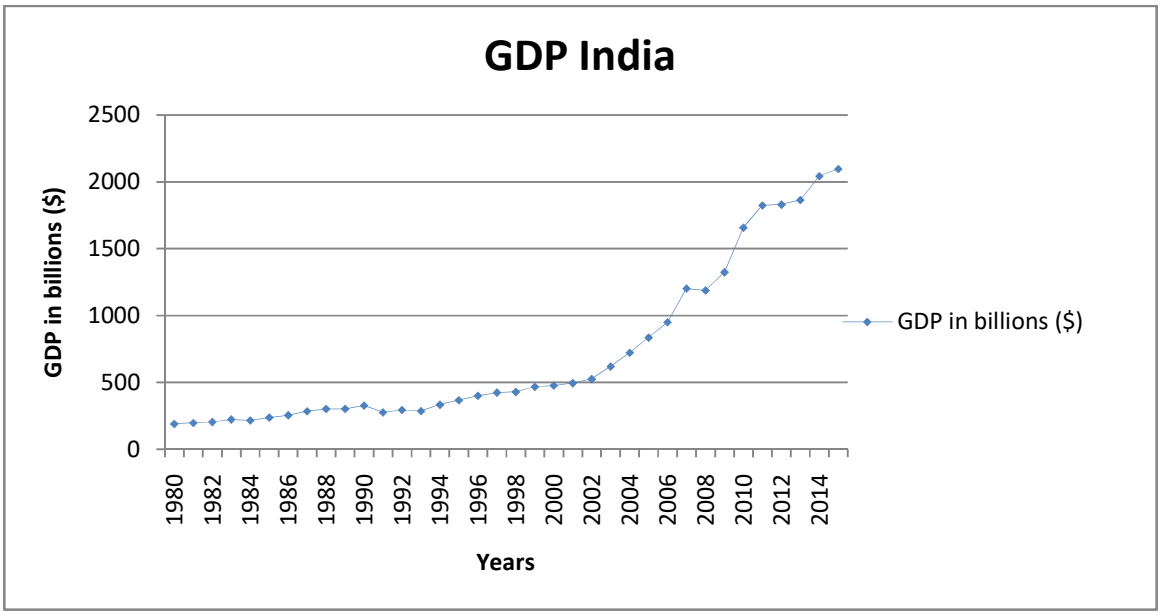
Modelling GDP

1.0 Introduction:

The GDP of a country is a primary indicator of a country's position in the economy and the trends it follows. The GDP, or Gross Domestic Product, is an indicator of the measure of a nation's economy, and essentially determines the influence or power of a nation. In 2016, the largest GDP amongst the nations of the world is that of the United States of America, with China close behind, and the remaining BRIC nations following a trend that would have them close the gap in the years to come (BRIC: Brazil, Russia, India, China).

The amount of influence that a nation's GDP has on the position of a nation in the world economy interested me. As a frequent reader of the Economic Times, economics on a global scale have always fascinated me, and have forced me to think about forecasting trends and estimates that countries may follow for the years to come. As has been observed in recent years, the GDPs of BRIC nations like China and India, have increased exponentially in comparison to the current leader, the United States of America, which has followed a more linear growth in recent years. While it is widely projected that China will surpass the United States in the years to come, India, a rising economy, could also upstage the current leaders in the future, and I hypothesized that the United States' influence over the world economy would decrease, with countries similar to India, such as Brazil, Russia, etc, gaining a wider span of influence. For the sake of keeping the investigation concise, Brazil and Russia will not be modelled.

Through this analysis I aim to model the GDPs of China, India, and the United States, to see what the global economy would be like at the 2050 mark. China was selected with the aim to prove the claim that they will surpass the United States. India was selected in order to show the potential of the BRIC nations and their ability to gain influence in the global market. Russia, due to it being USSR prior to 1991, would have proved difficult to model and again, to keep the analysis and comparisons precise, will not be included. In this investigation, the figures will be denoted in US Dollars (USD or $) and will be in billions.



