

# **The Impact of Research and Development Investment on the Economic Performance of Apple Inc.**

## **Introduction**

Research and Development refers to the activities undertaken by companies to innovate and improve new products and services to increase their long-term profitability (Kenton, 2022). The world is increasingly becoming technology driven and the companies must constantly strive to ideate, invent and innovate in order to keep up with the demands of their consumers. New growth theories posit that not only is innovation a key driver for economic growth, but also impacts the competitiveness, growth and productivity of firms, industries and national economies (Bayarcelik et al, 2012). The output per hour worked in the United States, for example, is ten times it was 100 years ago. This massive boost in the total factor productivity (TFP) can be attributed to technological change (Romer, 1989). Research and Development are complementary activities. While research provides a layout in the form of a theoretical foundation, development provides the technical infrastructure that builds upon the research to yield a tangible output (Aghion et al, 1996). Research and Development become indispensable especially in the technology sector as it allows global market players like Apple, Microsoft, Tesla and Dell to stay ahead on the curve in terms of anticipating customer demands and trends (Kenton, 2022). Furthermore, the impact of R&D in this sector is not just limited to the development of products, but also to maintain sustainability in the business practices of these companies, vying for a lower carbon footprint.

However, there are certain problems associated with innovations and investment in R&D and the most glaring one is uncertainty of returns. Often, companies fail to put together a cogent strategy of investing in Research and Development which leads to catastrophic results. Motorola, for example, invested in the iridium R&D project which turned out to be a total failure and cost the company close to \$5 Billion (Lei Lv et al, 2020). Nokia is another notorious example of a company that has invested close to \$8 Billion in R&D, and yet is reliant on Microsoft for survival (Forbes, 2012). Another problem associated with R&D investments is the return on investment becomes an obscure metric. Since knowledge is a non-rival asset, one

company's use of it does not preclude the use by other (Hall, 2002). Thus, while it is vital for companies to spend on R&D to churn out new innovations, it is munificent to have a sustainable capital structure in place to be able fund the research while safeguarding said company from the risks that accompany such investments.

The purpose of this study is to analyze whether Apple Inc. investment in Research and Development has been economical in terms of affecting the total assets of the company and whether it should continue with or alter their existing patterns of investment.

## **Background of Apple Inc. and Competitors**

Apple Inc is one of the leading technology companies of the world. Founded in 1976 by Steve Jobs, Steve Wozniak and Ronald Wayne, the company was initially named the Apple Computer Company (later Apple Computer Inc.). It is headquartered in Cupertino, California, United States and is the largest technology company by revenue, second largest manufacturer of mobile phones and fourth largest vendor of personal computers. It is included in top 5 information technology companies of the world alongside Microsoft, Meta, Alphabet and Amazon. Having delivered wildly popular products such as the iPhones, MacBooks and iPads, Apple has become a household name in the arena of technological innovations and is one of the most valuable brands of the world.

To analyze the competitors of Apple Inc I selected the set of companies with SIC codes between 3570 and 3579 from the S&P 1500 Dataset, i.e., companies specializing in manufacturing of PCs, peripherals and related services. This includes some of the world's leading tech companies such as Hp Inc., Cisco Systems Inc and Seagate Technology Holdings.

## **Objectives of the Data Analysis**

The objective of the data analysis for this project is to measure the impact of investments made by Apple Inc. on its Research and Development, on the economic value of the company. For said analysis I have considered 'R&D Expenses' as the company's total expenditure on R&D

and ‘Total Assets’ which represents the economic performance of the company from 2016-2018.

The basic methodology followed for achieving the aforementioned objectives is as follows. The first step involves the collection of the relevant data from the data set provided, and to clean this raw data sample to produce the final data that shall be used for the analysis. Then, a descriptive analysis is conducted in order to compare how Apple Inc. fares in the current market in comparison to the set of competitors. A regression analysis is then conducted in order to measure the impact of R&D investments on the company’s economic value. Subsequently, a forecasting analysis is carried out to ascertain whether Apple Inc. should be spending more on its Research and Development or if their current investment strategy would suffice. The implications of this study are then analyzed in comparison to the literature that has already been published in this regard.

