CFFA End-Term Project (BM60112)

(Source: Google Images)

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This report gives us a description of what all is done in the project right from the assumptions to the end execution process.

Objective

To investigate the Arbitrage Pricing Theory (APT) by applying it to a portfolio of 7 stocks in the telecommunication sector along with studying the relevance of the macroeconomic variables (features for predicting return) and then constructing and evaluating a risk-free portfolio (consisting of these same company stocks) based on our model.

Theory

Arbitrage pricing theory (APT) is a multi-factor asset pricing model based on the idea that an asset's returns can be predicted using the linear relationship between the asset's expected return and a number of macroeconomic variables that capture systematic risk

It was developed by the economist Stephen Ross in 1976, as an alternative to the capital asset pricing model (CAPM).

Unlike the CAPM, which assumes markets are perfectly efficient, APT assumes markets sometimes mis-price securities, before the market eventually corrects and securities move back to fair value. It thus provides arbitrageurs the opportunity to take advantage of this mispricing and eventually drive the security back to its fair value.
The fair value of a security under the APT is not fundamental but is rather based on consistent pricing of systematic risks by market participants.

APT factors are the systematic risks that cannot be reduced by the diversification of an investment portfolio.The factors as well as how many of them are used are subjective choices

The Model

$$E(R)i=E(R)f+(E(I)-E(R)f)\times\beta n$$

where,

$E(R)i$ = Expected return on the asset
Rf = Modelled Risk-free rate of return
βn = Sensitivity of the asset price to macroeconomic factor n

(E(I)−E(R)f)= The risk premium associated with factor n('λ')

Methodology

1) Stocks and Data collection:

We have based our study on seven telecommunication sector stocks in India, namely Bharti Airtel, Tata Communications, Vodafone Idea, Reliance Communications, Hathway, Infratel and Vindhya Telelinks
For the purpose of consistency of economic conditions, we have limited our study to a time period of 5 years between Oct 2014 and Oct 2019. This gives us 20 quarters of data while ensuring that economic conditions have not changed drastically within the period of our study
Data of quarterly returns of the seven stocks on the Bombay Stock Exchange(BSE) was taken from the website of Bombay Stock Exchange. (see **Appendix 1**)

2) Studying and Investigating Macroeconomic Factor Choices:

The next step was to decide the macroeconomic factors on which to model these returns. The APT gives us the flexibility to decide what factors to use and the number of factors to use as well. Prior studies have shown that 5 factors are sufficient to capture/model most of a security's systematic risk/return. A paper titled, '**The Effect of Macroeconomic Variables on Stock Price of Telecommunication Companies'**(Hamara et al), published in the International Journal of Science and Research (IJSR) gives insights into how different macroeconomic factors affect stock returns of telecommunication companies. The paper shows that factors like **Exchange Rate, Gdp growth, and interest rates** have significant effects on telecom stocks. To a lesser extent**, inflation** plays a role as well. Although this study was based on Indonesian Telecom stocks, we believe the results can be extrapolated to the Indian markets as well. This view is backed by a study on Indian markets(Sensex) made by Kiran Kumar Kotha and Bhawna Sahu in their paper '**Macroeconomic Factors and the Indian Stock Market: Exploring Long and Short Run Relationships**' The study finds that factors like **exchange rate, money supply, WPI, and treasury bill rate** have a significant influence on returns of SENSEX. Combining the findings of these two studies, we finally settled on 4 macroeconomic factors, namely:

1) CPI Growth Rate(Inflation)
2) Dollar-Rupee Exchange Rate
3)Real GDP Growth Rate(captured through GDP growth at constant 2010-11 prices)

4)Term Structure of Interest Rates(captured through spread b/w 10-year and 2-year govt. bonds, it reflects the state of the economy through the yield curve while also capturing information about money supply and interest rates)

It should be noted that standard economic theory also backs our factor choices. We further added a fifth factor, namely **Market(SENSEX) Return** to our model, adding some similarity with the CAPM. The data collected for the factors can be seen in **Appendix 2**

3)Model Development and Regressions:

a) Time Series Regression for Calculating the factor loadings

A time-series regression was run, modeling the quarterly returns of the seven stocks against our five economic factors. For the purpose of this regression, we need to calculate the unexpected component in the five economic factors, each quarter, i.e