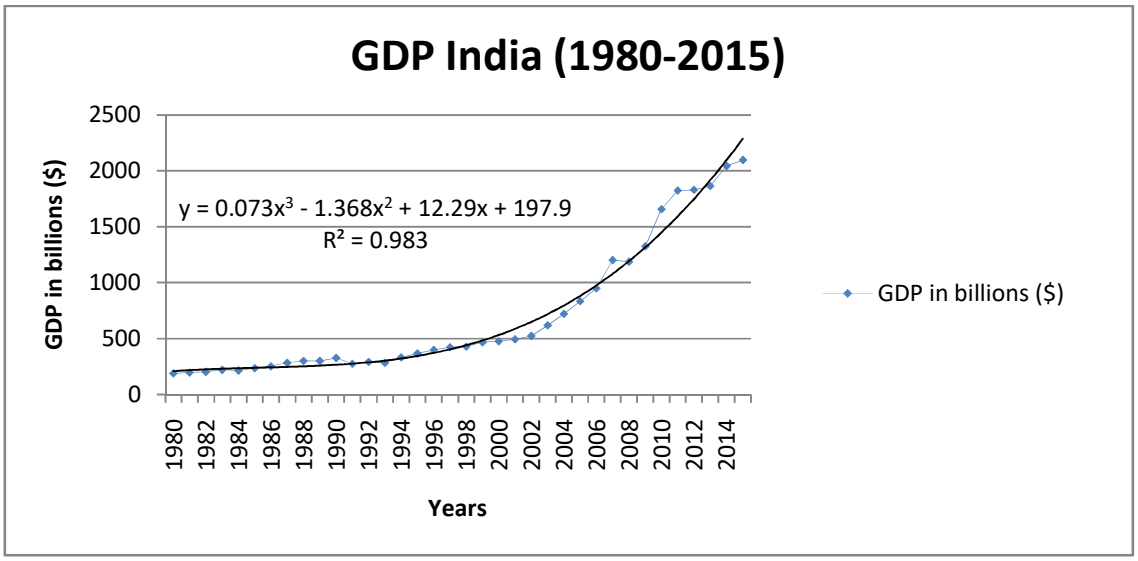
Graph 1: Example of a GDP Trend, GDP of India graphed from 1980 to 2015

1.1 Method:

The data used in this exploration was obtained from the Database of the World Bank which contains accurate numbers of the GDPs of member nations of the United Nations. The points will be plotted and by regression analysis, the relationship between the points will be determined. For the estimates, the model functions will be found by using Microsoft Excel and a GDC (TI nSpire CX). Further exploration of the data at hand will take place in order to determine the accuracy of the functions found. These functions will be used to predict the future of the GDPs.