## **Data Collection, Cleaning and Preparation**

The dataset used for this analysis is the S&P 1500 dataset for the years 2016-2018. The data that is pertinent to this report includes ‘Year’ to indicate the year from 2016-2018 of measuring a particular metric. ‘SIC Code’ which is a four-digit code that represents the industry the company belongs to. For the purpose of this study, I have gathered the data of companies belonging to SIC Codes 3570-3579, as competitors of Apple Inc. ‘Number of Employees’ which was renamed to ‘Emp’ indicates the number of employees working in the company in any particular year. ‘Total Assets’ which was renamed to ‘Tot’ indicates the total economic value of the company and is used as a metric to figure out the market performance of that company. ‘R&D Expenses’ represents the total expenditure of a company on research and development, and it has been renamed as ‘Rnd’. To determine the “cause and effect” relationship between R&D expenses and Total Assets, I set the former i.e., ‘Rnd’ as the independent variable and the latter i.e., ‘Tot’ as the dependent variable.

The data is then scanned to search for any missing data points. The extracted data, however, does not have any missing values and is thus ready to be deployed. The final data sample used for the analysis contains Year, SIC Code, Total Assets and R&D Expense.

## Descriptive Analytics

Descriptive Analysis was conducted on the Apple Inc data as well as that of the competitors. As per the results, the company's expenditure on research and development steadily increased from 2016 to 2018. R&D showed a minimum value of 10045 in 2016, while its maximum value was 14236 in 2018. The average value of investment is obtained as 11954. The number of employees during this period has been on the rise from 116000 in 2016 to 132000 in 2018. The Total Assets also show an upward trend from 321686 in 2016 to 375319 in 2018 which is a positive indicator of the company's economic performance during these three years.

Out[49]:

	Rnd	Emp	Tot	SIC Code	Year
<b>count</b>	3.000000	3.000000	3.000000	3.0	3.0
<b>mean</b>	11954.000000	123666.666667	354243.333333	3571.0	2017.0
<b>std</b>	2120.251636	8020.806277	28600.632411	0.0	1.0
<b>min</b>	10045.000000	116000.000000	321686.000000	3571.0	2016.0
<b>25%</b>	10813.000000	119500.000000	343705.500000	3571.0	2016.5
<b>50%</b>	11581.000000	123000.000000	365725.000000	3571.0	2017.0
<b>75%</b>	12908.500000	127500.000000	370522.000000	3571.0	2017.5
<b>max</b>	14236.000000	132000.000000	375319.000000	3571.0	2018.0

Figure 1 : Summary of Apple Inc. Data

From the dataset of competitors, the average expenditure on research and development was found to be 1704. The maximum investment was 14236 in 2018. Since the standard deviation is found to be much higher than that obtained from the data set of Apple Inc, it implies that certain companies from the competitor's data set heavily invest in their R&D wings, while others don't. E.g., Investments made by companies like Digi International Inc. and Omnicell Inc. are almost negligible when compared to tech giants like Hp Inc. and Cisco Systems Inc. which have a strong focus on R&D and a much larger capital reserve than the former companies.

Out[51]:

	Rnd	Emp	Tot	SIC Code	Year
<b>count</b>	60.000000	60.000000	60.000000	60.000000	60.000000
<b>mean</b>	1703.911000	49425.800000	39996.777783	3574.200000	2017.000000
<b>std</b>	2944.174201	82604.760001	81462.579987	3.068705	0.823387
<b>min</b>	28.566000	514.000000	336.166000	3570.000000	2016.000000
<b>25%</b>	183.678750	4601.000000	2448.895000	3571.000000	2016.000000
<b>50%</b>	410.500000	18850.000000	7987.000000	3576.000000	2017.000000
<b>75%</b>	1425.500000	56250.000000	30610.500000	3576.250000	2018.000000
<b>max</b>	14236.000000	380300.000000	375319.000000	3579.000000	2018.000000

Figure 2 : Summary of the Competitor Data

When compared with the competitors, Apple Inc. has a higher average expenditure on research and development. However, this statistic can be deceptive because the set of competitors contain both companies with large revenue bases and those with small. In comparison to Apple Inc. for example, HP Inc.'s investment in R&D is much lower. The total assets of the company are higher than that of the average of competitors which implies that they are in the mid to upper end of the market spectrum.

