

Final Report – Stock Market Analysis via FFTs

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Introduction to topic and analysis

The stock markets of the world are in a constant state of flux due to causes big and small, which makes for an interesting data set to analyse. In particular, during the past 2 decades, there have been two big crashes: The crash of 2008, which was due to a housing bubble that burst amongst other growing factors, the very recent (but perhaps less devastating so far) crash 2020, primarily due to the onset of the COVID-19 pandemic. This makes the decades of 2001-2010 and 2011-2020 an interesting focus for this report.

Analysis of the stock market is important for understand how regular world occurrences such as natural disasters, world events such as the Olympics or FIFA, and perhaps more relevant at the time of this report, pandemics, affect the stock market, which reflects the health of the world economy as a whole. In its position as one of the strongest, most developed and most influential countries in the world, the United States of America and the stock markets directly related to it, such as the Dow Jones Industrial Average and S&P 500, make for good indications of the overall world economy. Another country of interest would be Germany, which is why the DAX is another focus of the report, and having hosted the 2010 FIFA World Cup, the JSE Index under South Africa is another interesting dataset as well.

Before any analysis is done, a few traits that make stock market data a little unique must be laid out. For one, the stock market is only open, and hence recorded, 5 days a week, so data on Saturdays and Sundays are non-existent. In my analysis, I initially went about this by analysing and plotting the data with respect to arbitrary days ranging from 0 to 2330 days ($52 \text{ weeks} * 5 \text{ days} * 10 \text{ years} + 2 \text{ leap year days} = 2602 \text{ days}$, 2330 being the days after data being adjusted for various factors mentioned later). The reason the data is separated into decades instead of simply being consolidated into 2001-2020 is because the trends are better shown separately due to the differences in the rate of increase of stock market value, and to better demonstrate the crashes that occur in each data set.

The market is constantly updated throughout the day, but only the day closing data was taken for this report.

Coding and Data

The stock market data used in this report was obtained from Yahoo Finance. As certain markets have days during which data is not collected for various reasons such as public holidays, most analysis here will occur between the same markets for different time periods (i.e. 2001-2010 vs. 2011-2020). As 2020 only goes up till April (April 7 in the case of the data used here), comparisons with 2001-2010 data will also only go up to April 7, 2010, which is why the data was shortened to ~2330 days.

The coding techniques used here involve Python 3, using the numpy and matplotlib modules to assist with calculating the Fast Fourier transforms (FFTs) and convolutions used to analyse the data sets. FFTs allow for specific analysis regarding the overall trend and stability of the stock market. A Fourier transform of a data set represented by the function $F(t)$ is given by:

$$G(w) = \int_{-\infty}^{+\infty} F(t) e^{-iwt} dt$$

Where w is the frequency and t is the time. An FFT allows one to isolate frequencies within a function and hence allows one to manipulate the data to clearly show trends (low frequency) or instability (high frequency). In this case, both are important for stock market data. Taking the real FFT (rFFT) worked better here as the imaginary values obtained from regular FFT didn't work as well for the analysis done here.

Convolutions are operations between two functions $f(n)$ and $g(m)$, such that:

$$f(n) * g(m) = \sum_{m=-\infty}^{+\infty} f(n-m)g(m)$$

Convolutions allow one to correlate data in a way that shows how one is affected by the other. Since stock markets are very much interlinked in their performance, this is a convincing method to demonstrate that fact.

A further extension of convolutions is cross-correlation, which allows one to demonstrate the delay between the effect of one stock market on another. While I was eager to do this between the DOW and DAX indexes, the differences in market parsing (due to different holidays and such) made this difficult to achieve. As such, simply just using a convolution here didn't provide any additional information that the FFT plots didn't already provide, but simply confirmed that the DOW and DAX were indeed closely linked in their performances.

The datetime and Pandas modules were also used to better display the dates used for the stock market, as using arbitrary days is too vague when analysing market data at different points in time.

Analysis and Discussion

Dow Jones Industrial Average and DAX, trend and stability between 2001-2010

Starting with the decade of 2001-2010, there is a general increase between the years of 2001-2008 for both the DOW and DAX indexes, but the financial collapse of 2008 severely hampered the growth of these two markets (and by extension, most of the world's economy), as can be seen visually in Figures 1 and 3. Overall, the trend by the end of the decade for both figures shows a recovering and increasing trend.

While the above is probably common knowledge, the most interesting thing that can be gleaned from these plots is how interconnected these two economies are. At any point in time, a sharp change in the DOW index can be noticed in the DAX index only a few days later, and the converse is true as well, as changes in the DAX index are also reflected in the DOW index if they occur earlier.

