some cases that these kinds of situations even make the things get fuzzy for the company, especially stakeholders. For example there was a case where Boeing company was thought to get into a huge trouble.

**Table 1: Boeing company's net income and R&D expenses over years.**

<b>Years</b>	<b>Net Income in million dollars</b>	<b>R&amp;D expenses in million dollars</b>
2005	2572	2205
2006	2215	3257
2007	4074	3850
2008	2672	3768
<b>2009</b>	<b>1312</b>	<b>6506</b>
2010	3298	4121
2011	4009	3918
2012	3900	3298
2013	4578	3071
2014	5440	3047
2015	5172	3331
2016	5031	4626
2017	8452	3179
2018	10453	3269

As you can see, from this chart net income has never been below 2 billion dollars after 2009 and even before 2009 year. Therefore when the net income of the Boeing company for 2009 year was announced people got shocked by the number and of course they thought that this company was definitely going down. The reason for that was twofold decrease of the company from 2008 to 2009. In just one year the company went down by slightly more than 50% in terms of net income which was disasterous. Other than that, the year of this to happen was pretty terrible as well as it was around the days of worldwide financial crisis. But interesting enough, the whole thing was simply coincidence and there was no terrible thing even going on with this company. In fact, the company of Boeing was even growing at that year. The main reason however was that Boeing company paid 6.5 billion dollars to its Research and

Development which was almost the double size of the previous year. In fact, even until 2018 they never invested into Research and Development more than 5 billion dollars. Therefore as Research and Development is accepted as expense in accounting the numbers get fuzzy to understand from the net income standpoint.

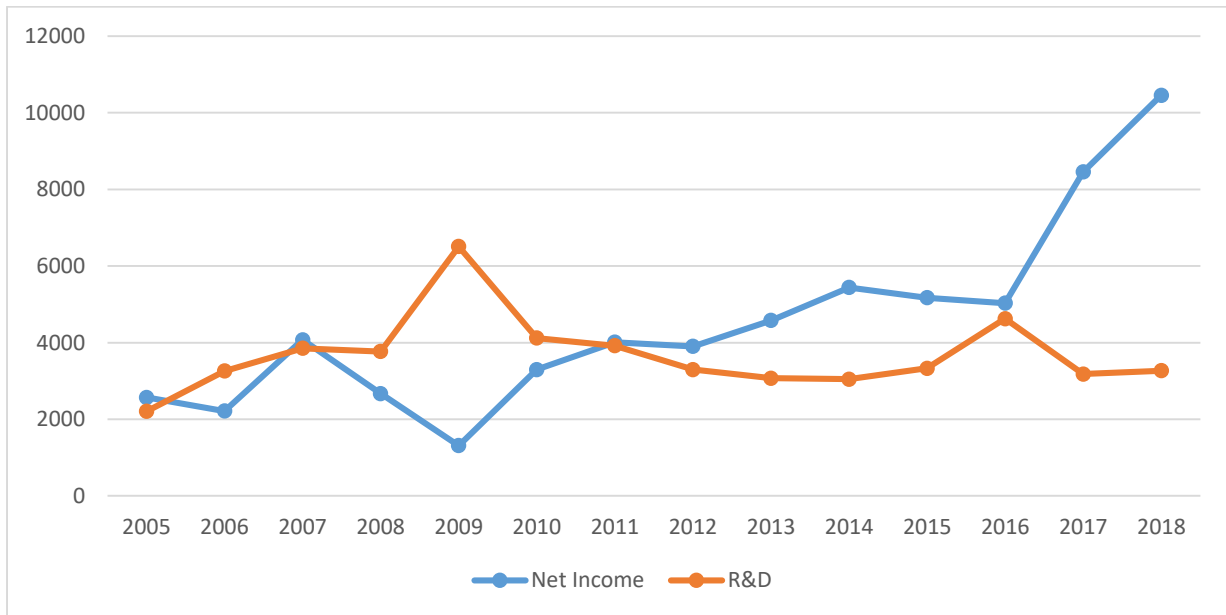


Figure 1: Boeing Net Income vs Research and Development expenses.

## 2.3 Benefits of Research and Development by sector type

In general a company that does research and development has been seen to develop in the long term even if it's not specifically technology sector such as pharmaceuticals and medicines that are being researched and developed. But when we delve deep into the benefits of research and development we start to see some changing correlations in different sides of the technology sector. From the research that is done by Francesco Crespi and Cristiano Antonelli in different type of companies with a Matthew effect conclusion. That means the more the company was technology oriented the more it helped the company to increase its profits with the help of research and development. Also if the company is low-tech oriented instead of high-tech it benefits less from research and development. But even if the correlation is low, the benefits of research and development simply holds itself in the cases of low-technology companies.

Some companies don't even pay for Research and Development to directly earn money from it but rather indirect. For example there are some companies try to replenish their equipment and production devices to evade their production appliances. Because as their appliances wear out the quality of the products also diminish with them.

While referring to the studies before mine, also showed that the Research and Development costs had a very good impact for the value of a firm. The outcomes of these researches imply that the successes in Research and Development basically made the firm to obtain serious jumps in profits. Digging into one study, on average a company expect their Research and Development costs to generate 185% acceleration in the profitability charts. Also the profitability in this department is quite persistent. The large persistent expected profitability increases arising from R&D expenditures enable the model to match the high levels of R&D expenditures observed in the data as well as the high Tobin's q levels. In addition, the model captures the low correlation between Tobin's q and investment observed in the data. Also, the estimation yields an obsolescence rate for R&D stocks of about 32%, somewhat higher than the value of 15% typically used in the literature (Griliches and Mairesse (1984)). An extension of the model that allows for R&D expenditures to influence both the success rate of innovations and the increase in profitability arising from an innovation generates broadly similar findings. Firms expect innovations to lead to about a 20% increase in profitability, and the estimated obsolescence rate of R&D equals 23%. (From-Missaka Warusawitharana - Research and development, profits, and firm value: A structural estimation)

## **2.4 Research and Development or Innovation.**

Research and Development may look like innovation and sometimes it is referred to as a part of innovation but in fact they have lots of differences: Research and Development is turning money into knowledge however innovation is turning knowledge into money. For example, when company invests into Research and Development it pays tons of money just to know if a specific type of product could work or not. Innovation on the other hand does not require any money, it simply need a knowledge, idea that can bring millions into the company.

Although Research and Development is a scientific development which is done internally and tries to improve from inside, the innovation has no limits for that. Innovation process may even take place marketing or sales sectors which is completely external operation.

Innovation can be done in the short period of time however the Research and Development is known to work only in the long run.

## **2.5 Partnerships, Merges and Acquisitions**

Although it's very important for technology companies to have their own research and development departments, laboratories and etc. they are not bound to stick with their interior power all the time. Even though Research and

Development is meant to be an interior process by the companies, in some cases this option may not give the most wanted benefit. So there are couple different options beginning with partnership. When two different companies work for different types of products but go through the similar procedures they may collaborate with each other. For example a company that produces laptops may partner with a company that sells mobiles in order to research and develop screens of the products, chipsets and etc. There are lots of benefits of partnerships such as investment share between the partners. When they share their investment costs they mainly become available to work on products and ideas that need larger investment as they both pay for the costs, and mainly the costs don't matter as much as it did before partnership even if the idea is doomed to failure. Another benefit of this partnership is that the partners both have deep understanding of the technology from their own perspective of the matter, therefore they even combine their knowledge about a new product or service they are trying to develop. Merges and acquisitions on the other hand are different from Partnership and from each other as well. Because as the partnership refers to the collaboration of two or more companies with each other in research and development field without having any control over the other, merges and acquisitions are basically enabling one company to either rule the other one by acquiring it or simply merging those two companies thus their research and development departments as well. The only main difference between merging and acquiring is that with merging there is no superior company that can take the lead, but with acquisition one company simply buys the other one to control and manage as well as its research and development department.

## **2.6 R&D Outsourcing**

For a few decades Research and Development outsourcing has been very famous among the companies but how did it even start developing? The development of this process started to do external Research and Development in 1930 when US government started carrying out scientific Research and Development experiments that involved private companies. They were called CROs (Contracted Research Organizations). The way they started working was that the while the companies had their own Research and Development tools they simply directed them for external uses and specialized in this sector. Nowadays there are tons of companies doing contracted researches for other companies depending on the type of research that is done by the companies. This is a major choice if a company doesn't want to do it by itself, which mainly attracts the smaller companies as they mainly don't have tools, laboratories special staff and etc.

Research and development outsourcing has some kind of similarities to partnerships for lowering the risk, but there's one main difference that you

simply put the whole research and development to the hands of a different company or an organization. Research and development outsourcing refers to a temporary and paid agreement between two organizations which enables one organization to handle the tasks for the client organization which is mainly provided by private related company or organization Howells (1999). If research and development services are handled by providers from a different country, then it's called international research and development outsourcing or research and development offshoring. Research and development services are mainly driven by other organizations therefore research and development outsourcing has improved considerably along the years. According to Arnold's outsourcing model (Arnold 2000) there are four main elements of Research and Development outsourcing:

1. Outsourcing subject
2. Outsourcing object
3. Outsourcing partner
4. Outsourcing design

Figure 2 depicts the Arnold's outsourcing model. At the faze of implementation of this model to Research and Development we understand that Research and Development itself is the subject of outsourcing model whereas the process of the Research and Development is the object of the outsourcing. Outsourcing partners are identified as the suppliers of the Research and Development and the way that research is implemented by the suppliers is the design of the outsourcing.