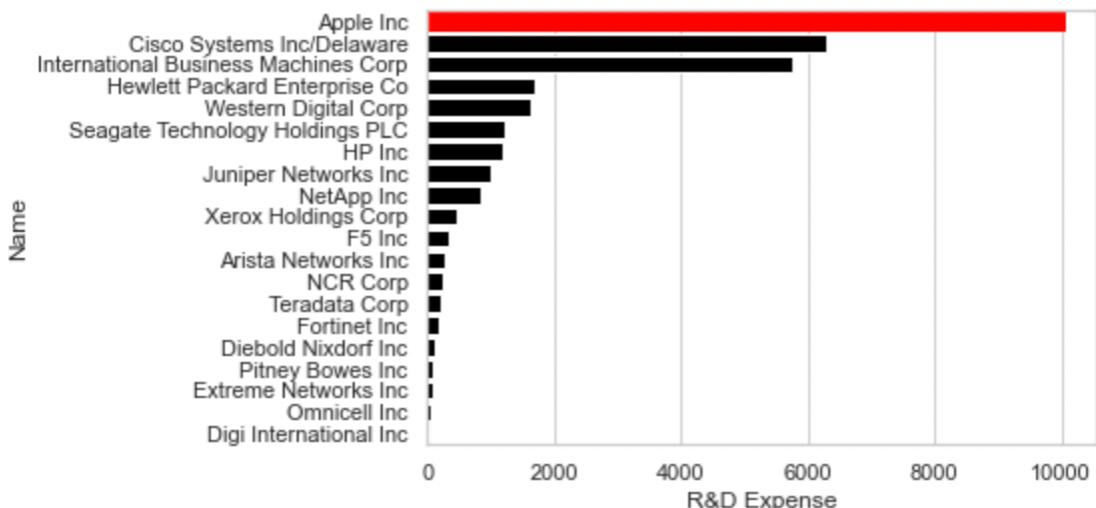


Figure 3a : R&D Expenses

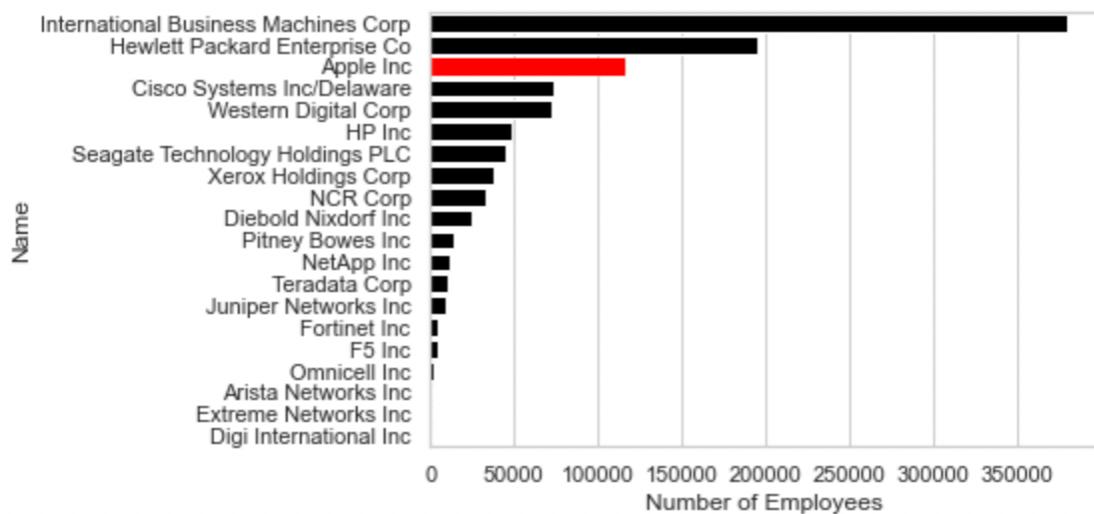


Figure 3b : Number of Employees

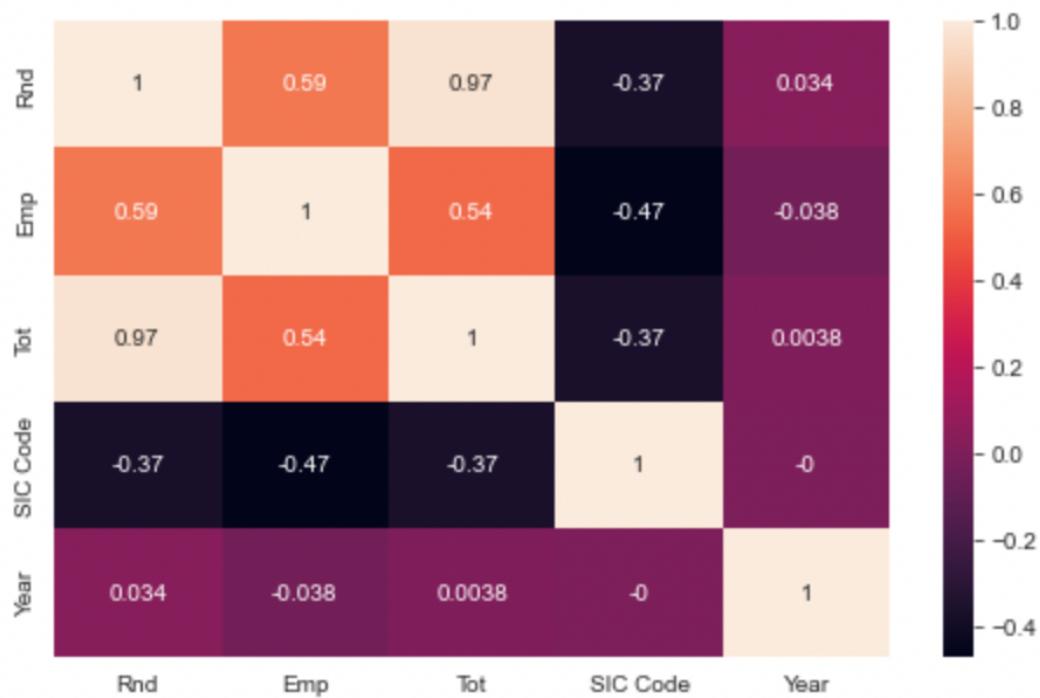


Figure 4 : Correlation Heatmap

## Regression and Predictive Analysis

The regression analysis was conducted for Apple Inc. between the total assets (renamed as ‘Tot’) which was the dependent variable and the R&D expenses (renamed as ‘Rnd’) which was the independent variable. The model of regression utilized for this analysis was the Ordinary Least Square (OLS) regression model. The conclusion that can be drawn from the results of the regression model is that, given the number of employees (‘Emp’) kept constant, the investments made in research and development will have a positive impact on the total assets of HP Inc. The regression output shows that for every 1 degree increase in R&D variable, the increase in total assets will be by 27.66. This suggests the investments made in research and development will have a significantly constructive influence on a firm’s economic performance.

OLS Regression Results							
Dep. Variable:	Tot	R-squared:	0.944				
Model:	OLS	Adj. R-squared:	0.942				
Method:	Least Squares	F-statistic:	484.4				
Date:	Wed, 21 Dec 2022	Prob (F-statistic):	1.69e-36				
Time:	15:19:04	Log-Likelihood:	-676.40				
No. Observations:	60	AIC:	1359.				
Df Residuals:	57	BIC:	1365.				
Df Model:	2						
Covariance Type:	nonrobust						
coef	std err	t	P> t	[0.025	0.975]		
Rnd	27.6687	1.066	25.957	0.000	25.534	29.803	
Emp	-0.0488	0.038	-1.285	0.204	-0.125	0.027	
const	-4735.7649	3031.520	-1.562	0.124	-1.08e+04	1334.749	
Omnibus:	12.721	Durbin-Watson:	1.558				
Prob(Omnibus):	0.002	Jarque-Bera (JB):	31.123				
Skew:	0.450	Prob(JB):	1.74e-07				
Kurtosis:	6.412	Cond. No.	1.15e+05				

### Notes:

- [1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
- [2] The condition number is large, 1.15e+05. This might indicate that there are strong multicollinearity or other numerical problems.