The stability of these two markets during 2001-2010 is also displayed in Figures 5 and 6. The markets are relatively stable between the years 2003-2008, with the DAX index being relatively more stable by a few values than the DOW index, but this is simply due to the difference in the market size that these two indices represent, as the DAX index represents the top 30 companies in Germany, while the DOW index represents the top 30 companies in the United States. As many of the world's largest companies are based in the USA, the DOW is inherently bound to be larger and fluctuate a little more.

Due to the crisis, the indices fluctuate wildly from the overall trend from 2008 onwards. However, going into 2009 and 2010 onwards, the plots clearly show that the DOW index and DAX index achieve similar levels of stability to what they had just before the crisis, perhaps due to government stimulus packages to help recover the economy. While this crisis is known as the "2008 recession" or similar names, it's clear again from these plots that the crisis has its roots in 2007. While this is not clear from the trend figures (1,3) it's clearer in figures 5 and 6 where the plot starts deviating more and more from the centre as 2007 progressed.

Dow Jones Industrial Average and DAX, trend and stability between 2011-2020

The decade of 2011 to 2020, at first glance from any of the figures representing the DOW and DAX indices during this period (Figures 2, 4, 7, 8), that this decade was overall more stable and had a greater increase in stock market value, perhaps due to the onset of new technologies such as the introduction of the smartphone that propelled companies such as Apple to the top of the scoreboard. During this time, the DOW index more than doubled its 2011 value by 2020, and the DAX index almost doubled its 2011 value by 2020 as well.

The trend by the end of this decade for both markets is a downward trend, due to the onset of the COVID19 pandemic. A key difference between this trend/crash and the one from 2008 can be seen within Figures 7 and 8. Before the 2008 crisis, both indices very clearly became more unstable, but before the 2020 crash, there is no significant decrease in the stability/increase in the variance of the market. This can be attributed to the fact that the recent crash of 2020 was not attributed to cumulative negative market effects that built up over the course of a few years, but rather drastic measures taken to reduce the impact of the pandemic that have also impacted the market.

Unfortunately, the 2008 crisis may not have been a good preparation for the ongoing pandemic and its associated effects. The current crisis might last for much longer due to the necessity of social distancing and preventative measures to halt the spread of the COVID19 virus. As the circumstances behind the 2008 crisis and the current crisis are different, it isn't necessarily clear

whether the better economic growth of 2011-2020 will allow the world to recover from the effects of the pandemic in a relatively quick fashion. Even if the pandemic dies down quicker than expected, lingering effects of the pandemic such as lost capital and increased unemployment may still hamper a smooth economic recovery, which is something no recent stock market data can accurately predict. The last time a pandemic affected the world greatly was the Spanish Flu of 1919, which occurred in world recovering from a militarised economy which still relied on heavy governmental influence and the gold standard, which would make data from that period a poor basis for understanding the current economic situation.

Despite their stability, the markets were still affected by external factors such as the Scottish Referendum of 2015, Brexit vote of 2016, and Presidential elections of 2012 and 2016. Both elections see small but sharp increases around November 2012 and 2016, while the Brexit vote of 2016 might be responsible for the increase in the stock prices of the DOW and DAX, as more companies may have diverted their operations and purchases from British companies to American and German ones.

While the DOW index continued its rise from 2015 onwards, the DAX index seems to grow much slower during 2015-2020. During this time, however, the DAX index is also much less impacted by the DOW index, as dips and increases in the DOW value don't seem to affect the DAX index as much as the years before it, especially compared to 2001-2010.

JSE, trend and stability between 2007-2010

While this specific range might seem a little odd, this index represents South Africa's overall economic performance, and data before this period was harder to obtain. As the 2010 FIFA world cup occurred during this period, this allows for an observation on how such a global event can affect the performance of regional economy.

The JSE index suffered from the 2008 crisis, but this is no different from the DOW and DAX indices analysed earlier, as such a crisis is bound to affect most of the world in some capacity. The FIFA world cup, perhaps demonstrated much better in Figure 10, played a part in improving the state of the JSE index and by extension, South Africa's economy, as the slope of the plot is much more pronounced after the World cup begins.

While this is only one example and such events may not always contribute positively to a country's economy in the long run, this example does demonstrate how such events can help boost an economy, and in this case, speed up recovery from market crashes. In this case, looking at Figure 12 confirms the fact that this was only a temporary boost to the index, which falls during 2011.

Conclusion

For a Physics lab report, analysing stock market data might seem like an odd choice, but it clearly demonstrates the effectiveness of using Fourier Transforms even in non-Physics

applications. As Physical data tends to be of a similar nature (in that most data can be boiled down to a combination of various sinusoidal functions), applying FFTs to stock market data demonstrates how one can similarly apply FFTs to data more relevant to the field of Physics, such as vibration or radioactive data. For example, the FFT method used to gauge the stability of the stock market could be used on vibration data (such as earthquakes) to observe the background vibrations not part of an earthquake, while the parameters used to smooth the trend could be used to omit these background vibrations.