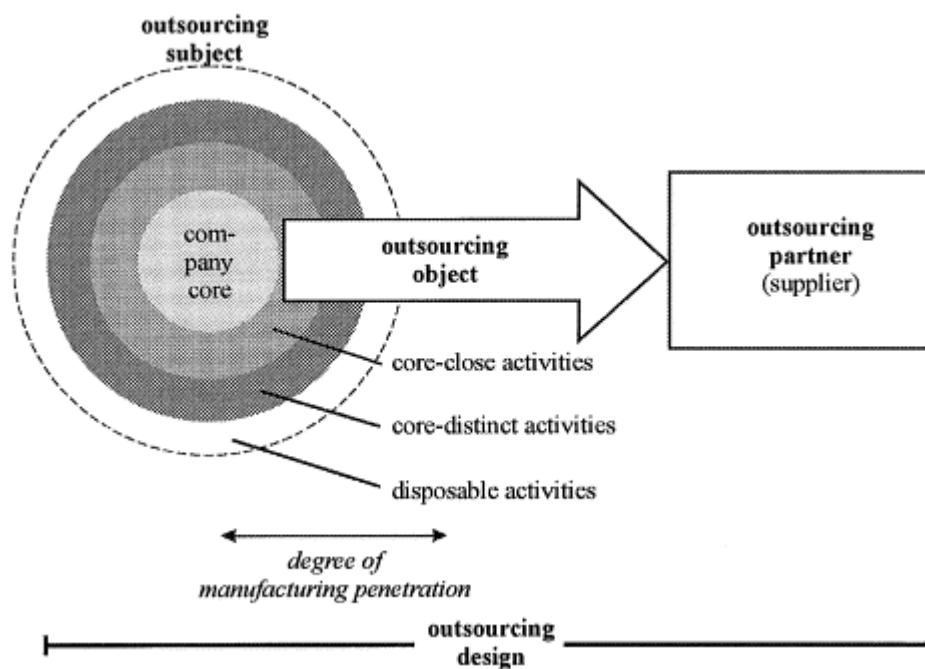


Figure 2: Arnold's Outsourcing Model (Arnold 2000).

There was a huge belief that the companies that use Research and Development outsourcing should not be the large companies but instead smaller companies. But as the overall usage of Research and Development outsourcing has been considerably increasing over the years, there were a lot of huge companies that also get provided by those outsourcing suppliers. The more dreadful way to put it would be that even larger companies were no longer capable of depending on solely their own in-house Research and Development departments. Therefore scholars attempted to create a model (Robins 1987) understand and explain the main reasons behind choices of the companies regarding to go for in-house or external Research and Development by the transaction-cost model (Williamson 1979). However there were simply too many critics about this research for having too many logical loopholes and lack of foundation in historical part for explanation. But, then a more precious analysis concluded the reason with the choice being “core competences” as capability capacity, knowledge and overall resources (Prahalad and Hamel 2006). However as the large also became unavailable to be only using its in-house Research and Development department the thoughts got slightly blurred. After more studies over the matter was conducted push and pull factors became more relevant to the situation. The push and pull factors here could be described as increasing sophistication and complexity of the matters for large companies and also the quick changes in the technology sector to cope with.

## **2.7 Why Long term?**

Although the effects of the research and development may seem to be a process of short period of time due to the reason that most people believe the impact of the new developed product, the process is completely opposite. The point of it is that the research and development neither work for one product or innovation nor it gets its results in the first try. That means whenever a research and development team creates a product it simply works for months or even years to make it. Therefore long the way of succession there were many failures or problems that occurred to stagnate the process to incur some investment and of course this is only authentic if the process becomes successful in the end. The meaning in this context is that the development process is not a single success of a company or an organization, rather it's an ongoing process of development that gives you the opportunity to surpass your competitors along the way of better development. It doesn't even necessarily mean to develop faster than the other companies with producing a new product every month, but it's to know what will be the demand of the futuristic world of economy that you should be supplying in terms of product development. For example if Samsung were to start to research and develop the foldable phone display a few years ago without

knowing the demand of future it could end up with stopping the project altogether as the demand shifts away from that kind of form factor. Nevertheless the research and development is not a sprint in terms of competition but it's a marathon as every technology company should use to develop further with steady steps to withstand the fierce competition.

This term could also be used in global terms. It means when one side of the economy flourishes the result of this effect takes a long time to penetrate the common community. But there's even a different factor which is the ripple effect and also the payback from that ripple effect which is simply another ripple effect that gets created from the first one to feed the first creator. This means when a company makes a huge invention in one process or a product they simply make difference in other sectors as well. For example, when the printing machines were first released they were sold to the companies and people with purposes of using it. This was the first ripple effect of this process which takes a while to get penetrate all the users. But then as a different company gets use from this machine their process also gets faster to finish therefore they release another process or a product to the community in a different sector. This ultimately again affects the first company to make some improvements as well which in total takes a huge time to travel along the sectors.

## **2.8 Research and Development Portfolio management and selection process**

Research and Development itself is a complicated procedure from the perspective of management. The procedure works with creation of idea and its movement from one department to another. None of the thoughts are directly put to be worked on instantly in the companies. There are several different factors needed to be considered by different management members. The procedure works in multiple steps. The first step is coming up with different ideas by the Research and Development staff and then some of them get eliminated due to theoretical possibility of the case to be very far from the reality. Then the selected possible ideas are being chosen by the team managers of the Research and Development. Then they inform the top management with full details of the projects especially including their approximate capital requirements. The reason of introducing those ideas to the top managers is that they have larger scale of view to the company which is mostly referred to as top down view of the company. This helps very much in terms of decision making procedure as they have more information in every department, especially financial department which lets them consider their investment limitations to the projects. Because the Research and development team has no idea of the financial department whatsoever to be able to decide about the investment scales of these projects. Of course if there was no limitation in the financial



sector Research and Development sector would try its full potential in every project but it's simply not possible at all. Making the decisions over those projects is the complicated part of the whole Research and Development portfolio as you can't have all of them in your basket. Also the basket reference of financial investment also keeps its validity as you can't invest all your money into one large project no matter how probable is the outcome as most surely it's not 100% definite to succeed. Therefore they should diversify their Research and Development portfolio as well. In order to analyze the situation Matheson(1997) introduced a very impressive method for looking into the matter with a matrix. The matrix is called Research and Development Project Portfolio Matrix.

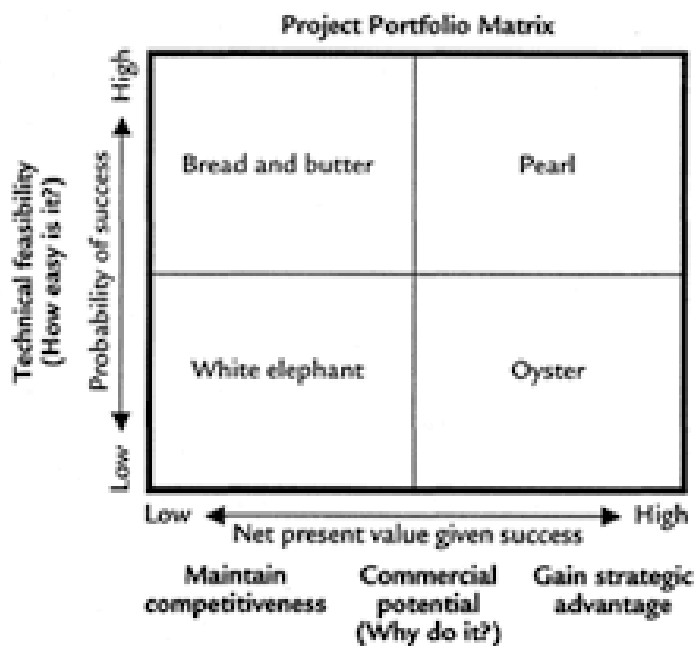


Figure 3: Feasibility of success and Net present value given success (Profitability).

This matrix is consisted of four sections like most of the other Economic matrices: Bread and butter, White elephant, Oyster and finally Pearl. We can see that on the bottom of the matrix there is Net present value given success going from left to right with respective values of low and high. That shows the success value that the project is predicted to have. The other parameter of this matrix however is the Probability of success or Technical feasibility of the project which indicates lower in the bottom of the matrix and higher in the upper sides.

In the section of net present value given success is the lowest and the technical feasibility of the project is low, the projects are called white elephants are mostly not considered as worthwhile to be implemented at all. The point here is that the feasibility is low and it doesn't even give any capital benefit to

the company. And in this reference **white elephant** is considered to be the troublesome and useless thing to possess.

The next one **Bread and butter**, which means ordinary or daily thing that is done as it refers to the projects that have high feasibility to create. These projects are mostly accepted to be implemented by the managers as they don't impact the company very much financially.

**Oysters** here are considered as the projects that are potentially good for delivering significant amount of benefit to the company but the problem with them is that their implementation feasibility is very low. Therefore they are called oysters to be very precious but getting them from the ocean is not easy at all. These projects are very hard to decide as it may deliver too much if it is implemented, but also it's very risky for small companies to accept these kinds of projects.

Pearl however are the best ones as it could be understood by its name as well which has high level of feasibility and also net present value given success is high. That means these are the most accepted projects among all the others, which is very easy to implement and get the highest amount of benefit with it. Therefore sometimes top managers even give the permission to the research and development team to proceed to these types of projects if the time factor is very important for starting these projects.

## **2.9 The Government's Role in Research and Development**

The long term growth and economic development is always the most important thing regardless of being a company or the government. The government has a very good incentive to support the research and development as it not only improves its technology companies and that sector but also its technological advancement brings newer ideas and possibilities of improved equipment to even more advanced technologies in the other sectors. That makes the whole country more advanced and with learning how to use those devices make that country have more and better spiecialists in that sector. For example, When the government pays more to research and development in X-ray or similar scientific fields, it may create a new device that utilizes the X-rays in a new device for medical purposes. With doing so it creates special people that are capable of using this type of technology more professional than the others. But the problem is that there are lots of fields to invest into which are sometimes not large enough to be visible to the government. However the main issue here is that government doesn't know what should be invested in, even if the fields are

visible to them which is a very important question to answer as well. Because the government should pay for the research and development of those ideas or innovations that will benefit the society in the time of future as well. Robert E. Lucas Jr. – Nobel prize winner economist once said that if we are looking for long-run development of the economy it's hard to look at anything else. With supporting the crucial growing points of science the economy of technology, the whole economy gets a huge benefit from the government in the long run. It's just like compound interest calculation. If investing into Research and Development with 1% every year improves the organization twice in 70 years, 3% investment will make it 23 years according to rule of 70. In case of a company it will eradicate its competitors altogether if its competitors are not investing as much, but most importantly in terms of a government this will increase the level of welfare in that country with advanced technology. In just a few decades the world some countries advanced more than the others in the field of computers and internet due to large amount of investments into Research and Development in those sectors. The motivation of federal support for Research and Development is known to be mostly in the basic Research and Development direction rather than applied Research and Development. Therefore it's more like investment into science rather than making a new product or a device. However Government uses a different approach to the companies that work in Research and Development companies such as subsidizing them. Other than that governments tend to improve the policy of patents so that the companies would be more interested in having their own new innovative idea. For example in Australia there is an eligibility of tax offset incentive. According to this rule if a company surpasses the certain limit of amount invested into Research and Development they do a tax offset for those companies. Tax offset is basically a refund to the company which may even decrease the company's taxes to zero. In some exceptions there can even be such cases that tax offsets surpasses tax itself. In Australia's case if the company invests into Research and Development more than 20 million dollars in that year that company gets a tax offset. With doing so the global rate of Research and Development increased compared to GDP.