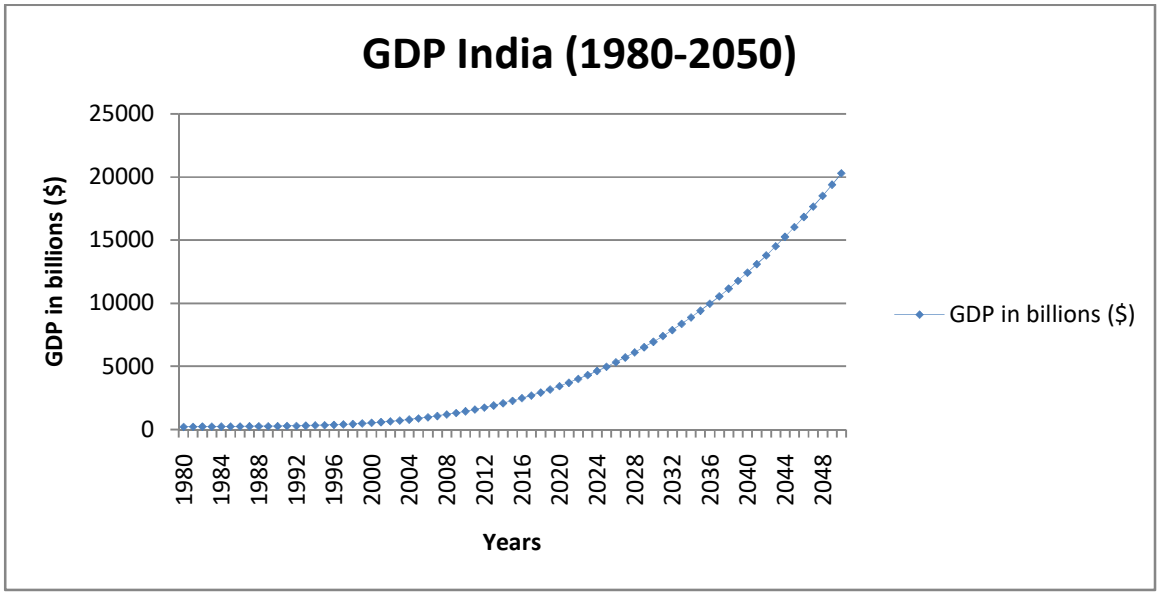
2.0 India

India, has in recent years experienced exponential growth as can be observed through the rise in its GDP. This can be attributed in part to the outsourcing of numerous multinationals into India, as many view it as a bountiful potential market. As is seen in Graph 2, India's GDP begins a period of frantic growth beginning in the late 90s. At the 2007-2008 mark, there is a plateau in the numbers. This could be due to the financial crisis in 2008. Despite another plateau in 2011, 2012, and 2013, the overall GDP growth of India remains positive, and by observing the graph, we can estimate the most accurate model for this graph to be exponential, however we obtain a consider amount of uncertainty when we model the GDP of India using an exponential function. By exploring the options further, I decided to use polynomial functions, to the third degree, as they proved to be more accurate that exponential functions.



Graph 2: GDP of India with exponential trendline

From the graph plotted above, we are able to obtain the exponential function of $y = 0.073x^3 - 1.368x^2 + 12.29x + 197.9$, where 'x' is the year number, starting at 1 for 1980, 2 for 1981, and so on. However since these numbers are in billions, the actual function will be $y = 0.073x^3 - 1.368x^2 + 12.29x + 197.9 \times 10^9$. Therefore the graph with the projections until the year 2050 is as shown below.



Graph 3: Projected GDP of India from 1980 to 2050

2.1 Accuracy

The accuracy of the forecasting will be measured by the formula:
Accuracy = (Actual Value - Estimated Value)×100/Actual Value

Since we can only obtain the accuracies for existing data, we will have to estimate the range of accuracy to be within the largest inaccuracy obtained through the calculation.

Example Calculation (Year 2005):

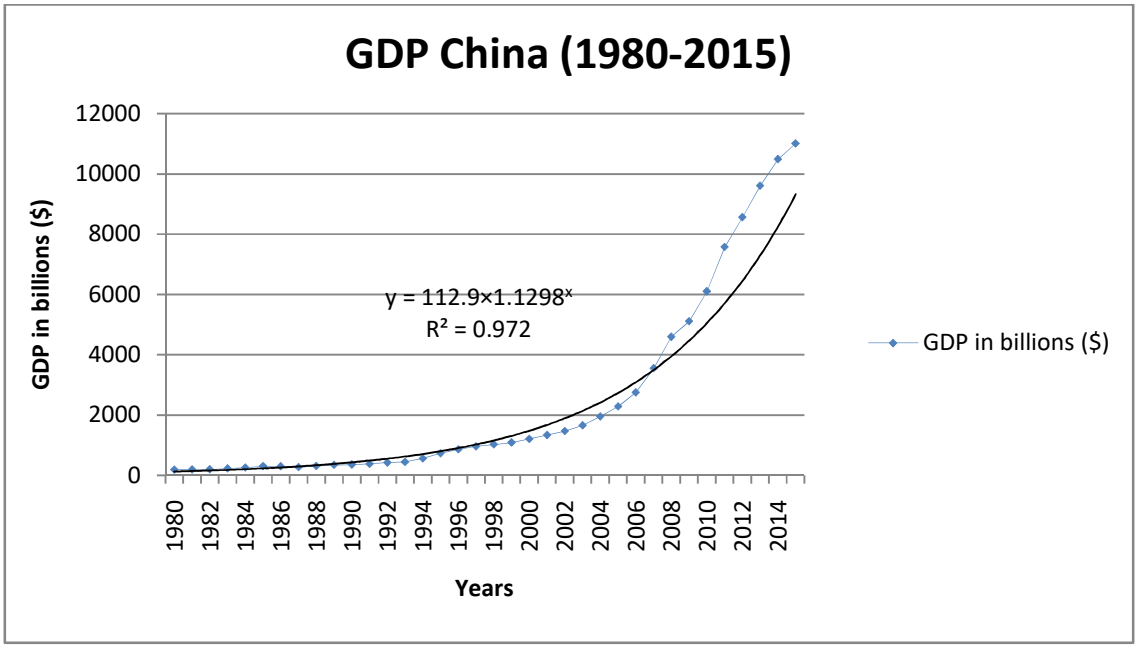
$$=(834.2147-866.9443)*100/834.2147$$
$$\approx -4.97537\%$$

Looking at the accuracy of the values, the largest inaccuracy is of ±18.94718%, and the average percentage error is of ±8.305195%, thus we can assume the uncertainty of the projected values to be approximately ±8%. (Data can be found in **Appendix**)

Additionally, the R^2 value for the function is 0.983, thus it fits the regression line 98.3% accurately.