As for the data analysed here, this report has hopefully demonstrated in some capacity how FFTs can be used to observe market trends and predict future booms or recessions (such as how the increasing variance of the 2007 data led to the 2008 recession), and how market indices are connected to each other in an increasing interconnected world.

Improvements

With a better understanding on how to quickly sort the data I used or had I manipulated the data sets further to better work with each other (say, match the DAX data with the DOW data so that their array sizes were the same by omitting German holidays from the DOW data, and American holidays from the German data), I would've been able to perform a cross-correlation on them to demonstrate clearly the time lag in days between these two data sets, as the stock price plots below do show time lag between these two indices. Even if it's just by a few days, it would've been interesting to see how long, for example, changes in the Dow Jones index take to reflect themselves in the DAX index.

In a more comprehensive report, I would've additionally done something similar to the JSE/FIFA World Cup analysis, such as how the Olympics affects developed 1st world economies vs. developing 3rd world economies when it's hosted in countries falling under those two categories, as this would better elaborate on how such a large event can affect economies of different sizes, and by extension, whether hosting such events does indeed benefit developing economies or not.

References

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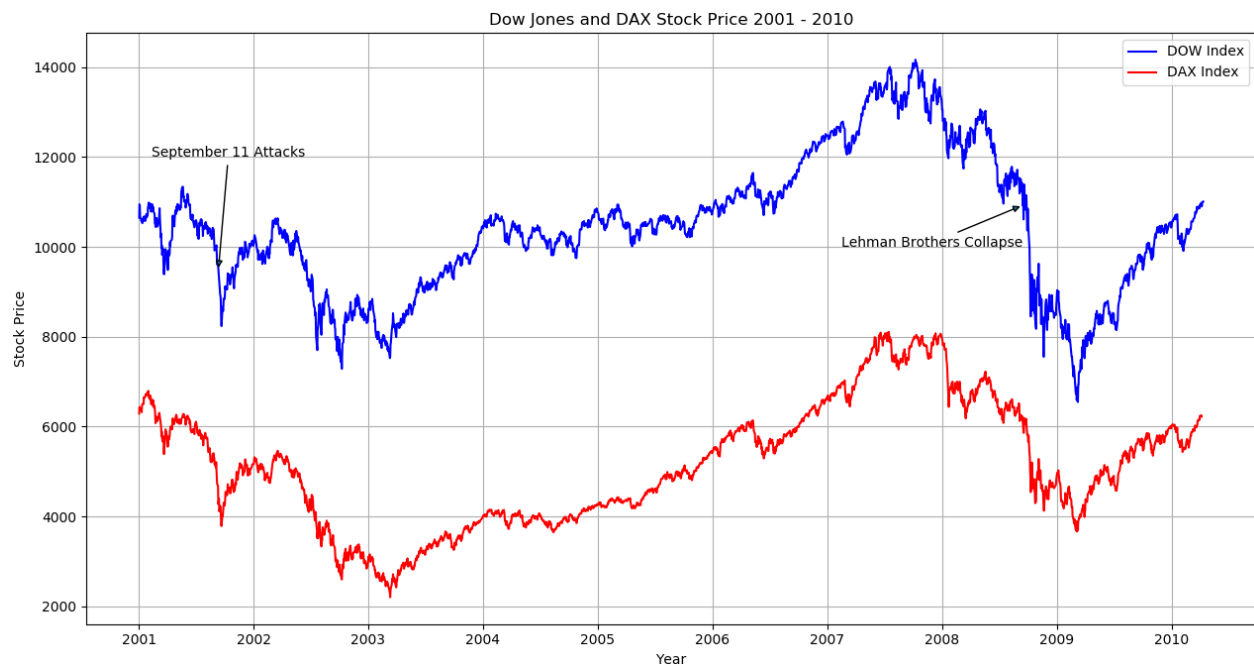


Figure 1: The DOW and DAX markets between Jan 1, 2001 to April 7, 2010.