Figure 5 : Results of the Regression Model

This result is in coherence with the existing literature that evaluates the relationship between R&D activities and economic growth. E.g., Tsegaye's (2022) study draws a similar conclusion that R&D activities have a robust and substantial impact, not only on the performance of a firm but also on the firm's energy consumption, which is indispensable today as companies push for a more sustainable and environment-friendly approach of conducting business. Apple Inc. are also strong champions of the climate action initiative, having made significant efforts to achieve their target of becoming 100 percent Carbon Neutral by 2030. Their products are increasingly planet friendly, having been made out of recycled materials, and their energy consumption has gone down by a whopping 70 percent since 2008 (Apple, 2022). Le Thanh Tung and Quan Minh Quoc Binh (2022) are of similar views, that R&D investments and profits show a positive relationship because increasing sales revenues caused by new innovative products or lower production costs thanks to the development of cutting-edge technology. In addition, R&D will allow companies to use their assets effectively thereby enabling them to gain a higher market share.

Next, I evaluate that given the results of the regression analysis, should Apple Inc. increase, decrease or continue with their existing investment pattern for research and development. In 2016 Apple Inc's R&D expenses were 10045, while in 2018 they amounted to 14236. This implies an approximate increase of 1397 per year. This means that in 2019, the company's R&D expenses can be estimated to 15633. Similarly, the control variable 'Emp' (number of employees) has a value of 116000 in 2016 and 132000 in 2018. The average increase per year is 5,333.33. Hence, the value in 2019 can be estimated at 137333. These values of the two variables 'Emp' and 'Rnd' are then employed in the predictive analytics model and the value obtained for the total assets is 421106. This value is higher than the value of total assets of Apple Inc. in 2018, which suggests that moving forward it would be profitable for the company to keep their investment in research and development on the higher side.

The findings of the predictive model are in line with Apple's investment strategy in research and development for 2019. In said year, the company's R&D expenses reached as high as \$16 Billion which was approximately 8% of its total revenue generated that year. The main reason as to why Apple fueled its spending further was because of a slight dip in the sales of one of its major products, the iPhone by about 12%. In order to bolster the revenue generated from the iPhones, they increased their R&D bill for the development of their core technologies. Besides ameliorating the numbers of sales, Apple Inc's R&D expenses has borne several fruits.

As of today, Apple has commenced the development of their own processors for iPhones, a requirement for which they were previously reliant on companies like Qualcomm. Apple is also designing their own Bluetooth chips, an essential technology for AirPods, another one of their hot-selling products. Apple is also setting foot in the automotive industry, having initiated ‘Project Titan’ in which they are collaborating with Testa to work on the designing of self-driving cars. Another avenue of expenditure by Apple has been augmented reality wherein they are attempting to design AR apps for iPhones as well as working on producing AR glasses for their consumers. (Leswing, 2019) Thus, heavy investments in their research and development by Apple Inc has led to them becoming one of the flag-bearers of technological innovation in the world, which has expanded their consumer base as well as enhanced their revenue.

Soferman (2020) states that even during tough financial times, firms with high R&D expenditures are likely to fare better than those that control those expenditures. This is because R&D activities signals to both customers and investors that they can rely on the firm to produce cutting-edge technology which would be superior than it's contemporaries. For example, Apple Inc. lead the way during the economic crisis of 2001, selling over 4 million iPhones and 2.5 millions Macs. While other IT companies were struggling in the Silicon Valley, Apple Inc. leadership's strategic investment in research and development saved the day.

## Conclusion

This project was aimed at analyzing the impact of R&D investments made by Apple Inc. on their economic performance over the duration of 3 years, from 2016-2018. The company's Total Assets were used as a proxy for its economic performance through these three years and was the dependent variable, R&D expenses was the independent variable and the number of employees of the company was used as the control variable for the analysis. The relationship between the dependent and the independent variables was then explored using regression analysis, after which a predictive model was used to determine whether Apple Inc. should alter or follow their existing investment patterns in R&D. The regression analysis as well as the predictive analysis yielded a positive relationship between R&D investments and the Total Assets of Apple Inc. It can therefore be said with some confidence that investing in research and development does enhance a firm's performance significantly. However, it is always advisable to have a strategy in place, one that reflects current market trends, so as to ensure

that the company executives make wise decisions by allocating the appropriate amount of funds commensurate to consumer demands.