Equation:
R(i)= Intercept B_1i*Factor1 +B_2i*Factor2 +B_3i*Factor3+B_i1Factor4+B_5i*Factor5
beta_1i = factor loading for ith security for cpi_growth
beta_2i = factor loading for ith security for exchnage_rate
beta_3i = factor loading for ith security for market_return
beta_4i = factor loading for ith security for gdp_growth
beta_5i = factor loading for ith security for bond_rate_difference

Factor1 = unexpected change in cpi_growth
factor2 = unexpected change in exchnage_rate
factor3 = unexpected change in market_return
factor4 = unexpected change in gdp_growth
factor5 = unexpected change in bond_rate_difference

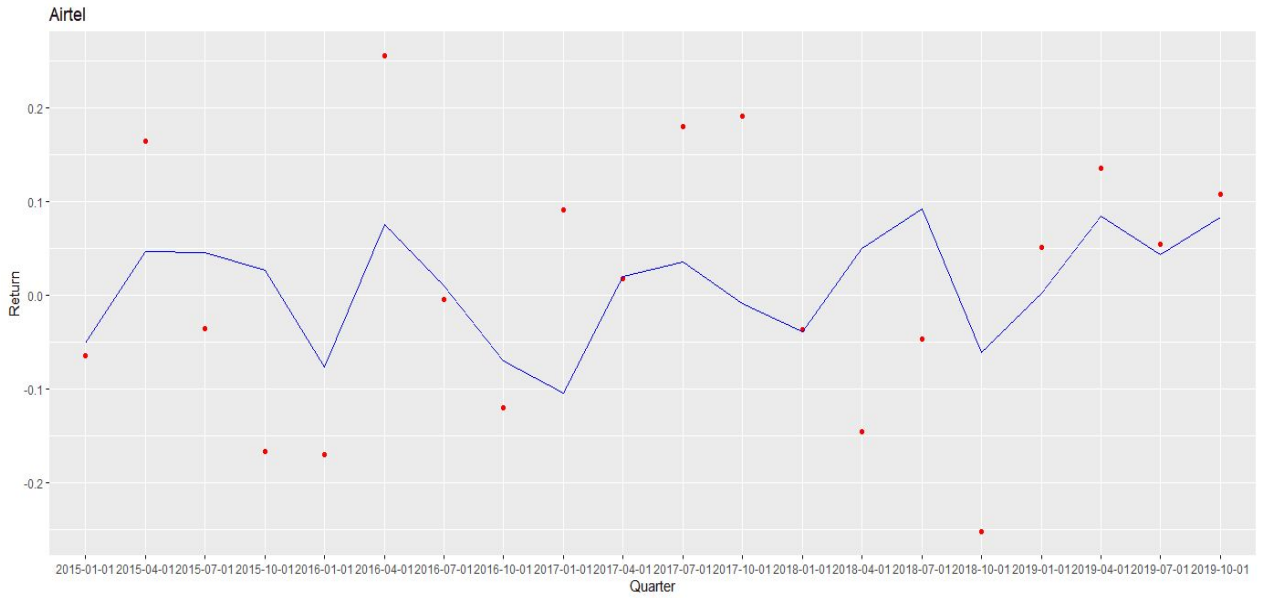
The unexpected component is the excess value of the macroeconomic variable in a particular quarter over its mean over the 5 year period
The regressions gave us the sensitivities(betas) of each stock w.r.t to the 5 factors.

company	intercept	cpi_growth	exchange_ rate	market_return	gdp_growth	bond_rate_dif
airtel	0.010544	3.788714	-0.004794	-0.149434	-0.6197	7.841702

tata	0.002061	-5.43913	0.006782	0.471402	-1.660586	-21.1407
voda-idea	-0.08911	0.40345	-0.02228	-1.10476	-2.35255	-58.40089
reliance-telecom	-0.15749	1.70169	-0.01262	1.75184	4.26621	-26.44991
infratel	-0.01271	2.051016	-0.004737	0.849234	-0.168579	-27.52734
vindhya	6.46E-02	4.69E-01	-2.25E-04	-4.93E-01	1.13E-01	-4.72E+01
hathway	-0.02079	-14.07811	0.04523	0.64548	-0.78251	-25.14687