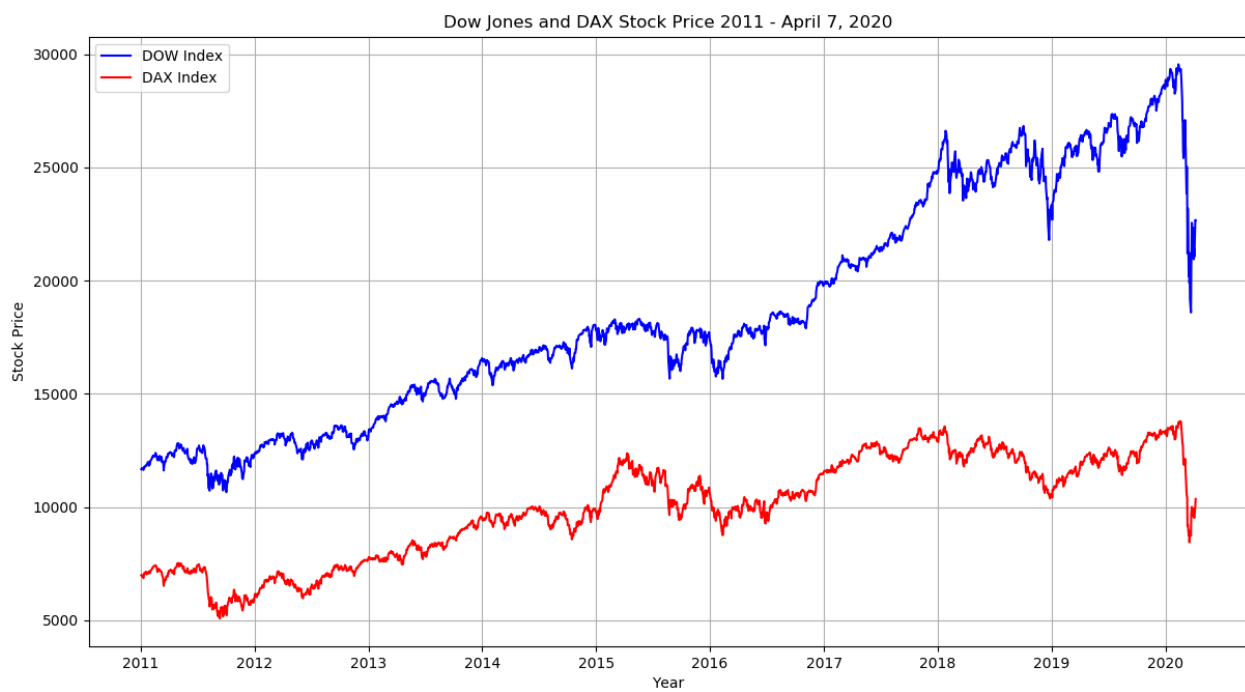


Figure 2: The DOW and DAX markets between Jan 1, 2011 to April 7, 2020.

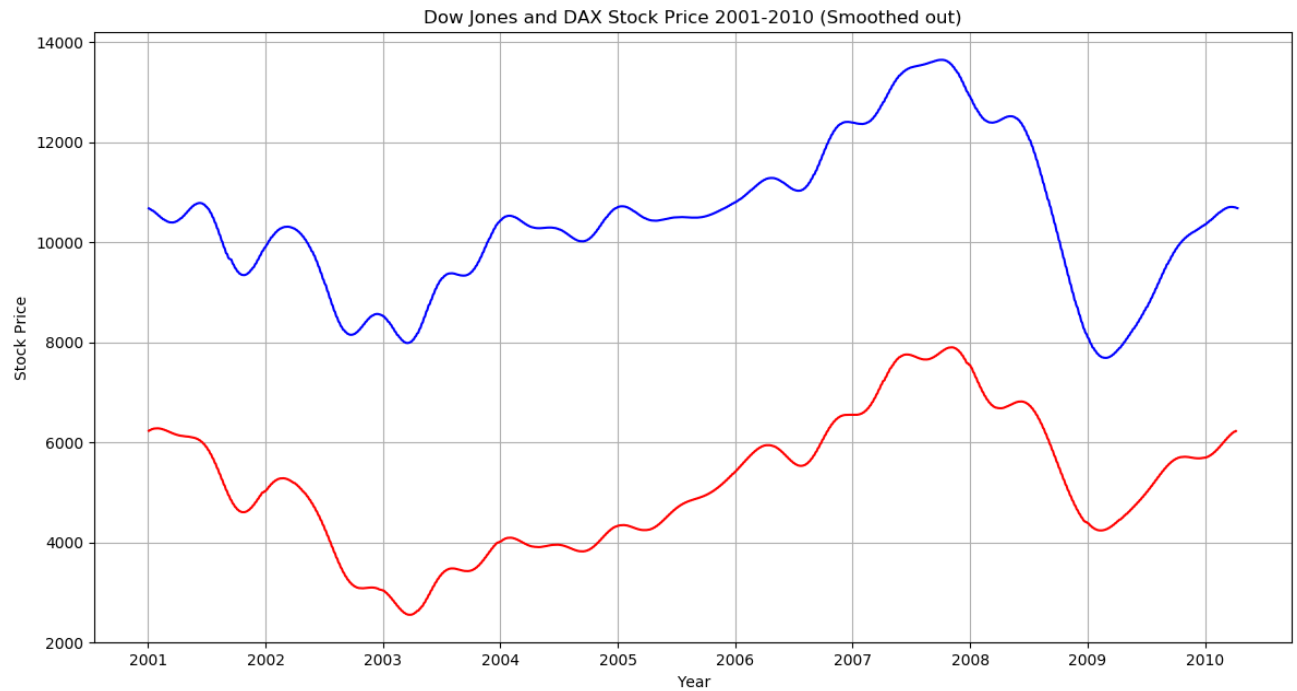


Figure 3: The DOW (blue) and DAX (red) markets between Jan 1, 2001 to April 7, 2010, smoothed out via FFT.