3.0 China

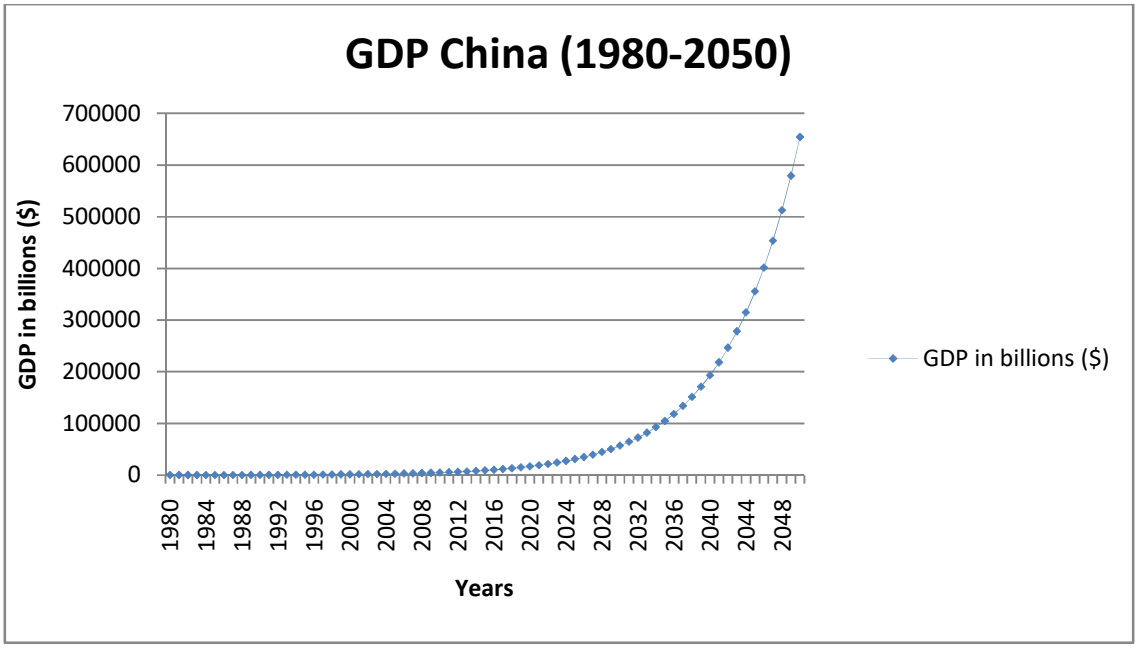
China, the world's second largest economy, is widely expected to upstage the United States in the coming half century. Observing the graph below, we can again estimate that the most accurate model for China would be an exponential model. I attempted to model it using a polynomial function of the third degree, however the starting GDP was in the negatives and this negated that model. Thus I decided to use an exponential model.



Graph 4: GDP of China with exponential trendline

From the graph plotted above, we can obtain the equation as $y = 112.9\times1.1298^t$, with 't' following the same norm as before. Again since the values are in billions, the equation

is essentially $y = 112.9 \times 1.1298^{x} \times 10^{9}$. Therefore the graph with the projected values for China can be found in the graph below:



Graph 5: Projected GDP of China from 1980 to 2050

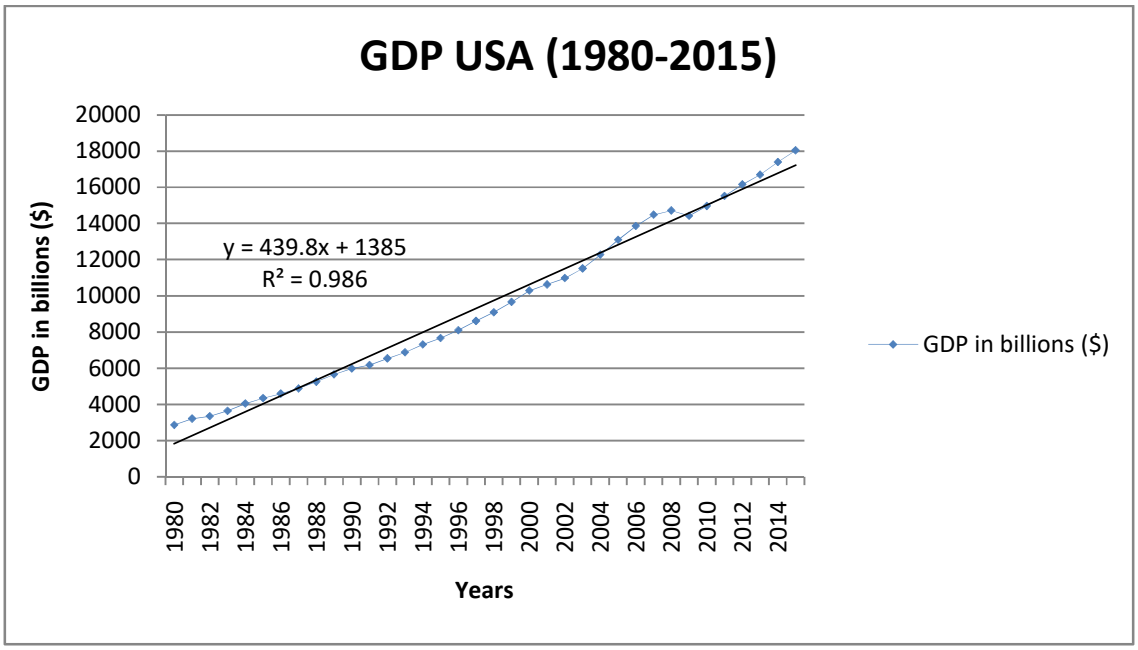
3.1 Accuracy

By using the same formula as in **2.1**, we obtain the largest uncertainty as ±40.1582%, and the average percentage uncertainty as ±19.2256%, thus again we can assume the uncertainty of projected values to be ±19% (Data can be found in **Appendix**).

Additionally, the R^2 value for the function is 0.972, thus it fits the regression line 97.2% accurately.

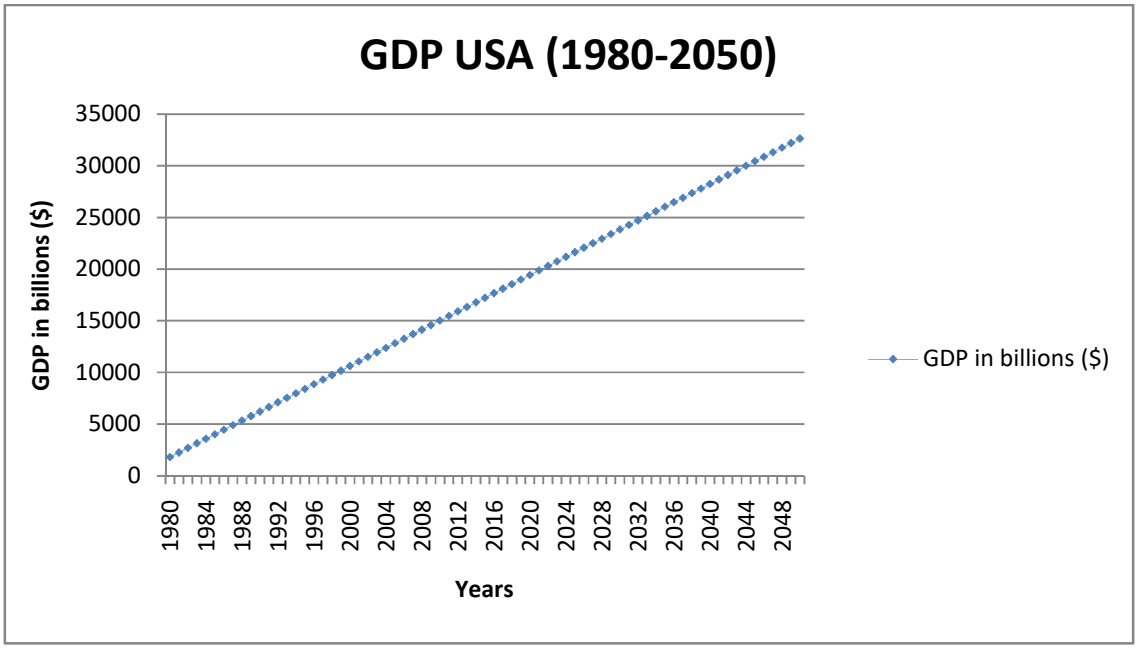
4.0 United States of America

Ever since the end of the Cold War, USA has been near if not always at the very top of the rankings when it comes to GDP. Thus their influence in the global market is vast. Unlike the two other countries we modelled in this analysis, USA followed more of a steady growth and thus from the graph below we can observe that its function looks to be linear.