**Table 2: Research and Development percentage in GDP.**

<b>Years</b>	<b>Percentage</b>
1996	1.971%
1997	1.969%
1998	1.983%
1999	2.058%
2000	2.058%
2001	2.078%
2002	2.042%
2003	2.031%

2004	1.983%
2005	1.965%
2006	1.965%
2007	1.944%
2008	1.998%
2009	2.037%
2010	2.024%
2011	2.011%
2012	2.075%
2013	2.033%
2014	2.121%
2015	2.115%
2016	2.229%

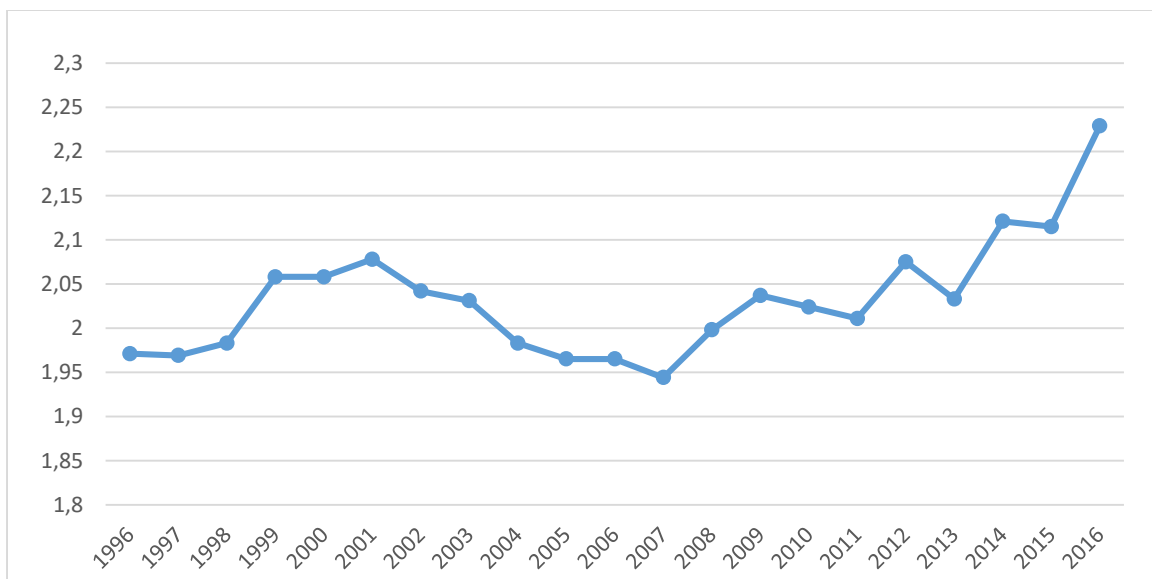


Figure 4: Boeing Net Income vs Research and Development expenses.

From this slope we can see that in recent years the global research and development has been incentived one way or the other. Whatever the reason is, it's most definitely a good sign for improvement.

# 3 Research Methodology

## 3.1 Research design

In this research we are going to test the hypothesis that if you increase the amount of investment into Research and Development will it increase the high-tech product exports or is it simply random. Then I will analyze if the correlation is more on business part of it or non-business. That will show us if a government wants to increase its exports which one should it go for. Do the research as a government itself or give incentive for the companies to pay for Research and Development. Then I will put ITU and ITU per capita with Research and Development datasets to know if a country improves as a technology country if more money is invested into Research and Development. After testing if the companies that paid most into the Research and Development were the ones to get more revenue compared to each other, I will test three of them in detail. Those three companies (Amazon, Apple and Toyota) will be tested thoroughly including their yearly revenue, net income and even stock prices for Apple.

## 3.2 Methodology and Empirical Results

For methodology as I wanted to know the relevance of the profitability of Research and Development for companies and how much is the total community benefit of Research and Development. The point here was that as Research and Development was considered to be an expense for a company or government there should be payback of it. But the question here was that if it is really beneficial for usage or not. For that reason finding the correlation between the statistical datasets became to be the solution for it. Correlation is a statistical method for two datasets to be compared in order to find if they are related and what is the statistical value of this relation. This relationship is by no means perfect. Although the most famous hypothesis which is the height of a person and this person's weight it's not really hard to think of two people whom have more height with less weight and also more weight with less height. At these points, the correlation figure gets a huge hit as they don't follow the rest of the dataset. However I tried to generalize the correlation it was still going towards one special correlation method which at the end was the one that I used. But how can you even decide on which correlation to use in the first place. There are three main correlation methods that are used:

- Kendall's Tau
- Spearman's Correlation
- Pearson correlation

**Pearson Correlation** is simply the most popular method for finding the strength of the correlation between two datasets to know how much they are related by the help of definite values. There are some pros and cons of it too. The pros of Pearson correlation is that it's the most sophisticated one amongst the others which makes it more superior in finding specific correlations such as linear correlation between the datasets, but if the data itself is more complicated then Pearson correlations get slightly off the actual r value which indicates the correlation. Although nonlinear correlation could be used to calculate that as well but now that one will be specific as well and it should be implemented accordingly. The formula is:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

$r$  = Pearson correlation coefficient

$N$  = amount of observations

$\sum xy$  = sum of the paired scores

$\sum x$  = sum of x scores

$\sum y$  = sum of y scores

$\sum x^2$  = sum of squared x scores

$\sum y^2$  = sum of squared y scores

**Spearman's Correlation** is similar to Pearson correlation except it doesn't have the numerical values of the points. Instead, it has the numerical values of their ranks to measure the whole correlation. This approach has some advantages such as if there's non-linear numerical values that don't follow each other in linear directions but still has the correlation. For example even if one of the datasets is increasing in quadratic order it may decrease the value of the Pearson correlation even if they have the relationship, as their placements don't change they will still have the high correlation in Spearman's correlation as long as their order stays intact.

$$r_R = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

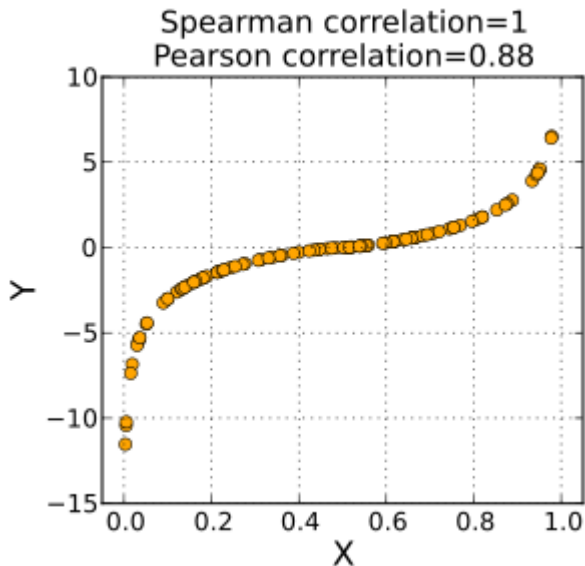


Figure 5: Pearson and Spearman correlation of the same nonlinear datasets.

As we can see from the Figure 5 that the correlation between the numbers are not linear which makes the Pearson correlation to have less amount of value while Spearman's correlation stands at 1 as the x values are increasing with each next value in the y axis as well even if the increasement is miniscule in some areas. That means their ranks are increasing with the increase of every x on y axis as well but slower in some parts of the figure.

**Kendall's Tau** on the other hand is even simpler than Spearman's correlation. Kendall's correlation does not even bother with the values of the ranks, it simply takes the directions of the numbers from one another. Therefore it's less used in statistical analysis as it doesn't bear neither numerical values of a data nor their ranks but directions.

The correlation coefficient is identified as  $r$  and is the measure of the strength of linear relationship between two datasets in numerical values. The correlation coefficient can vary from -1 to 1 which determines the strength of the correlation. As the variables change the correlation between them also change even if their ranks stay the same unlike Spearman's correlation. Between -1 and 1 the following numerical values could be analyzed in the following way as they are the main accepted borders of correlation:

1. "0" shows no linear correlation at all. This means if the numerical variables change in one dataset it simply has no effect on the other one.
2. "+1" means there is a perfect positive correlation between the datasets as one side of the numbers change the other side is increasing as well and also at an identical scale. That means they are linearly parallel or on top of each other if we look at their chart. This is called exact linearity rule.

3. “-1” shows the complete opposite of the previous assumption as it means perfect negative linear correlation between the numerical values. This means if two datasets have -1 correlation then when one value in one dataset increases the corresponding value in the other dataset decreases perfectly the same. In numerical values it may not be the same but the scale of decrease in the second value will always be the same with the scale of increase in the first one.
4. Values between 0 and 0.3 or also 0 and -0.3 means the values have weak positive and weak negative correlations respectively. This is called shaky linear rule. This is also known as when one value in the independent dataset increases an  $x$  amount the dependent value increases 30% of that amount if the correlation is 0.3. If it's negative then simply the dependent value decreases by the same amount.
5. Between 0.3 and 0.7 or also -0.3 and -0.7 means a moderate relationship between the datasets and it's determined by fuzzy-firm linear rule. This amount is mostly accepted as the numbers have relationship.
6. Between 0.7 and 1.0 or also -0.7 and -1.0 means there's a strong linear correlation between the datasets. If the correlation is in these barriers it's concluded that they are correlated and very strongly.
7. The values of the “ $r$ ” are also taken as the percent value variation of one variable in one dataset corresponding to the other one in all of these values.
8. The Linearity assumption. The Pearson correlation coefficient as previously noted only considers the two datasets are linearly correlated between each other. This is the main requirement for testing out the analysis of the datasets. If the correlation between these values are not linearly correlated such as quadratic nonlinearity case, the strength of the correlation between them may not be useful or at least questionable.