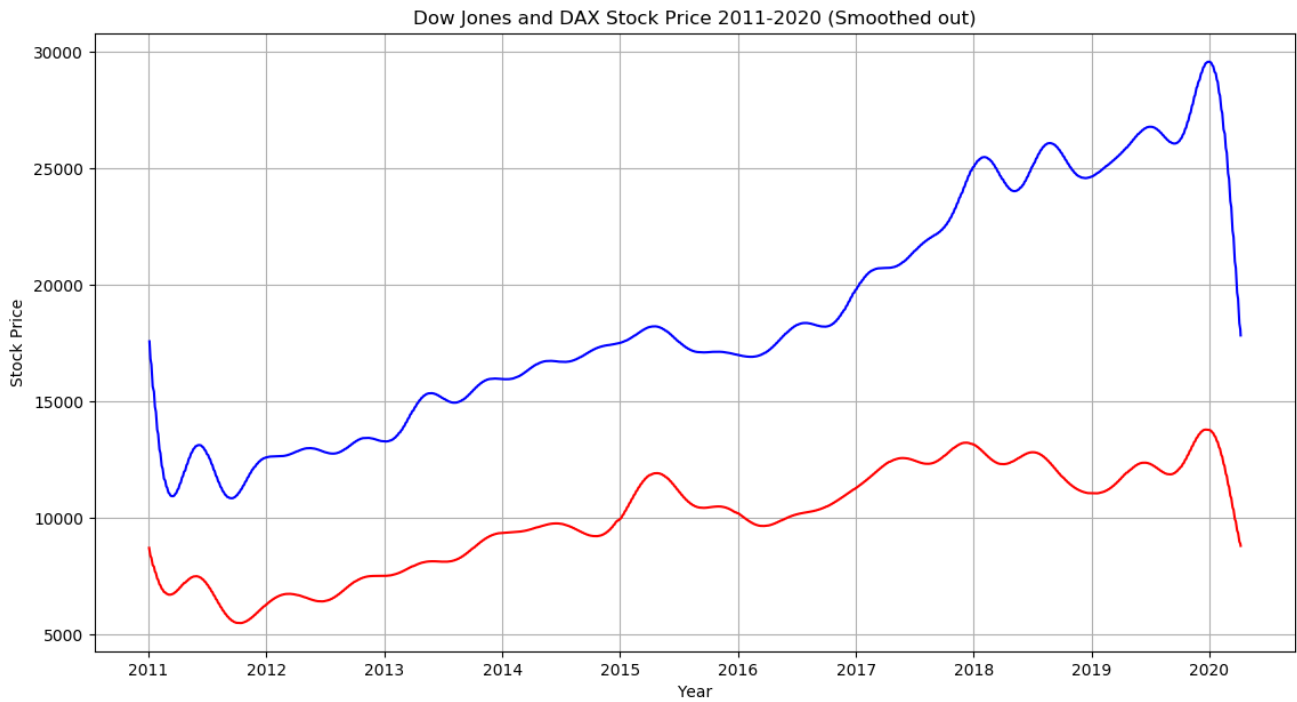


Figure 4: The DOW (blue) and DAX (red) markets between Jan 1, 2011 to April 7, 2020, smoothed out via FFT.