Graph 6: GDP of USA with Linear Trendline

From the graph plotted above, we can obtain the equation as y = 439.8x+1385, with 'x' following the same norm as before. Again since the values are in billions, the equation is essentially y = (439.8x+1385)×10^9. Therefore the graph with the projected values for USA can be found in the graph below:



Graph 7: Projected GDP of US from 1980 to 2050

4.1 Accuracy

While initially fairly inaccurate, with an uncertainty of 36.25164%, the obtained equation proves to be very accurate post 1984, with the uncertainty never exceeding ±10%, and the average uncertainty in total being ±6.945% and the average uncertainty post 1984 being ±4.378%. Thus we can assume the projected values to have an uncertainty of approximately ±4.378%

Additionally, the R^2 value for the function is 0.986, thus it fits the regression line 98.6% accurately.

5.0 Observation and Analysis

Thus the model functions obtained for each of the countries are:

1. India: $y = 0.073x^3 - 1.368x^2 + 12.29x + 197.9$
2. China: $y = 112.9 \times 1.1298^x$
3. USA: $y = (439.8x+1385)$

The model functions obtained through this investigation can be used by projectionists and economists to estimate and project a country's GDP for the future. However, the functioning of these models is dependent on certain assumptions. We make the assumption that the countries will continue the trends they have experienced over the past 36 years, however external factors such as natural disasters and/or an economic crisis may skew the projections we make in this exploration. It can also be affected by factors such as inflation, unemployment, and the exchange rate of the country's currency.

Relation between GDP and some factors:

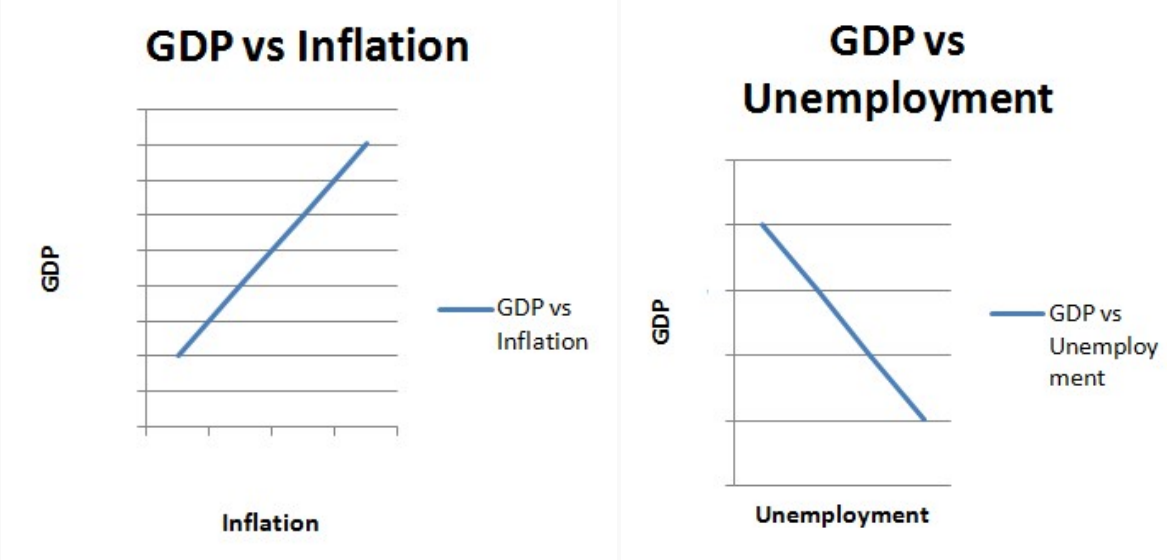
$$GDP \propto Inflation$$
$$GDP \propto -Unemployment$$

When the level of demand for any goods in a nation surpasses the supply, this causes inflation, causing the prices for said goods to rise, causing the GDP to go up. Inflation also has adverse effects on the economy, but not too many pertaining to the context of this exploration. Therefore a graph of GDP versus Inflation is a straight line graph.

Next while representing a graph of the relation between GDP and Unemployment, saying they are inversely proportional is not exactly correct, as their relationship is still considered to be linear (See Okun's Law in Bibliography), and instead, GDP is directly proportional to the negative values of Unemployment.