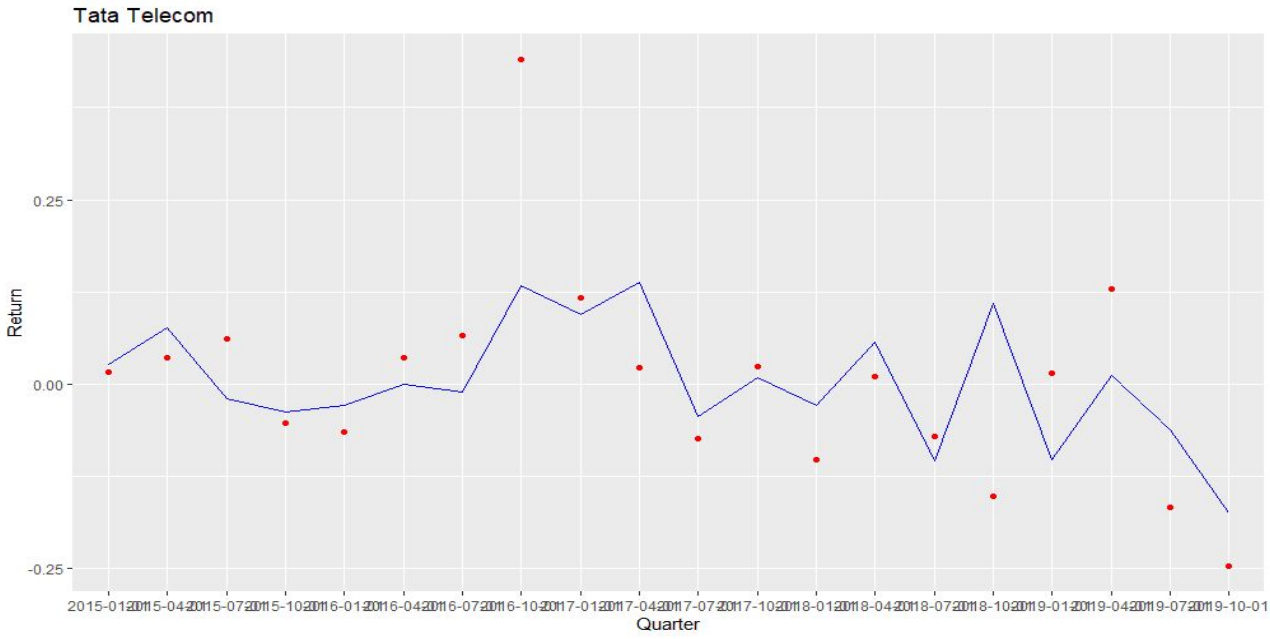
a1) Airtel

return_airtel = 0.010544 + 3.788714*factor1 + -0.004794*factor2 + -0.149434*factor3 + -0.6197*factor4 + 7.841702*factor5