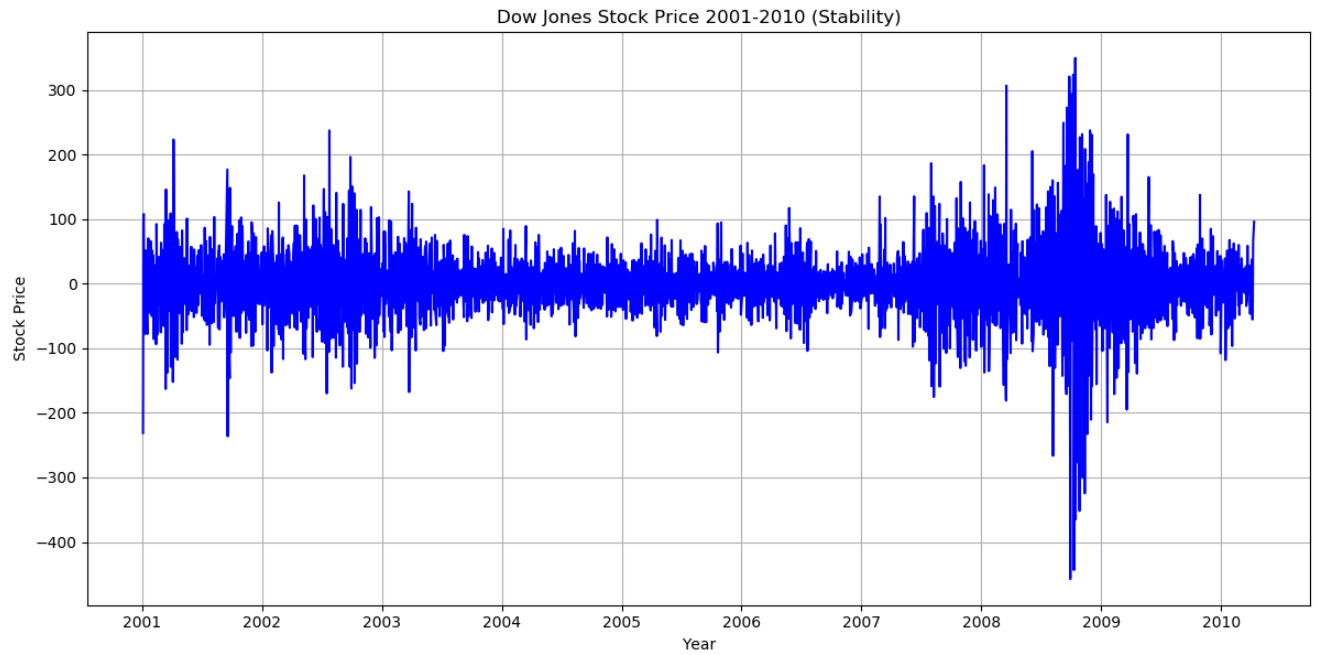


Figure 5: The DOW stock variation/stability between Jan 1, 2001- April 7, 2010.

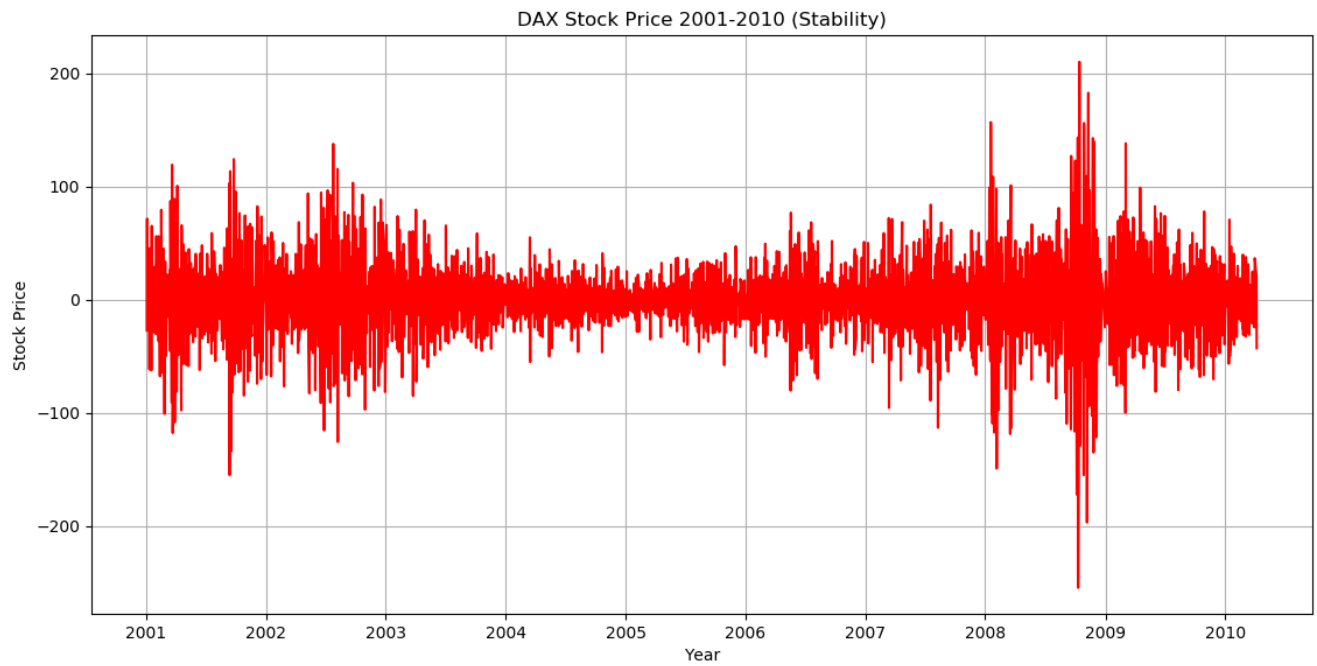


Figure 6: The DAX stock variation/stability between Jan 1, 2001- April 7, 2010.