A third factor that is selected is the effect of efficient utilization or the availability and exploitation of natural resources by a nation. This, as expected is a directly proportional

relationship, and is graphically represented below as well. Thus the relative graphs for the three selected factors affecting GDP are:



Figures 1 & 2: GDP vs Inflation & GDP vs Unemployment

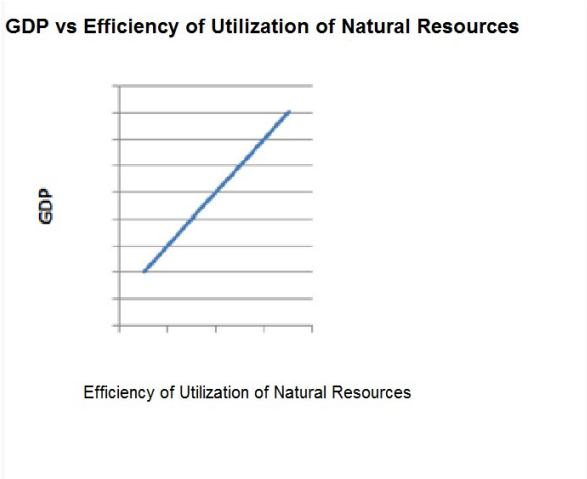
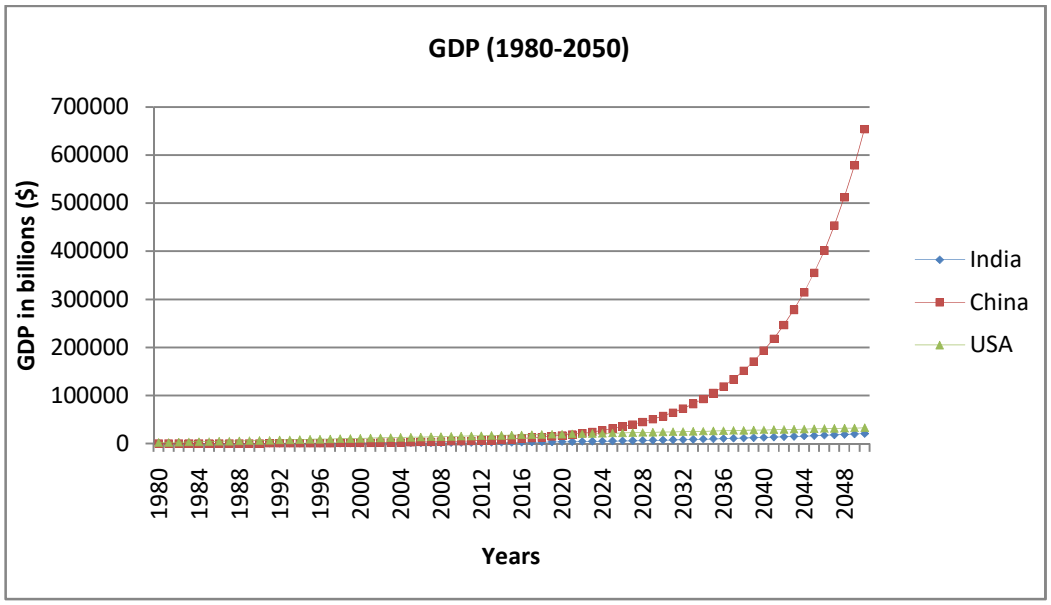


Figure 3: GDP vs Efficiency of Utilization of Natural Resources

Additionally by judging the uncertainties amongst the various models we have analysed, we can observe that the model for the United States is the most accurate. We can also observe that in the year 2022, China overtakes USA and becomes the most influential nation in the global economy, we a continued rise that far surpasses USA by the year 2050. Meanwhile, India rises considerably, and by the year 2050, its GDP equals nearly two-thirds that of the United States, a modest but still impressive rise.



Graph 8: Cumulative graph of projected GDPs

6.0 Scope and Application

The model functions obtained from this investigation can be used to obtain a rough estimate of the world economy in the years to come.

Graph 8 provides shows that China's GDP by the year will dwarf that of the United States, and India will continue to rise exponentially, yet it will not overtake the United States. Assuming that no external factors come into play, these trends can be estimated to be true, keeping their uncertainties in mind. Thus they can be used by economists and projectionists.

7.0 Conclusion

By using exponential and linear functions, we obtained three equations in the aim of modelling the GDPs of the three selected countries. To check their accuracy, we used the formula "*Accuracy = (Actual Value - Estimated Value)×100/Actual Value*" .