The limitation of this paper is that it fails to consider the contribution of other investment facets, such as marketing, which can also be a major contributor to the economic performance of a firm. Secondly, the results suggest a linear relationship between R&D expenditure and Total Assets. However, the relationship between these two metrics is more complex as companies do at times incur losses despite investing in research and development. Hence, a possible avenue of future research could be to consider the effects of overspending on R&D on the financial standing of companies.

## References

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Will Kenton (2022) Research and Development (R&D) Definition, Types, and Importance  
<https://www.investopedia.com/terms/r/randd.asp>

Kif Leswing (2019) Apple is spending more than ever on R&D to fulfill the ‘Tim Cook doctrine’ <https://www.cnbc.com/2019/08/03/apple-rd-spend-increases-fulfilling-tim-cook-doctrine.html>

## Appendix

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File Edit View Insert Cell Kernel Widgets Help Trusted Python 3 (ipykernel)

In [48]:

```
import pandas as pd
import seaborn as sns
import statsmodels.formula.api as smf
import statsmodels.api as sm
from statsmodels.formula.api import ols
import matplotlib.pyplot as plt
from statsmodels.stats.outliers_influence import variance_inflation_factor
import numpy as np
```

In [49]: #Apple Inc

```
df = pd.read_csv('Sample_1_CSV_S&P1500_Raw Dataset_Data Analytics in Business Assignment_2021.csv')
df = df.rename(columns={'R&D Expense':'Rnd', 'Total Assets':'Tot', 'Number of Employees':'Emp', 'Social Disclosure Score': 'SIC Code'})
df_B = df.loc[df['Name'] == 'Apple Inc']
dfb = df_B[['Name', 'Rnd', 'Emp', 'Tot', 'SIC Code', 'Year']]
dfb.describe()
```

Out[49]:

	Rnd	Emp	Tot	SIC Code	Year
count	3.000000	3.000000	3.000000	3.0	3.0
mean	11954.000000	123666.666667	354243.333333	3571.0	2017.0
std	2120.251636	8020.806277	28600.632411	0.0	1.0
min	10045.000000	116000.000000	321686.000000	3571.0	2016.0
25%	10813.000000	119500.000000	343705.500000	3571.0	2016.5
50%	11581.000000	123000.000000	365725.000000	3571.0	2017.0
75%	12908.500000	127500.000000	370522.000000	3571.0	2017.5
max	14236.000000	132000.000000	375319.000000	3571.0	2018.0

In [52]: #Data of Competitors

```
dfcompl1 = df[(df['SIC Code'] >= 3570) & (df['SIC Code'] <= 3579)]
dfcomp2 = dfcompl1[['Name', 'Rnd', 'Emp', 'Tot', 'SIC Code', 'Year']]
dfc=dfcomp2.dropna()
dfc
```

Out[52]:

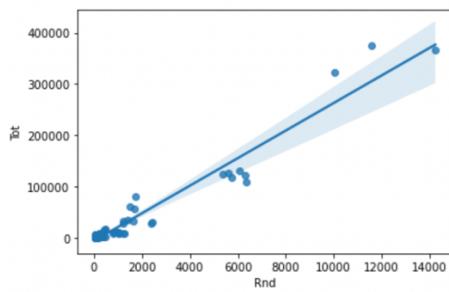
	Name	Rnd	Emp	Tot	SIC Code	Year
24	HP Inc	1209.000	49000.0	28987.000	3570.0	2016
26	International Business Machines Corp	5751.000	380300.0	117470.000	3570.0	2016
44	Cisco Systems Inc/Delaware	6296.000	73700.0	121652.000	3576.0	2016
61	Seagate Technology Holdings PLC	1237.000	45500.0	8213.000	3572.0	2016
81	Diebold Nixdorf Inc	110.200	25000.0	5270.300	3578.0	2016
166	Xerox Holdings Corp	476.000	37600.0	18051.000	3577.0	2016
233	Hewlett Packard Enterprise Co	1714.000	195000.0	79629.000	3570.0	2016
342	Digi International Inc	30.955	515.0	336.166	3576.0	2016
363	Pitney Bowes Inc	107.378	14200.0	5837.133	3579.0	2016
465	Apple Inc	10045.000	116000.0	321686.000	3571.0	2016
690	NetApp Inc	861.000	12030.0	10037.000	3572.0	2016