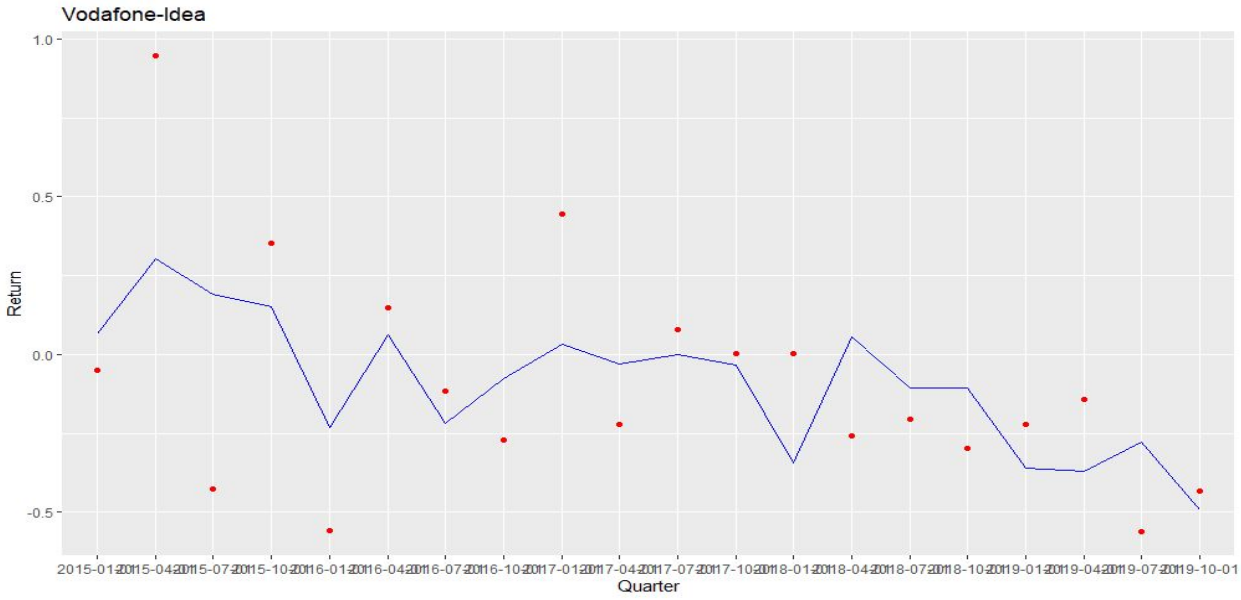
a2) Tata Telecom

return_tata = 0.002061 + -5.43913*factor1 + 0.006782*factor2 + 0.471402*factor3 + -1.660586*factor4 + -21.140698*factor5



a3) Vodafone-Idea

return_voda-idea = -0.08911 + 0.40345*factor1 + -0.02228*factor2 + -1.10476*factor3 + -2.35255*factor4 + -58.40089*factor5

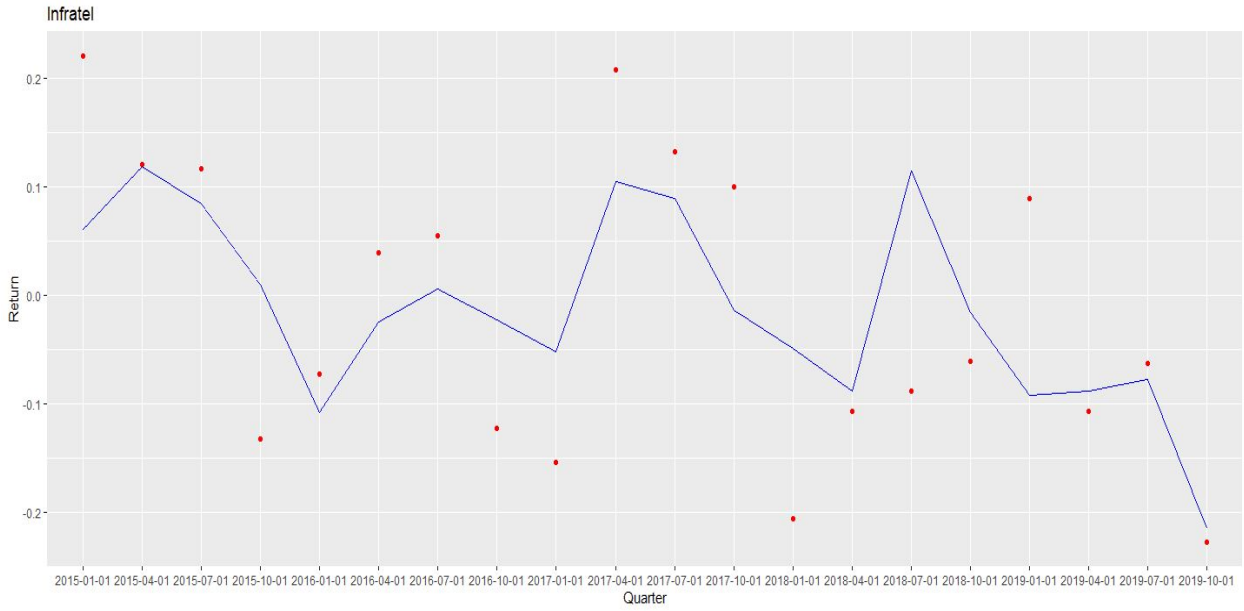


a4) Reliance-Communication

return_reliance_comm = -0.15749 + 1.70169*factor1 + -0.01262*factor2 + 1.75184*factor3 + 4.26621*factor4 + -26.44991*factor5