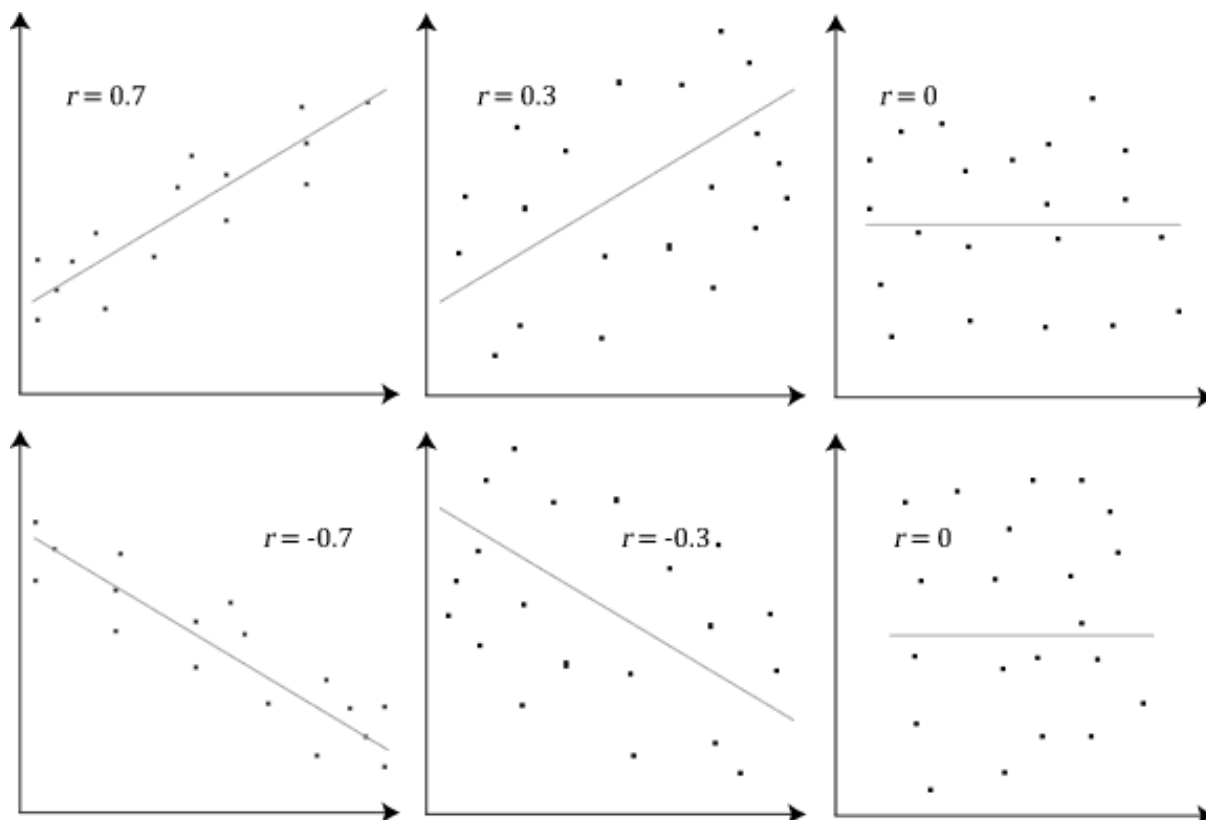


Figure 6: Any type of Pearson correlation.

### 3.2.1 Role of Research and Development on Top high-tech product exporting countries

For this research analysis we are going to use Pearson Method, also known as Pearson Correlation Coefficient. Therefore we are going to look at the tables and use Correlation Coefficient to see correlation between the two numbers. The sample size will be 20 countries in our case. Those 20 countries are going to be the countries with highest high-tech exports in 2018.

**Table 3: Countries with respect to their high-tech exports.**

COUNTRIES	HIGH-TECH EXPORTS
CHINA	\$560,058,333,865
GERMANY	\$193,087,960,652
UNITED STATES OF AMERICA	\$147,833,168,925
SINGAPORE	\$135,601,531,429
SOUTH KOREA	\$130,460,427,536
FRANCE	\$112,999,509,750
JAPAN	\$105,075,614,374
NETHERLABD	\$69,039,551,874
MALAYSIA	\$60,371,906,718
SWITZERLAND	\$53,350,361,422

MEXICO	\$45,418,666,690
THAILAND	\$33,901,233,425
ITALY	\$29,752,353,792
CANADA	\$29,136,849,244
VIETNAM	\$27,819,466,251
UNITED KINGDOM	\$24,215,736,361
IRELAND	\$21,914,722,722
CZECH REPUBLIC	\$20,921,357,479
PHILIPPINES	\$19,644,559,022
AUSTRIA	\$18,412,394,058

In order to know the correlation of the data, Pearson correlation function from Excel and looked at the number value. And the correlation of this data gives us the 0.700614 number which is between 0.7 and 1 that indicates a strong positive correlation between the two numbers. That means the countries that invest into Research and Development are most likely to increase their high-tech exports.

***Table 4: Countries with respect to their Research and Development investments.***

<b>COUNTRIES</b>	<b>RESEARCH AND DEVELOPMENT</b>
CHINA	\$370,605.00
GERMANY	\$119,562.00
UNITED STATES OF AMERICA	\$476,460.00
SINGAPORE	\$10,069.00
SOUTH KOREA	\$73,099.00
FRANCE	\$60,565.00
JAPAN	\$169,554.00
NETHERLAND	\$16,404.00
MALAYSIA	\$9,728.00
SWITZERLAND	\$14,744.00
MEXICO	\$11,519.00
THAILAND	\$5,138.00
ITALY	\$29,448.00
CANADA	\$27,794.00
VIETNAM	\$1,777.00
UNITED KINGDOM	\$43,811.00
IRELAND	\$3,625.00
CZECH REPUBLIC	\$6,699.00
PHILIPPINES	\$886.00

AUSTRIA

\$12,797.00

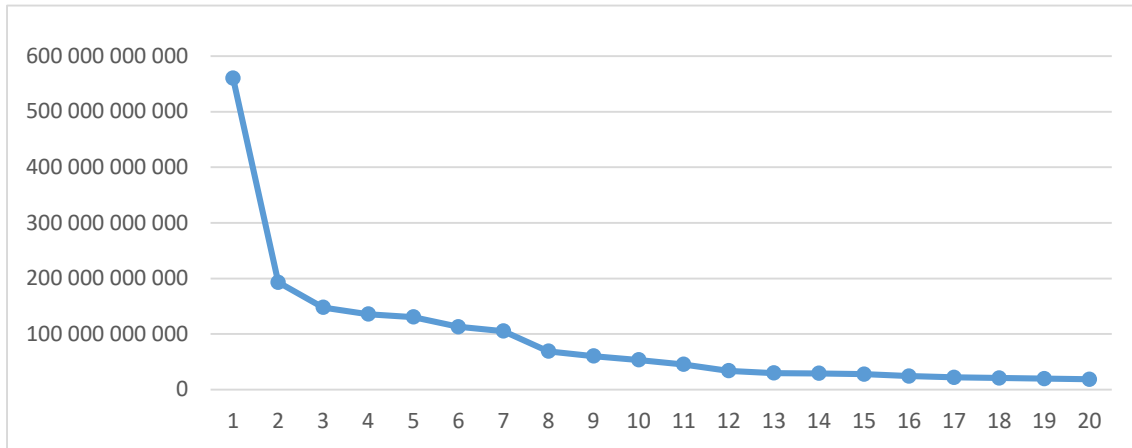


Figure 7: High-tech Exports in dollars.

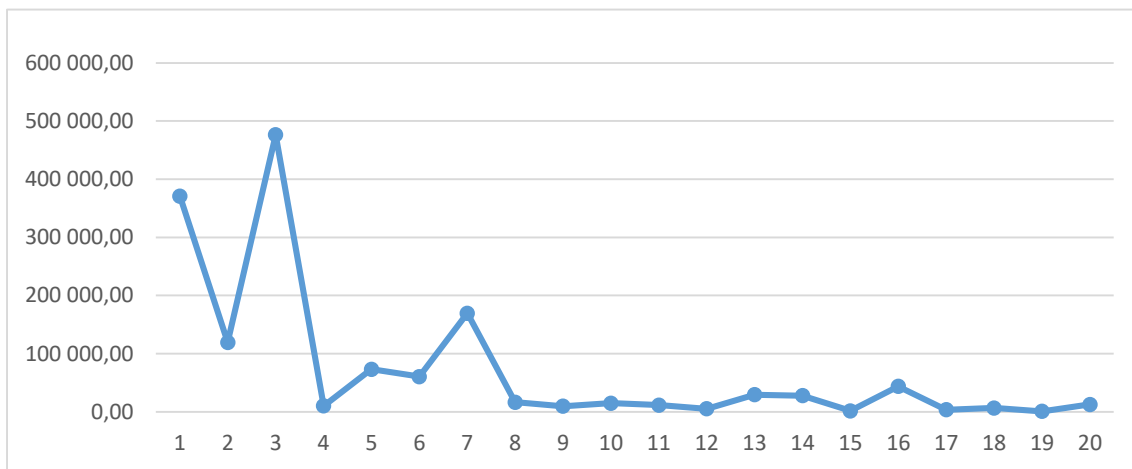


Figure 8: Research and Development expense in mln dollars.