In [51]: dfc.describe()

Out[51]:

	Rnd	Emp	Tot	SIC Code	Year
count	60.000000	60.000000	60.000000	60.000000	60.000000
mean	1703.911000	49425.800000	39996.777783	3574.200000	2017.000000
std	2944.174201	82604.760001	81462.579987	3.068705	0.823387
min	28.566000	514.000000	336.166000	3570.000000	2016.000000
25%	183.678750	4601.000000	2448.895000	3571.000000	2016.000000
50%	410.500000	18850.000000	7987.000000	3576.000000	2017.000000
75%	1425.500000	56250.000000	30610.500000	3576.250000	2018.000000
max	14236.000000	380300.000000	375319.000000	3579.000000	2018.000000

```
In [53]: #Scatterplot
scatter, ax = plt.subplots()
ax = sns.regplot(x = 'Rnd', y = 'Tot', data = dfc)
plt.show()
```



```
In [54]: #Regression Analysis
y = dfc.Tot
X = dfc[['Rnd', 'Emp']].assign(const=1)
model = sm.OLS(y,X)
results = model.fit()
print(results.summary())
```

OLS Regression Results						
		Tot	R-squared:	0.944		
Dep. Variable:		OLS	Adj. R-squared:	0.942		
Model:		Least Squares	F-statistic:	484.4		
Date:	Wed, 21 Dec 2022		Prob (F-statistic):	1.69e-36		
Time:	15:19:04		Log-Likelihood:	-676.40		
No. Observations:	60		AIC:	1359.		
Df Residuals:	57		BIC:	1365.		
Df Model:	2					
Covariance Type:	nonrobust					
	coef	std err	t	P> t	[0.025	0.975]
Rnd	27.6687	1.066	25.957	0.000	25.534	29.803
Emp	-0.0488	0.038	-1.285	0.204	-0.125	0.027
const	-4735.7649	3031.520	-1.562	0.124	-1.08e+04	1334.749
Omnibus:	12.721	Durbin-Watson:			1.558	
Prob(Omnibus):	0.002	Jarque-Bera (JB):			31.123	
Skew:	0.450	Prob(JB):			1.74e-07	
Kurtosis:	6.412	Cond. No.			1.15e+05	

#### Notes:

- [1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
- [2] The condition number is large, 1.15e+05. This might indicate that there are strong multicollinearity or other numerical problems.

```
In [56]: #Predictive Analysis 6423, 136829
data = {'Rnd': 15633 , 'Emp': 137333},
df = pd.DataFrame(data).assign(const=1)
results.predict(df)
```

```
Out[56]: 0    421106.08722
dtype: float64
```

```
In [113]: plt.figure(figsize=(8,5))
correlation = dfc.corr().round(4)
sns.heatmap(data=correlation, annot=True)
plt.show()

Out[113]: <function matplotlib.pyplot.show(close=None, block=None)>
```



```
In [2]: import numpy as np
import pandas as pd

df = pd.read_csv('Sample 1_CSV_S&P1500_Raw Dataset_Data Analytics in Business Assignment_2021.csv')

#create a dataset with only the companies that have sic codes between 3570 and 3579
df = df[(df['SIC Code'] >= 3570) & (df['SIC Code'] <= 3579)]

#show df
df

#create a dataset with unique names in df
df_unique = df.drop_duplicates(subset=['Name'])
```

```
#create a seaborn horizontal bar chart of the number of employees in each company in df_unique with the color of the bar
import seaborn as sns
import matplotlib.pyplot as plt
sns.set_theme(style="whitegrid")
ax = sns.barplot(x="Number of Employees", y="Name", data=df_unique, color='black', order=df_unique.sort_values('Number of Employees'))

#change the color of the company with Name = 'Apple Inc.' to red
ax.patches[2].set_color('red')
```



```
In [3]: ax2 = sns.barplot(x="R&D Expense", y="Name", data=df_unique, color='black', order=df_unique.sort_values('R&D Expense'),
ax2.patches[0].set_color('red'))
```