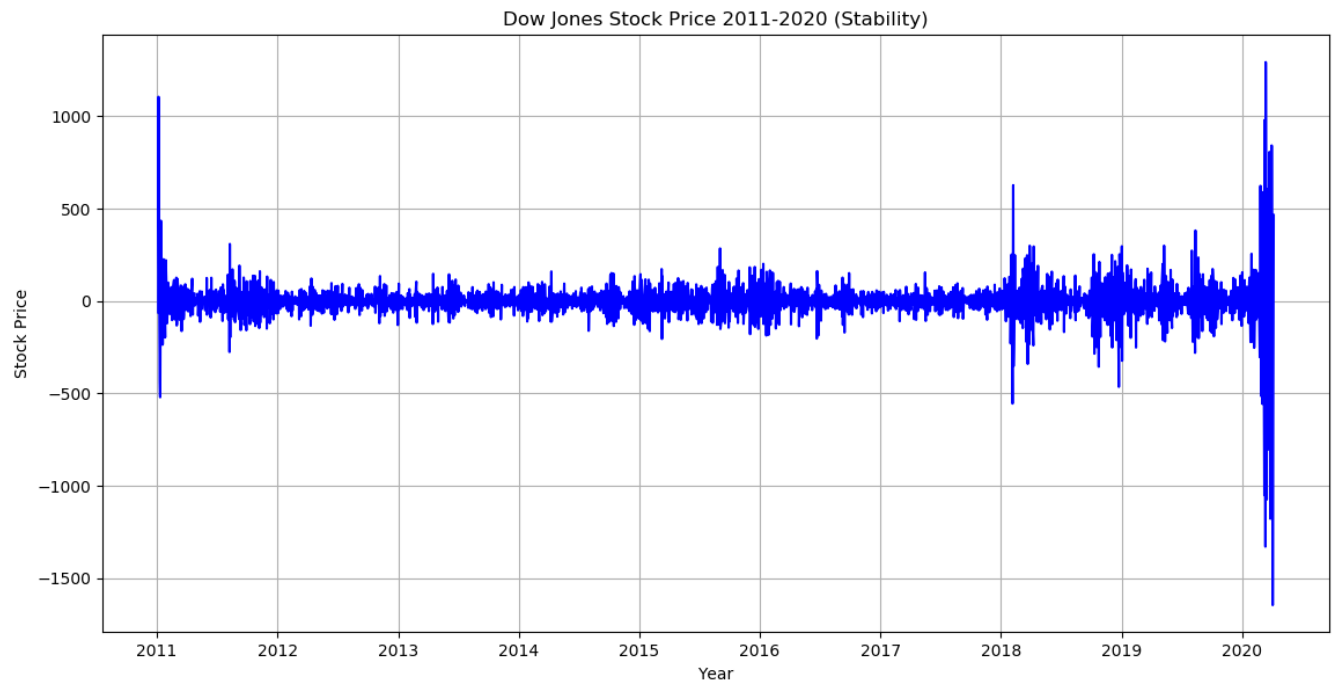


Figure 7: The DOW stock variation/stability between Jan 1, 2011- April 7, 2020.