The interesting part was which type of Research and Development improves the amount of high-tech product exports of the country. In order to know that I analyzed the data of “business” and “non-business” datasets with respect to high-tech exports.

**Table 5: Business side of Research and Development of countries with respect to their high-tech exports.**

Countries	R&D expenses in million dollars	Business R&D expenses in million dollars	High-tech exports
CHINA	370,605.00	286,465.00	560,058,333,865

GERMANY	119,562.00	74,123.00	193,087,960,652
UNITED STATES OF AMERICA	476,460.00	340,728.00	147,833,168,925
SINGAPORE	10,069.00	8,159.00	135,601,531,429
SOUTH KOREA	73,099.00	57,180.00	130,460,427,536
FRANCE	60,565.00	38,551.00	112,999,509,750
JAPAN	169,554.00	131,839.00	105,075,614,374
NETHERLAND	16,404.00	9,198.00	69,039,551,874
MALAYSIA	9,728.00	4,441.00	60,371,906,718
SWITZERLAND	14,744.00	10,542.00	53,350,361,422
MEXICO	11,519.00	3,449.00	45,418,666,690
THAILAND	5,138.00	2,787.00	33,901,233,425
ITALY	29,448.00	16,688.00	29,752,353,792
CANADA	27,794.00	14,798.00	29,136,849,244
VIETNAM	1,777.00	919.00	27,819,466,251
UNITED KINGDOM	43,811.00	28,542.00	24,215,736,361
IRELAND	3,625.00	2,572.00	21,914,722,722
CZECH REPUBLIC	6,699.00	3,698.00	20,921,357,479
PHILIPPINES	886.00	316.00	19,644,559,022
AUSTRIA	12,797.00	9,118.00	18,412,394,058

It turns out to be business type was indeed helpful due to higher correlation than overall with 0.722225. So then does that mean non-business one is going to be lower?

***Table 6: Non-business side of Research and Development of countries with respect to their high-tech exports.***

<b>Countries</b>	<b>R&amp;D expenses in million dollars</b>	<b>Non-business R&amp;D expenses in million dollars</b>	<b>High-tech exports</b>
CHINA	370,605.00	84,140.00	560,058,333,865
GERMANY	119,562.00	45,439.00	193,087,960,652
UNITED STATES OF AMERICA	476,460.00	135,732.00	147,833,168,925
SINGAPORE	10,069.00	1,910.00	135,601,531,429
SOUTH KOREA	73,099.00	15,919.00	130,460,427,536
FRANCE	60,565.00	22,014.00	112,999,509,750
JAPAN	169,554.00	37,715.00	105,075,614,374
NETHERLAND	16,404.00	7,206.00	69,039,551,874

MALAYSIA	9,728.00	5,287.00	60,371,906,718
SWITZERLAND	14,744.00	4,202.00	53,350,361,422
MEXICO	11,519.00	8,070.00	45,418,666,690
THAILAND	5,138.00	2,351.00	33,901,233,425
ITALY	29,448.00	12,760.00	29,752,353,792
CANADA	27,794.00	12,996.00	29,136,849,244
VIETNAM	1,777.00	858.00	27,819,466,251
UNITED KINGDOM	43,811.00	15,269.00	24,215,736,361
IRELAND	3,625.00	1,053.00	21,914,722,722
CZECH REPUBLIC	6,699.00	3,001.00	20,921,357,479
PHILIPPINES	886.00	570.00	19,644,559,022
AUSTRIA	12,797.00	3,679.00	18,412,394,058

This result showed the logical pattern as this time the correlation between non-business Research and Development and high exports had only 0.625739.

For answering a different question, this time I added the ITU index of the countries with the same country order from the previous data set. The question was, what is the relevance of the country's Research and Development costs with its technological advancement.

**Table 7: R&D expenses of countries with respect to their ITU level.**

<b>COUNTRIES</b>	<b>R&amp;D expenses in million dollars</b>	<b>ITU index of 2017</b>
CHINA	370,605.00	5.6
GERMANY	119,562.00	8.39
UNITED STATES OF AMERICA	476,460.00	8.18
SINGAPORE	10,069.00	8.05
SOUTH KOREA	73,099.00	8.85
FRANCE	60,565.00	8.24
JAPAN	169,554.00	8.43
NETHERLAND	16,404.00	8.49
MALAYSIA	9,728.00	6.38
SWITZERLAND	14,744.00	8.74
MEXICO	11,519.00	5.16
THAILAND	5,138.00	5.67
ITALY	29,448.00	7.04
CANADA	27,794.00	7.77

VIETNAM	1,777.00	4.43
UNITED KINGDOM	43,811.00	8.65
IRELAND	3,625.00	8.02
CZECH REPUBLIC	6,699.00	7.16
PHILIPPINES	886.00	4.67
AUSTRIA	12,797.00	8.02

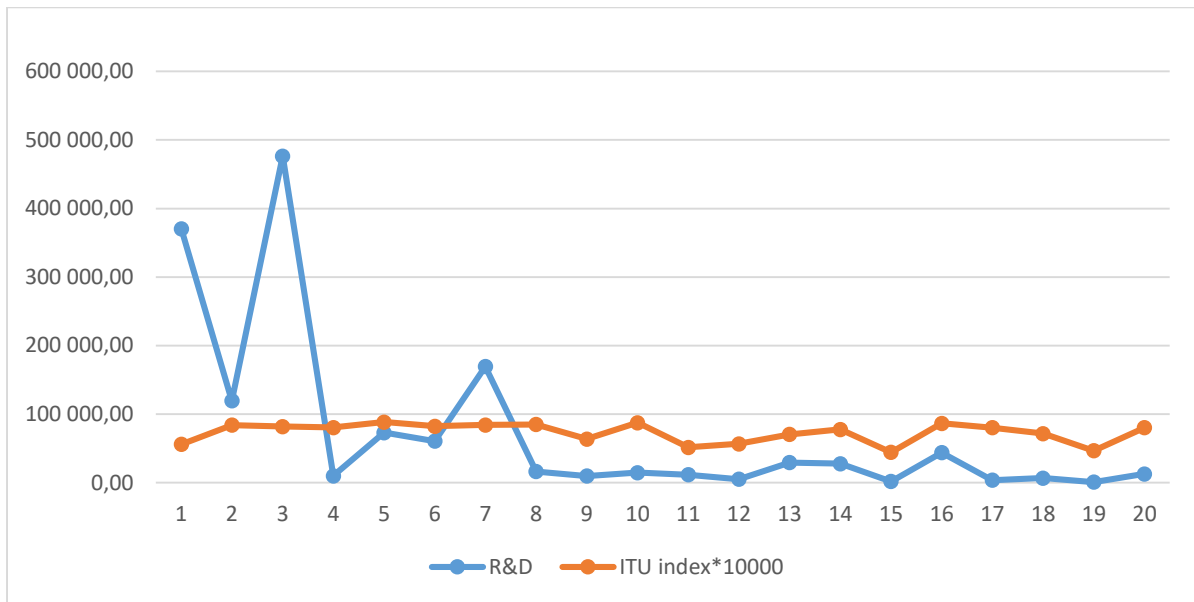


Figure 9: R&D costs vs ITU index\*10000.

However after analyzing the dataset it became obvious that the correlation was 0.101809 which is identified as a weak positive correlation. (The only reason for using 10,000 times of ITU index in the chart was to be able to compare them, otherwise one of them does not become comparable or even visible.) But there was something off in this dataset altogether, which can only be identified by looking at the table with logical reasoning unlike statistical analysis. If we look at the dataset, even if the Ireland is highly developed country in the ITU index list the Research and development is more than thousand times smaller than China, which has significantly lower amount of ITU index than Ireland. The reason for that was because China's population and therefore companies to do research which is very large compared to Ireland. So even if the companies are doing a few dollars worth of research which has no effect in real life of economy it matches to thousand dollars worth of Research and Development

costs in Ireland. Thus I took the dataset of Research and Development, then divided it to their own population and used the CORREL function again on those numbers to see their correlation.

**Table 8: R&D expenses per capita of countries with respect to their ITU level.**

<b>COUNTRIES</b>	<b>R&amp;D costs per capita in dollars</b>	<b>ITU index of 2017</b>
CHINA	260.9894366	5.6
GERMANY	1450.995146	8.39
UNITED STATES OF AMERICA	1448.206687	8.18
SINGAPORE	1718.259386	8.05
SOUTH KOREA	1424.931774	8.85
FRANCE	924.6564885	8.24
JAPAN	1335.070866	8.43
NETHERLAND	959.2982456	8.49
MALAYSIA	299.3230769	6.38
SWITZERLAND	1712.42741	8.74
MEXICO	87.26515152	5.16
THAILAND	74.14141414	5.67
ITALY	497.4324324	7.04
CANADA	747.1505376	7.77
VIETNAM	18.24435318	4.43
UNITED KINGDOM	653.8955224	8.65
IRELAND	747.4226804	8.02
CZECH REPUBLIC	631.9811321	7.16
PHILIPPINES	8.203703704	4.67
AUSTRIA	1459.179019	8.02

After this analysis things became clear that it was indeed the case in this dataset, because after testing out their correlation it turned out to be 0.854944 which is identified as strong positive correlation.

### **3.2.2 Analysis of the role of Research and Development in Companies**

First of all I wanted to understand if there was any correlation of Research and Development expenses with the company's revenue in 2017. After getting the numbers of the highest Research and Development payers, I tested their correlation and as it turns out they didn't have a strong correlation whatsoever, but there are logical reasons for that. The correlation of these two numbers were 0.368103 which means moderate positive correlation that starts from 0.3 and goes all the way up to 0.7. After this test we may think that there's a very small amount of correlation between research and development and the revenue of the company, but come to analyze it, there are too many loopholes in this experiment.