The model functions were used to make a cumulative comparative graph in **5.0**, and comparisons and observations were made. Three types of functions were used to model the GDPs of the three countries, polynomial, exponential, and linear, and the model functions were fairly accurate.

8.0 Bibliography

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9.0 Appendix

India			China			USA		
Calc value	**Actual Value**	**Uncert-ainty**	**Calc value**	**Actual Value**	**Uncert-ainty**	**Actual Value**	**Calc value**	**Uncert-ainty**
208.895	189.5929	-10.1808	127.5544	191.15	33.26999	2862.505	1824.8	36.25164
217.592	196.8838	-10.518	144.111	195.8651	26.42335	3210.956	2264.6	29.47272
224.429	204.2351	-9.88758	162.8166	205.0916	20.61275	3344.991	2704.4	19.15075
229.844	222.0899	-3.49142	183.9502	230.6858	20.25943	3638.137	3144.2	13.57665
234.275	215.8788	-8.52154	207.8269	259.9464	20.05009	4040.693	3584	11.30234
238.16	236.5894	-0.66385	234.8029	309.4864	24.13145	4346.734	4023.8	7.429348
241.937	253.3524	4.50574	265.2803	300.7594	11.79652	4590.155	4463.6	2.757096
246.044	283.927	13.34251	299.7136	272.9731	-9.79603	4870.217	4903.4	-0.68135
250.919	301.7903	16.85651	338.6165	312.3539	-8.40795	5252.629	5343.2	-1.7243
257	301.234	14.68427	382.5689	347.7672	-10.0072	5657.693	5783	-2.21481
264.725	326.608	18.94718	432.2263	360.8585	-19.7772	5979.589	6222.8	-4.06735
274.532	274.842	0.11286	488.329	383.372	-	6174.04	6662.6	-

	2	5	3	8	27.3771	3		7.91308
286.859	293.2627	2.183605	551.7144	426.9152	-29.2328	6539.299	7102.4	-8.61103
302.144	284.194	-6.31611	623.327	444.7309	-40.1582	6878.718	7542.2	-9.64543
320.825	333.015	3.660496	704.2348	564.3252	-24.7924	7308.755	7982	-9.21149
343.34	366.6002	6.344841	795.6445	734.548	-8.31756	7664.06	8421.8	-9.88693
370.127	399.7873	7.41902	898.9192	863.7464	-4.07212	8100.201	8861.6	-9.39975
401.624	423.1608	5.089507	1015.599	961.6034	-5.61515	8608.515	9301.4	-8.04883
438.269	428.7407	-2.22239	1147.424	1029.043	-11.504	9089.168	9741.2	-7.17373
480.5	466.8667	-2.92017	1296.359	1093.998	-18.4974	9660.624	10181	-5.38657
528.755	476.6091	-10.941	1464.627	1211.346	-20.909	10284.78	10620.8	-3.26716
583.472	493.9542	-18.1227	1654.735	1339.395	-23.5435	10621.82	11060.6	-4.13093
645.089	523.9684	-23.116	1869.52	1470.55	-27.1306	10977.51	11500.4	-4.76328
714.044	618.3565	-15.4745	2112.183	1660.288	-27.2179	11510.67	11940.2	-3.73158
790.775	721.5848	-9.58864	2386.345	1955.347	-22.042	12274.93	12380	-0.85597
875.72	834.2147	-4.97537	2696.092	2285.966	-17.9411	13093.73	12819.8	2.09207
969.317	949.1168	-2.12832	3046.045	2752.132	-10.6795	13855.89	13259.6	4.303513
1072.004	1201.072	10.74607	3441.422	3552.183	3.118115	14477.64	13699.4	5.375462
1184.219	1186.913	0.226975	3888.118	4598.205	15.44269	14718.58	14139.2	3.936385
1306.4	1323.896	1.321554	4392.796	5109.954	14.03453	14418.74	14579	-1.11147
1438.985	1656.562	13.13425	4962.981	6100.62	18.64792	14964.37	15018.8	-0.36373
1582.412	1822.99	13.19689	5607.176	7572.554	25.95396	15517.93	15458.6	0.382332
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1903.54	1863.20	-	7157.26	9607.22	25.5011	16691.5	16338.	2.11676

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2082.125	2042.439	-1.94307	8086.282	10482.37	22.85826	17393.1	16778	3.53646
2273.3	2095.398	-8.49013	9135.882	11007.72	17.00478	18036.65	17217.8	4.539923