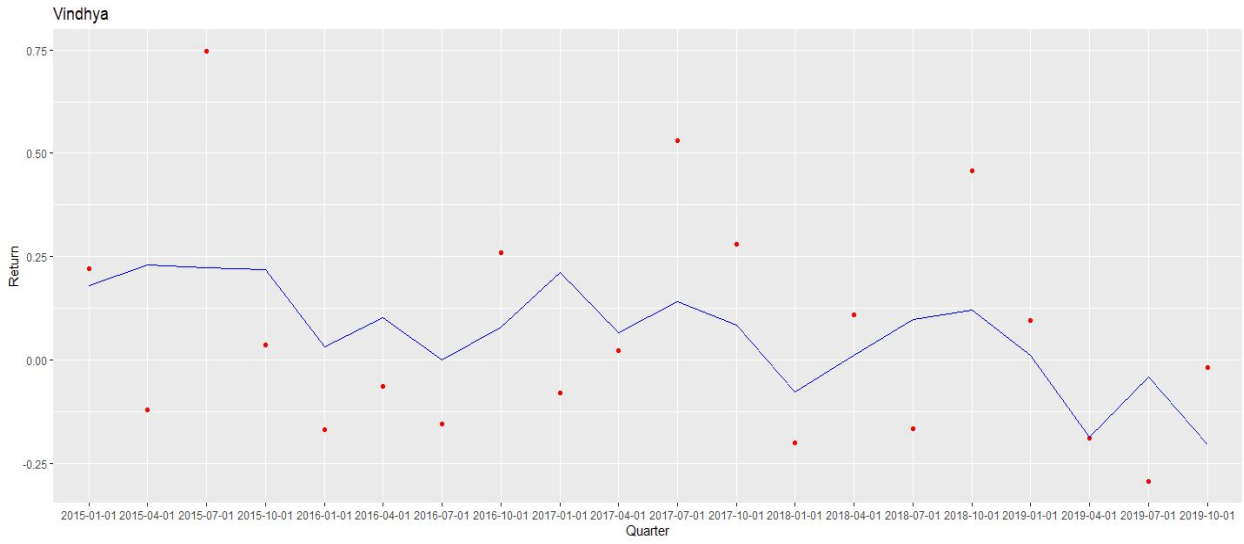
a5) Infratel

return_infratel = -0.01271 + 2.051016*factor1 + -0.004737*factor2 + 0.849234*factor3 + -0.168579*factor4 + -27.527342*factor5