**Table 9: Most R&D paying companies vs their revenue.**

<b>Company</b>	<b>RD expense in billion dollars</b>	<b>Revenue in billion dollars</b>
Amazon	22.6	193.20
Alphabet	16.2	117.90
Volkswagen	15.8	272.00
Samsung	15.3	224.60
Intel Co	13.1	64.00
Microsoft	12.3	103.30
Apple	11.6	247.50
Roche	10.8	54.20
Johnson & Johnson	10.6	78.70
Merck	10.2	40.80
Toyota	10	265.20
Novartis	8.5	50.30
Ford	8	159.60
Facebook	7.8	44.60
Pfizer	7.7	52.70
General Motors	7.3	144.40
Honda	7.1	138.60
Daimler	7.1	193.20
Sanofi	6.3	39.50
Siemens	6.1	94.50

With having one exclusively important explanation of this analysis we can easily tell that the companies don't always go forward with research and



development even if it's one of the most important parts of it. The point here is that these companies may have different types of marketing strategy that affects them a lot. A very good example for that would be Apple that is known to have a huge amount of prosperity from its marketing side as it earned more than Samsung even though Samsung was the one to pay more to the Research and Development. The other point here was that as we mentioned before the Research and Development is a very risky part of economy as nobody knows what will be unveiled after paying millions of dollars into one specific product. For example it could also be like Samsung tried out different types of product possibilities and tested them to know if they are worth to produce or not and ended up having nothing better than it already has. That makes the company lose money into Research and Development, but that's not the issue here as we're simply considering the cost of the Research and Development not just the cost of successful products. But there are still some limitations with keeping the most important one to the end, we can say that even though these companies are technology companies they are not necessarily focused into one type of product segment as one of them produces smartphones, the other one produces medical stuffs, the others are automobile companies and etc. That surely affects their revenue differentiation in respect to their cost of Research and Development. Finally and most importantly however, as we mentioned before in the literature part of this study, the research and development has a specific characteristic which is affecting in a long term period not immediately. That means this data should be converted into a data that shows the company's revenue per year instead of showing different companies in one particular time slice. Thus I moved on to research those parts in order to find out the role of Research and Development in Technology Companies.

### **3.2.3 Analysis of the role of Research and Development in specific companies over years.**

### 3.2.3.1 Amazon's Research and Development

For doing this research I tried to use the number one company that pays the most amount of money as a cost to research and development which is Amazon. Putting all the numbers into a diagram with respect to its revenue, we end up with this kind of table:

*Table 10: Amazon company's R&D expenses with respect to their revenue along the years.*

Years	R&D expenses in million dollars	Revenue in 10 million dollars
2006	662	1071
2007	818	1484
2008	1033	1917
2009	1240	2451
2010	1734	3420
2011	2909	4808
2012	4564	6109
2013	6565	7445
2014	9275	8899
2015	12540	10701
2016	16085	13599
2017	22620	17787
2018	28837	23289

In this analysis it can be seen that the data was divided 10 times for the Revenue part of the statistics. The correlation will not have any impact by that at all and with dividing the Research and Development we will be able see some interesting details on the chart, but before that let's look at the correlation of these two numbers. The shocking number of correlation between the costs of Research and Development of Amazon company and its revenues over the years is 0.99476. This number not only falls into the part that says the numbers have strong correlation between each other with being over 0.7 , but with being over

0.99 simply means that they even increase almost proportionally which makes the whole Research and Development very useful for the company.

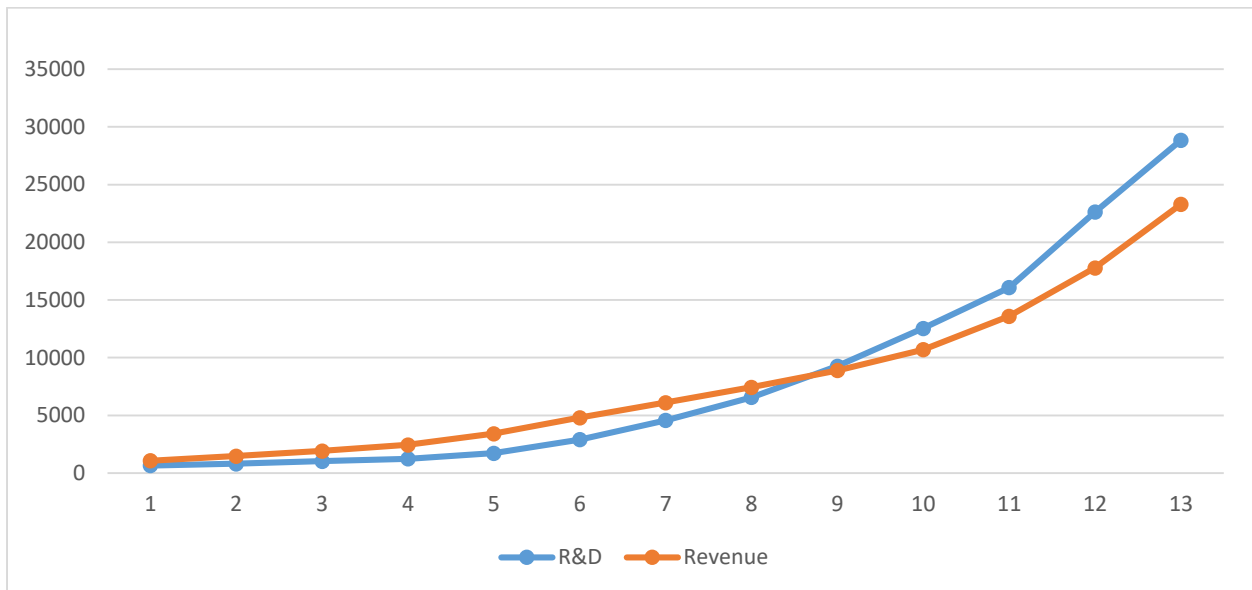


Figure 10: R&D costs vs Revenue's 10%.

The interesting part in this chart however is how Research and Development increases and passes 10 percent values of the Revenue or if we look from the other side we can say how Revenue's 10 percent decreases down compared to Research and Development costs. It is probably not a precise indicator but from this figure we may make an assumption of the elasticity of Research and Development costs to Revenue of the company. It shows that from 2014 to 2015 Amazon company increased its Research and Development costs more than its proportional value of Revenue. Therefore, the assumption indicates that if the company increases the Research and Development costs even further it is more likely to increase the revenue less than it in percentage values. It is very important to know how much money is invested into the Research and Development in terms of percentage rate of the whole company net worth as well. With this chart Amazon may look at its numbers that it paid for Research and Development and divide it to the net worth of the whole company in order to think about the next year's costs of Research and Development. For example if we assume that the net worth of the company is 1 billion dollars, then the last

year's costs for Research and Development would make 2.88% of the whole company. If they want to increase it they should think about the diminishing rate of return rule as well.

Although we know the revenue is not the whole story about the company, therefore I tried to look at the graphs of net income of the same company. In this graph I also took the data from 2006 to 2018 and matched with each other. After that I used the correlation function to find if these two columns have something in common in statistical terms and found out that the correlation between them was 0.80664 which is quite high considering that they are hard to be compared due to their value type differences. The correlation here as we know is strong as it past 0.7 barrier and headed for 1 but the reason why it couldn't pass 0.9 was simply because their value types.

**Table 11: Amazon company's R&D expenses with respect to their net income along the years.**

<b>Years</b>	<b>Research and Development costs in millions of dollars</b>	<b>Net income of Amazon in million dollars</b>
2006	662	190
2007	818	476
2008	1033	645
2009	1240	902
2010	1734	1152
2011	2909	631
2012	4564	-39
2013	6565	274
2014	9275	-241
2015	12540	596
2016	16085	2371
2017	22620	3033
2018	28837	10073

So what does value type difference even mean in the first place. The meaning of it is that we may not see any company to have negative value of costs on Research and Development at any date which is due to the reason that it's

practically impossible. With that being said, we can see some companies to have negative value of net income easily as it is the case in our data as well. Thus, in this table it's not hard to see the net income of Amazon falling down from zero to negative in couple different years. The first one of which happened in 2012 with the value of negative 39 million dollars of net income that translates into 39 million dollars of loss in income and the next one is huge negative 241 million dollars of net income that took place in 2014. These values shatter the correlation between the two columns as one of them continues to increase while the other goes to the opposite side, which may happen in the short run with lots of other reasons. The reason may also be that Amazon was trying to get the market into its hands before it increased its net income which can be presumed from this chart.

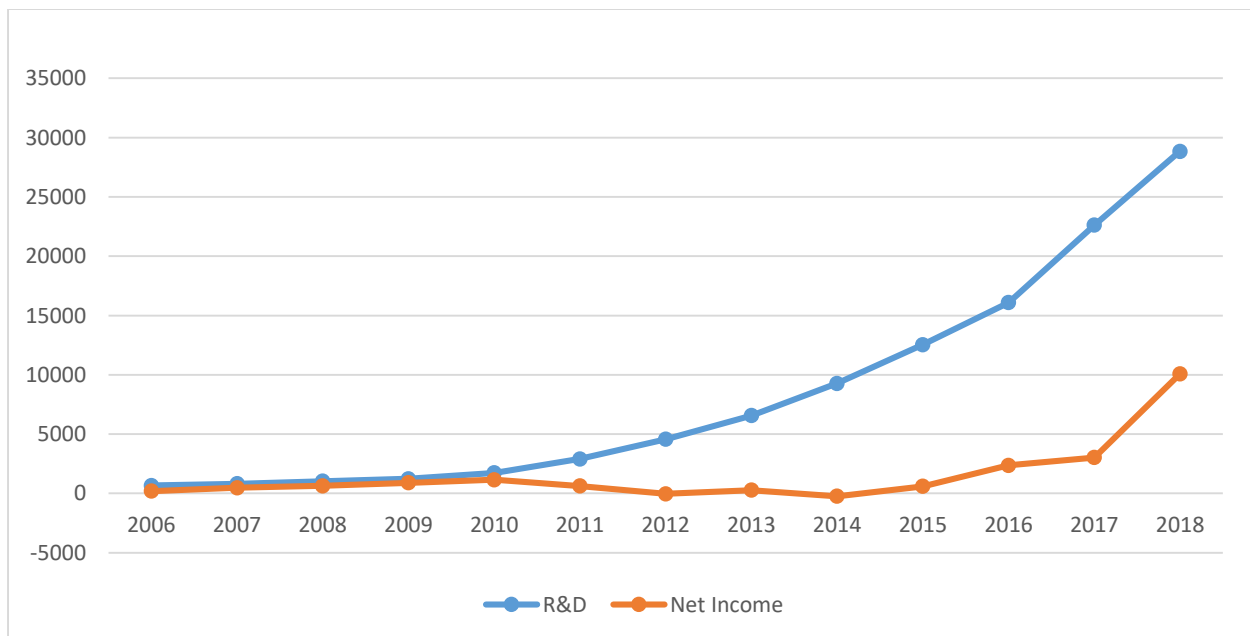


Figure 11: Research and Development and Net income in million dollars.