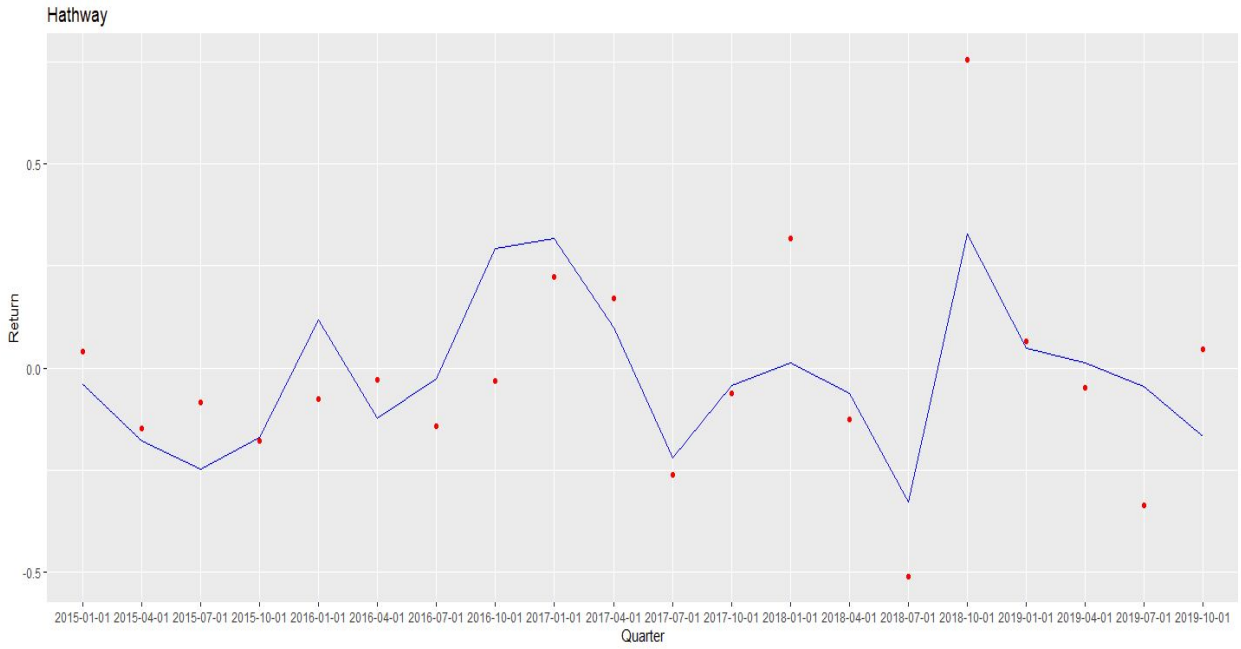
a6) Vindhya

return_vindhya = 6.46E-02 + 4.69E-01*factor1 + -2.25E-04*factor2 + -4.93E-01*factor3 + 1.13E-01*factor4 + -4.72E+01*factor5



a7) Hathway

return_hathway = -0.02079 + -14.07811*factor1 + 0.04523*factor2 + 0.64548*factor3 + -0.78251*factor4 + -25.14687*factor5



b) Cross-Sectional Regression for calculating the Risk Premium Values:

A cross-sectional regression on the seven stocks was run with the aim to calculate the risk premium values that represent how much investors discount any security when its factor loading increases by 1 unit. The expected return of the stocks was regressed against their sensitivities to the five factors through the equation

$E(R)i= \lambda o + B1_i*\lambda_1 + B_2i*\lambda_2 + B_3*\lambda_3 + B_4i*\lambda_4 + B_5i*\lambda_5$
Where,
λ_i represents the risk premium w.r.t factor_i

The expected returns of our 7 stocks were calculated using the geometric mean over the 5 year period b/w 2014-2019
The regression gave the following results:

lambda0	l_cpi	l_exchange	l_market	l_gdp	l_termstructure
-0.063099	0.028612	8.485876	0.014797	-0.035613	-0.00104

Hence;
Expected return on security i = -0.063099 + beta_1i * 0.028612 + beta_2i * 8.485876 + beta_3i*0.014797+ beta_4i * -0.035613 + beta_5i * -0.00104

4) Constructing Risk-Free Portfolio

We attempted to create a risk free(systematic risk) portfolio for the next quarter b/w Oct 2019 to Jan 2020. **The expected return on this portfolio is -6%**. As it is -ve,we will short the constructed portfolio

The risk-free portfolio was designed with weights being W1, W2, W3, W4, W5, W6 and W7, respectively of the stocks of Airtel, Tata, Vodafone, Reliance, Infratel, Vindhya and Hathaway. The return of the portfolio is as follows:
R(p) = W1*R(1) + W2*R(2) + W3*R(3) + W4*R(4) + W5*R(5) + W6*R(6) + W7*R(7)

Now since this portfolio is risk-free, the total sum of coefficients corresponding to the risk-premium term 'λ_i' (i.e the betas w.r.t to the different factors) where 1<=i<=7 should be zero.

Following that, we got 5 linear equations but in 7 unknowns along with an additional equation:
W1+W2+W3+W4+W5+W6+W7 = 1

So, in total we had 6 equations but in 7 variables which would lead to an infinite combination of different portfolios with the same risk-free total return. **We had a free variable(w7)**, which we could choose arbitrarily.

For this purpose, we used oir model to predict the returns in the next quarter for Hathway.
The predicted return came out to be 23.45%
As we will be shorting our constructed portfolio, a stock with an expected positive return must have a -ve weight in our portfolio. We choose w7=-0.25.
This reduced us to 6 equations and with 6 variables which would yield us a unique solution.
Following the standard matrix-inverse method in excel we got our required weights which could be seen in '**Results.xlsx**'

Results (*Assumption* : W7 = -0.25)

W1	0.6375369161
W2	0.9103028003
W3	-0.3283278741
W4	0.1786572345
W5	-0.6862596222
W6	0.5380905454
W7	-0.25

Please note that the negative weight associated with stocks simply means that we are shorting that particular stock.

Expected Return on portfolio = -6.3%

5)Evaluating our Portfolio:

We decided to evaluate the performance of our portfolio over the next quarter, i.e the fourth quarter of fiscal year 2019-2020.
For this, we calculated the returns of the seven stocks in that quarter, which we obtained as follows;

airtel	tata	voda	reliance	infratel	vindhya	hathway
21.07%	13.32%	57.07%	33.85%	34.14%	5.19%	-6.62%

The return on our portfolio as the weighted average of the return on these stocks, and it comes out to be **-6.11%**
While the return comes out to be pretty close to the expected return, there is some difference which can be attributed to the **idiosyncratic risk** which cannot be diversified away through this model, and in particular because all our stocks belong to the same sector.

Conclusion

Though it is a standard practice to calculate alpha for each stock and see that whether it is currently being undervalued/overvalued in the market and adjust our positions accordingly, we wanted to put our portfolio skills to test and see if we can bring value to our investors!

Of course, since the **total return on our portfolio is negative**, we should rather **short this portfolio**. In other words, we must go long on the stocks we went short in our current portfolio as well as go short on the stocks where we went long in our current portfolio. So, we would get an expected return of a total of 6.3% on our portfolio.

By shortening the above portfolio we can **use the money received by selling the portfolio to buy risk-free government bonds.**

Appendix

1) Stock Returns (Source:https://in.finance.yahoo.com/)

Date	Airtel		Tata Indicom		Vodafone -Idea		Reliance		Infratel		Vindhya		Hathway	
	Close	Return	Close	Return	Close	Return	Close	Return	Close	Return	Close	Return	Close	Return
2014-10-01	365.64		402.50		98.39		106.10		293.35		464.60		61.31	
2015-01-01	342.18	-0.06	409.35	0.02	93.35	-0.05	79.50	-0.25	358.05	0.22	566.85	0.22	63.80	0.04
2015-04-01	398.50	0.16	424.30	0.04	181.75	0.95	63.60	-0.20	401.20	0.12	498.00	-0.12	54.35	-0.15
2015-07-01	384.27	-0.04	450.25	0.06	104.40	-0.43	70.45	0.11	447.95	0.12	870.00	0.75	49.85	-0.08
2015-10-01	320.15	-0.17	426.30	-0.05	141.15	0.35	75.25	0.07	388.85	-0.13	900.75	0.04	41.00	-0.18
2016-01-01	265.95	-0.17	398.50	-0.07	62.27	-0.56	62.10	-0.17	360.70	-0.07	748.50	-0.17	37.90	-0.08
2016-04-01	333.97	0.26	412.85	0.04	71.45	0.15	56.25	-0.09	374.80	0.04	699.75	-0.07	36.85	-0.03
2016-07-01	332.36	0.00	440.30	0.07	63.12	-0.12	52.55	-0.07	395.25	0.05	591.65	-0.15	31.60	-0.14
2016-10-01	292.52	-0.12	634.20	0.44	46.02	-0.27	46.60	-0.11	347.00	-0.12	745.10	0.26	30.65	-0.03
2017-01-01	319.37	0.09	708.10	0.12	66.56	0.45	34.20	-0.27	293.65	-0.15	684.80	-0.08	37.45	0.22

2017-04-01	324.97	0.02	723.40	0.02	51.73	-0.22	34.50	0.01	354.80	0.21	699.60	0.02	43.80	0.17
2017-07-01	383.54	0.18	669.90	-0.07	55.87	0.08	26.25	-0.24	401.70	0.13	1070.15	0.53	32.35	-0.26
2017-10-01	456.84	0.19	685.45	0.02	56.11	0.00	17.15	-0.35	441.95	0.10	1370.35	0.28	30.35	-0.06
2018-01-01	440.10	-0.04	615.70	-0.10	56.26	0.00	29.50	0.72	351.00	-0.21	1094.95	-0.20	39.95	0.32
2018-04-01	375.97	-0.15	621.95	0.01	41.71	-0.26	15.25	-0.48	313.55	-0.11	1213.50	0.11	34.90	-0.13
2018-07-01	358.66	-0.05	578.15	-0.07	33.16	-0.20	14.37	-0.06	286.10	-0.09	1010.35	-0.17	17.10	-0.51
2018-10-01	268.19	-0.25	490.55	-0.15	23.31	-0.30	12.33	-0.14	268.85	-0.06	1472.00	0.46	30.00	0.75
2019-01-01	281.96	0.05	497.70	0.01	18.18	-0.22	11.75	-0.05	292.95	0.09	1613.00	0.10	31.95	0.07
2019-04-01	320.20	0.14	561.70	0.13	15.60	-0.14	1.71	-0.85	261.85	-0.11	1307.35	-0.19	30.45	-0.05
2019-07-01	337.80	0.05	468.00	-0.17	6.84	-0.56	1.39	-0.19	245.60	-0.06	922.50	-0.29	20.20	-0.34
2019-10-01	374.40	0.11	352.40	-0.25	3.89	-0.43	0.65	-0.53	189.80	-0.23	905.15	-0.02	21.15	0.05
2020-01-01	496.70	0.33	415.30	0.18	5.31	0.37	0.77	0.18	247.00	0.30	884.10	-0.02	19.25	-0.09