### 3.2.3.2 Apple's Research and Development

Interesting enough that we can not draw our statistical conclusions over one single company's data collections to verify the authenticity of our notion. For the sake of the authenticity of my hypothesis I chose another technology companies that are one automobile company and one from mobile technology

industry which also is one of the largest companies in the world. First I started with revenue statistics from 2006 to 2018 again as I did in Amazon company to see the correlation with Research and Development costs of Apple with respect to its Revenue.

The results were much lower than Amazon company's correlation due to the decrease of revenue in 2016. However the low amount of correlation is only compared to the previous one as it still bears 0.924156 in itself which translates into

***Table 12: Apple company's R&D expenses with respect to their revenue and net income along the years.***

<b>Years</b>	<b>R&amp;D expense in million dollars</b>	<b>Revenue in million dollars</b>	<b>Net income of Apple in million dollars</b>
2006	712	19315	199
2007	782	24578	350
2008	1109	37491	612
2009	1333	42905	824
2010	1782	65225	1401
2011	2429	108249	2592
2012	3381	156508	4173
2013	4475	170910	3704
2014	6041	182795	3951
2015	8067	233715	5339
2016	10045	215639	4569
2017	11581	229234	4835
2018	14236	265595	5953

Interesting part here was that moving on to the net income values the correlation was more than Amazon's net income and Research and Development costs with 0.887573 which was quite impressive.

In a nutshell, we have seen huge correlation values in both of these companies no matter which of these two data sets were compared to Research and Development, we have seen a determination of correlation in both companies. But these are not the only things that the companies want to increase in most of the times. The other thing that companies basically do whatever they can to increase is their stock prices of course without decreasing the amount of

those stocks. Therefore I added Apple's values into the table to research that as well. The question here is that if you benefit any increase in stock prices when you increase the amount of money that is invested into Research and Development.

**Table 13: Apple company's R&D expenses with respect to their stock prices along the years.**

<b>Years</b>	<b>R&amp;D expense in millions</b>	<b>Stock price of Apple in every June</b>
2006	712	8.1814
2007	782	17.4343
2008	1109	23.92
2009	1333	20.3471
2010	1782	35.9329
2011	2429	47.5929
2012	3381	83.4286
2013	4475	56.6471
2014	6041	92.93
2015	8067	125.425
2016	10045	95.6
2017	11581	144.02
2018	14236	185.11

Even if the stock prices are very volatile and jumps lower and higher they still have things in common. That's why the correlation got all the way up to 0.957405. For example from 2007 to 2008 Research and Development increased from 782 to 1109 which is 41.8% sequential increase but from 2008 to 2009 Research and development went from 1109 to 1333 which is only 20.2% increase. Therefore stock prices of Apple increased 37.2% and decreased 14.96% respectively. These type of number changes show that stock prices really tend to follow Research and Development expenses, which is the key

characteristic that drives the correlation to an even higher number.

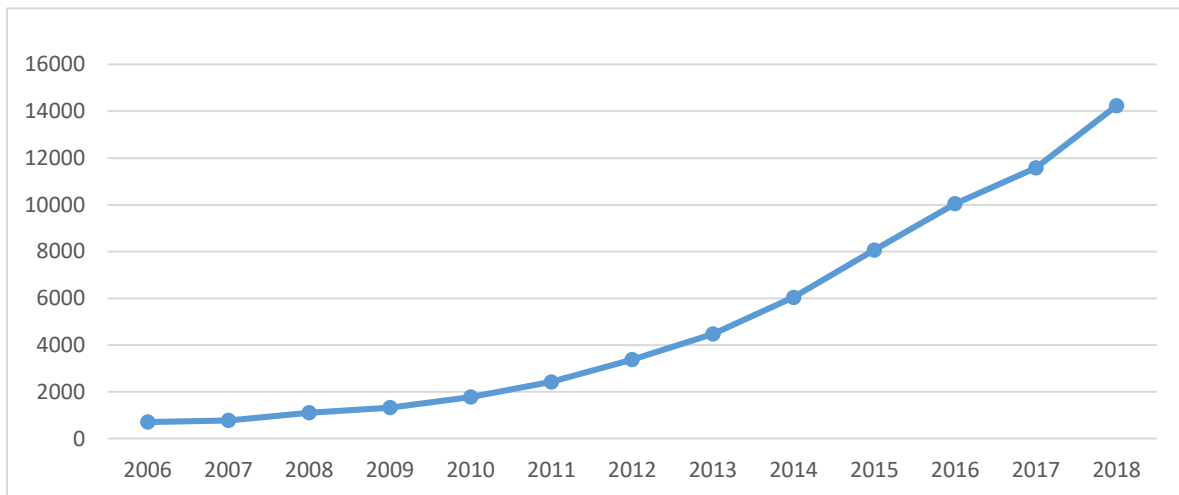


Figure 12: Research and Development Expenses in million dollars.

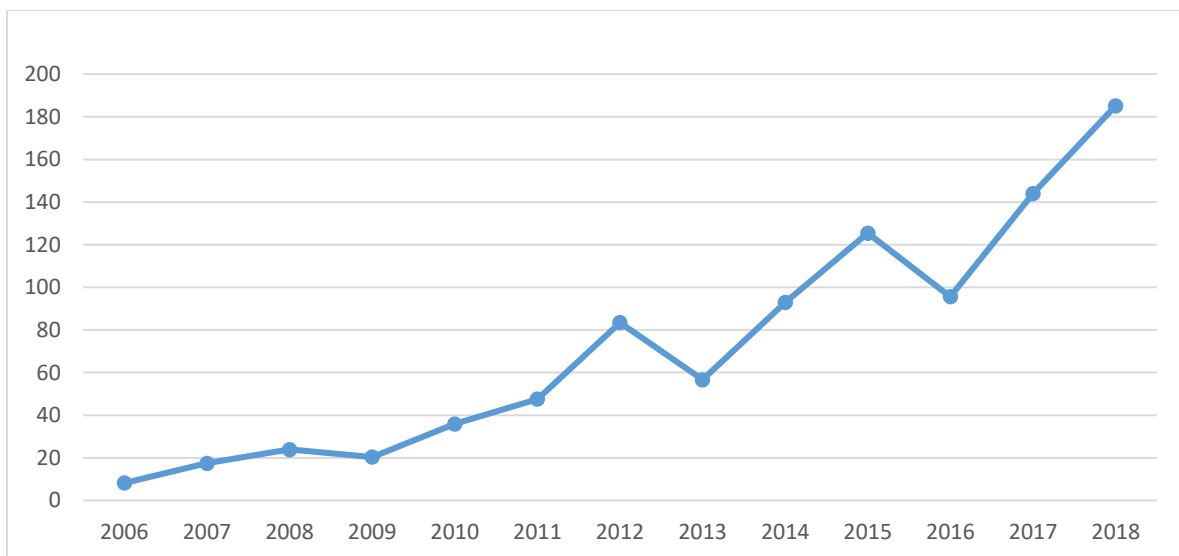


Figure 13: Stock price of Apple in dollars.

### 3.2.3.3 Toyota's Research and Development

After Amazon and Apple companies I chose an automobile company to test the hypothesis. In this hypothesis however we may have understood something about the first company that we just tested.

*Table 14: Toyota's Research and Development compared to its revenue.*

Years	R&D expense in million dollars	Revenue in million dollars
-------	--------------------------------	----------------------------



2007	890,782	202,864
2008	958,882	262,394
2009	904,075	208,995
2010	725,345	203,687
2011	730,340	228,427
2012	779,806	226,106
2013	807,454	234,601
2014	910,517	256,919
2015	1,004,547	247,834
2016	1,055,600	235,746
2017	1,037,500	256,654
2018	1,064,200	264,416

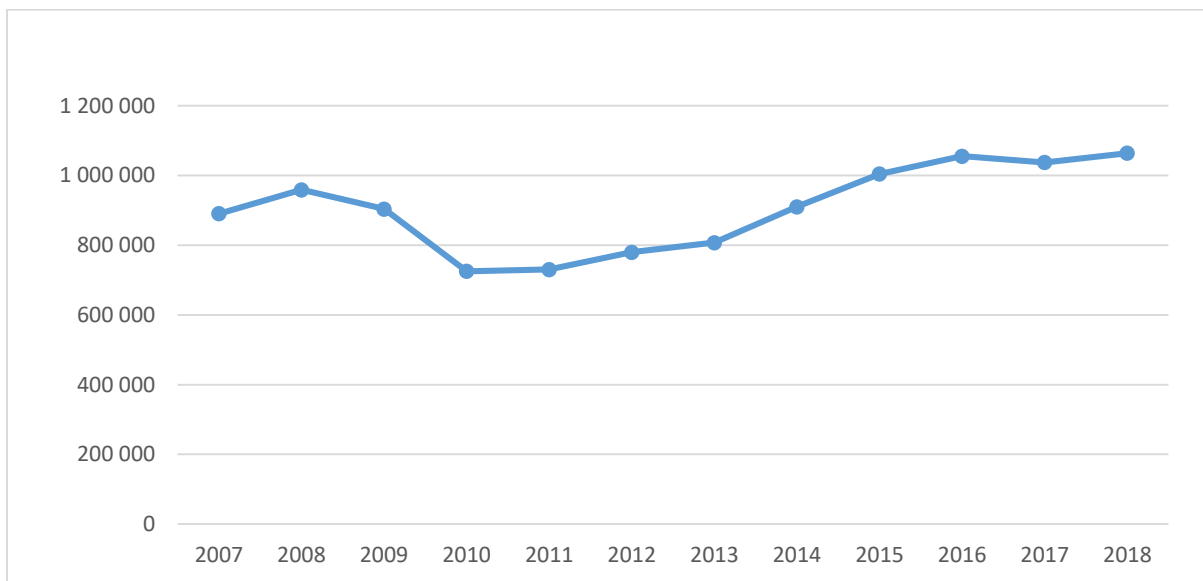


Figure 14: R&D expenses of Toyota from 2007 to 2018.

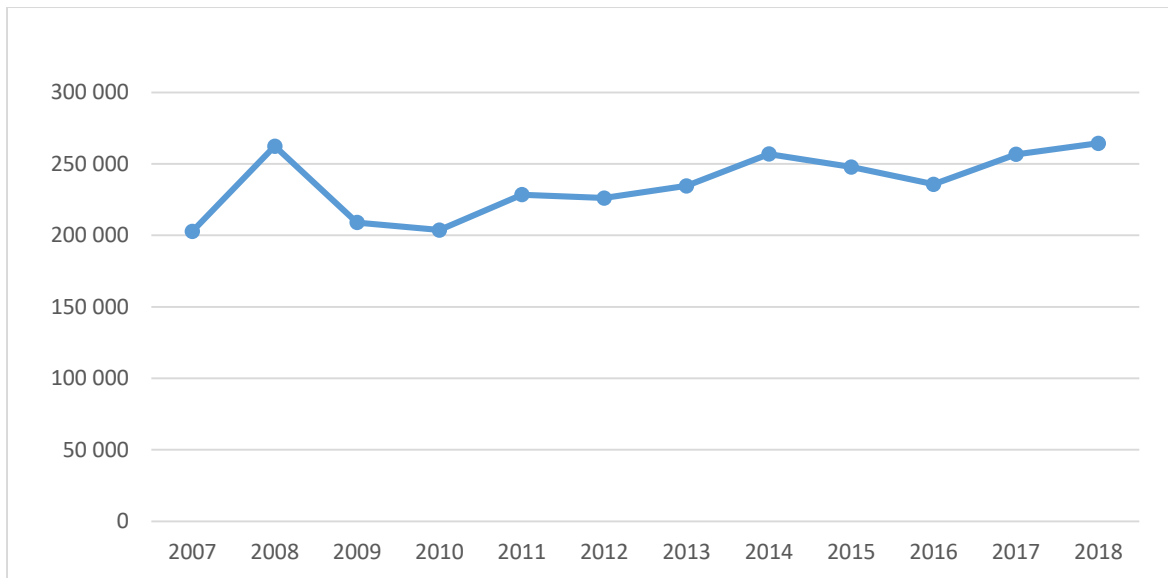


Figure 15: Revenue of Toyota from 2007 to 2018.

The interesting thing here is that after testing out the correlation between the Research and Development with Revenue the correlation became equal to 0.623651 which is still a positive correlation, it's not a huge amount of correlations that we previously tested. But the interesting part of the analysis afterwards with matching Research and Development with net income.

**Table 15: Toyota's Research and Development compared to its net income.**

years	R&D	Net Income
2007	890,782	13,927
2008	958,882	17,146
2009	904,075	-4,448
2010	725,345	2,251
2011	730,340	4,909
2012	779,806	3,450
2013	807,454	10,230
2014	910,517	18,231
2015	1,004,547	19,777
2016	1,055,600	19,195
2017	1,037,500	17,029
2018	1,064,200	22,446

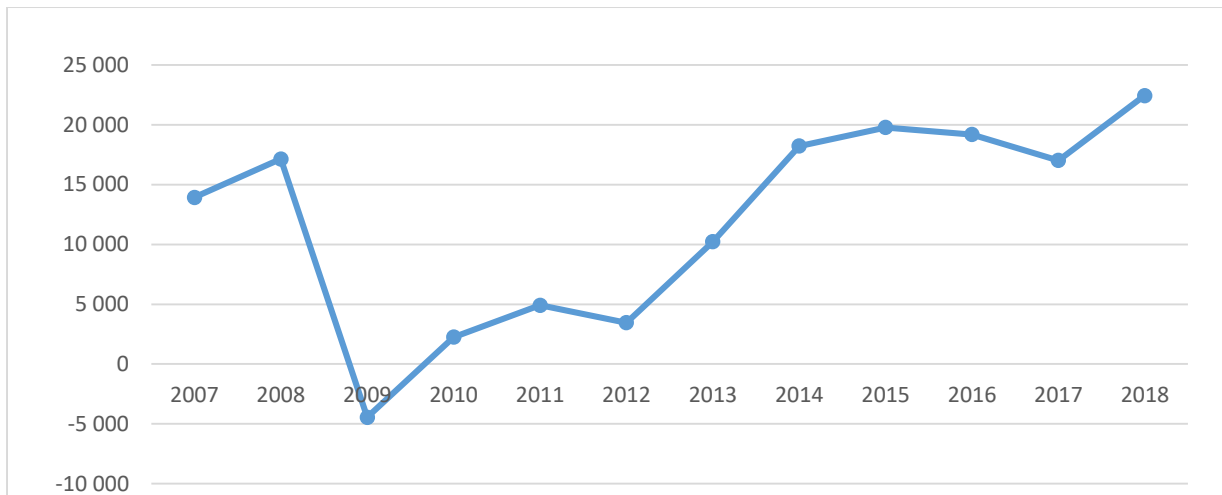


Figure 16: Net Income of Toyota from 2007 to 2018.

In this stance logically speaking the net income of a company is known to be more volatile than its revenue and volatile dataset mostly doesn't have high correlation with the other statistics. Because in order to have a correlation near to 1 with one volatile dataset is having the other dataset to follow that volatile dataset in the same manner as well. And in this case knowing that  $r$  equals to 0.751656 is a completely interesting matter. After making the net income of 2009 turn into zero (which does not seem coincidence as it was around global crisis times) the correlation even jumped to 0.818847. That means this volatile net income is strongly correlated to Research and Development. But there's one more important detail to analyze from the last two companies. That is the correlation of net income with Research and Development was higher than the correlation of revenue with Research and Development. However in our first case Amazon had an astonishing rate of 0.994, so the question rises that is Amazon trying to peg its Research and Development to its Revenue or at least relate them in one way? From my results it seems like Amazon is indeed trying to determine its Research and Development values by doing statistical analyze majorly on its revenue values. But from the way that it still pushes its Research and Development costs upwards is also interesting. We have seen that Amazon was getting diminishing rate of return from its Research and Development costs in the Revenue side but if it's still trying to increase it's costs in that department

then this means they are targeting their long time existence in the market so that in the long run they could still be surviving. It's not a very small price to pay but for the future gains it's most definitely very smart idea to push Research and Development even faster than revenue.

## 4.0 Conclusion

In this study I presented information about Research and Development after putting the questions that I was going to endeavor answering with my research part. As I answered that a company may survive without Research and Development but it's not going to be so much effective in the literature part, I had to answer the part needed answers with analyzing and calculating. For the researching part the questions were if Research and Development has a positive contribution to the community from the perspective of macro economy by researching the ITU and the governmental investments into Research and Development or if Research and Development can possibly affect a company to improve itself in terms of profit or revenue. My methodology was finding the correlation between the two elements of this matter and I used Pearson correlation method as opposed to the Spearman and Kendall's Tau correlation methods. The first part of the research was mainly about Research and Development from macroeconomics viewpoint, however the next part was mainly focusing on companies and their benefits from it. From the macroeconomic research part we saw that Research and Development indeed has a huge effect in increasing the amount of high-tech exports which is very important in every country. But then we did another analysis over it and understood that for production of these types of products were increasing more when the research is done by companies themselves instead of government. Therefore government should support and give incentives to the companies that pay more to Research and Development department.

The second part of the analysis was merely from the perspective of the companies themselves. In this analysis we also saw that there was a very strong correlation between the Research and Development expenses with revenues and profits. Except Amazon the other two companies had more correlation with net income. Amazon's unbelievable correlation was either simply an unexpected

coincidence or most probably they were coming up with the next year's Research and Development budget by analyzing more heavily the revenue of the company. Therefore It's safe to say that the Research and Development has a huge impact in technology company, but we also know from Matthew effect that we went through, the more the company is high-tech based rather than low-tech the more the benefit it gets from Research and Development.

## 5.0 Suggestion:

The overall suggestions for governments would be in two different types. If a government to have more high-tech based country with future of robots and etc. and also if the government wants to increase the amount of high-tech exports, thus overall exports of the country then they should go for incentivizing the companies to do the job like Australian economy that does tax offsets for Research and Development or subsidizing them. It also affect the name branding of the companies in that country and thus the countries themselves. For example, Germany is simply known for its automobile manufacturing as it has too many successful automobile companies. If the government wants to have even longer period time effects of the Research and Development and wants to increase the knowledge level in the country it can do basic Research and Development and incentivize the institutions for coming up with new scientific breakthroughs or even important innovations. But this will not affect the companies to improve as much as the business Research and Development does.

Other than that the suggestion of mine to small companies would be breaking the belief of not doing Research and Development just because of being a small company. Even if their excuse is that they don't have sufficient amount of resources for doing Research and Development there's a way of doing it with either partnership, merges, acquisitions or most importantly outsourcing the whole process. We went through in the outsourcing chapter that even the large companies nowadays start to outsource their Research and Development as it becomes more and more complicated every year. It's not even an illogical thing to consider using outsourcing for Research and Development for large companies in recent years as it becomes more efficient or at least more effective in some use cases. The perfect example for it would be that Qualcomm company was once only supplying the companies with their

chipsets which didn't have their own Research and Development departments large enough. But now they are even selling their chipsets to Samsung even if they have their own Research and Development department which can do the same type of chipset but less effectively.



## 6.0 Reference

### Links:

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Prahaland and Hamel (2006)

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Griliches and Mairesse (1984)

Matthew Effect: How Advantage Begets Further Advantage (2010)

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