2) <u>Factor Data</u> (Source: Federal Reserve Bank of St. Louis, M.O.S.P.I, World Government Bonds)

Frequency: Quarterly		FACTOR 1	FACTOR 2		FACTOR 3					FACTOR 4	FACTOR 5
Observation date	CPI	Quarterly CPI Growth (%)	Exchange Rate($)	Sensex Price	Market Return	3month (91days) bond yield	Effective Quarterly Risk Free Rate	Market Premium	GDP at constant 2011-12 prices	GDP growth	Term Structure (Yield Spread b/w 10y and 2y bonds)
2014-10-01	96.780		61.9189	26681.47					2,645,947		
2015-01-01	97.035	0.26%	62.2003	27485.77	3.01%	8.49%	2.12%	0.90%	2,783,733	5.207%	0.0680%
2015-04-01	98.821	1.84%	63.3791	27954.86	1.71%	8.33%	2.08%	-0.37%	2,728,279	-1.992%	-0.0260%
2015-07-01	101.116	2.32%	64.9561	27823.65	-0.47%	7.88%	1.96%	-2.43%	2,768,087	1.459%	0.0240%
2015-10-01	103.028	1.89%	65.8762	26344.19	-5.32%	7.59%	1.89%	-7.21%	2,836,387	2.467%	0.0810%
2016-01-01	102.518	-0.50%	67.4879	26101.50	-0.92%	7.02%	1.75%	-2.67%	3,036,738	7.064%	0.4200%
2016-04-01	104.941	2.36%	66.8590	25301.70	-3.06%	7.14%	1.78%	-4.84%	2,965,088	-2.359%	0.2950%
2016-07-01	106.471	1.46%	66.9251	27064.33	6.97%	6.85%	1.71%	5.26%	3,035,756	2.383%	0.4100%
2016-10-01	105.834	-0.60%	67.3954	27997.29	3.45%	6.54%	1.63%	1.82%	3,079,622	1.445%	0.2560%
2017-01-01	104.941	-0.84%	66.9403	26,711.15	-4.59%	6.48%	1.62%	-6.21%	3,227,728	4.809%	0.0680%
2017-04-01	106.471	1.46%	64.4679	29737.73	11.33%	6.10%	1.52%	9.81%	3,136,572	-2.824%	0.2140%
2017-07-01	109.021	2.40%	64.2899	31156.04	4.77%	5.80%	1.45%	3.32%	3,232,072	3.045%	0.1480%
2017-10-01	109.786	0.70%	64.7079	31537.81	1.23%	6.30%	1.57%	-0.35%	3,314,801	2.560%	0.2890%
2018-01-01	109.914	0.12%	64.3736	34059.99	8.00%	6.08%	1.52%	6.48%	3,491,719	5.337%	0.5610%
2018-04-01	110.679	0.70%	66.9910	33030.87	-3.02%	6.13%	1.53%	-4.55%	3,359,162	-3.796%	0.4680%
2018-07-01	115.142	4.03%	70.1988	35545.22	7.61%	6.12%	1.53%	6.09%	3,432,553	2.185%	0.2240%

2018-10-01	115.397	0.22%	72.0440	36274.25	2.05%	6.42%	1.60%	0.45%	3,500,033	1.966%	0.1900%
2019-01-01	117.692	1.99%	70.4578	36161.80	-0.31%	7.03%	1.75%	-2.06%	3,689,674	5.418%	0.4740%
2019-04-01	120.115	2.06%	69.5258	38858.88	7.46%	6.67%	1.66%	5.80%	3,535,267	-4.185%	0.7900%
2019-07-01	122.537	2.02%	70.4131	39543.73	1.76%	6.18%	1.54%	0.22%	3,584,335	1.388%	0.5540%
2019-10-01	125.343	2.29%	71.2198	38813.48	-1.85%	5.98%	1.49%	-3.34%	3,642,748	1.630%	0.9450%