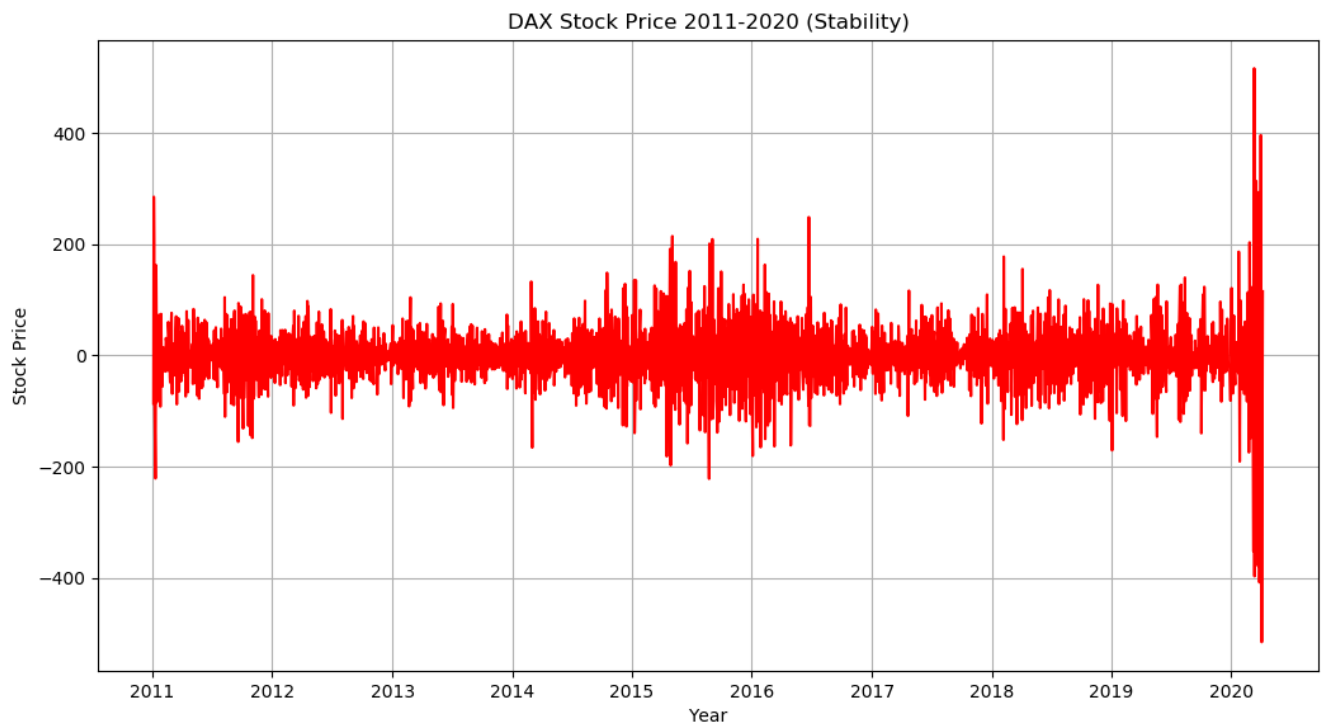


Figure 8: The DAX stock variation/stability between Jan 1, 2011- April 7, 2020.

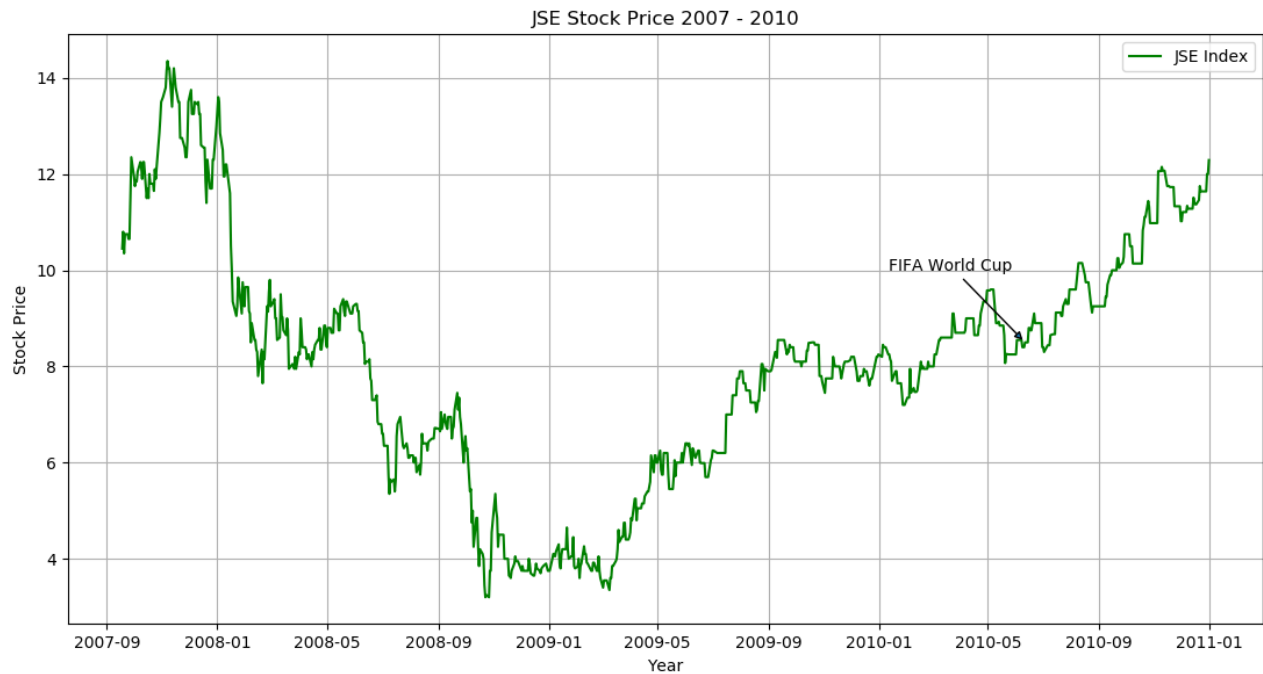


Figure 9: The JSE index between September 2007 to December 31, 2010.

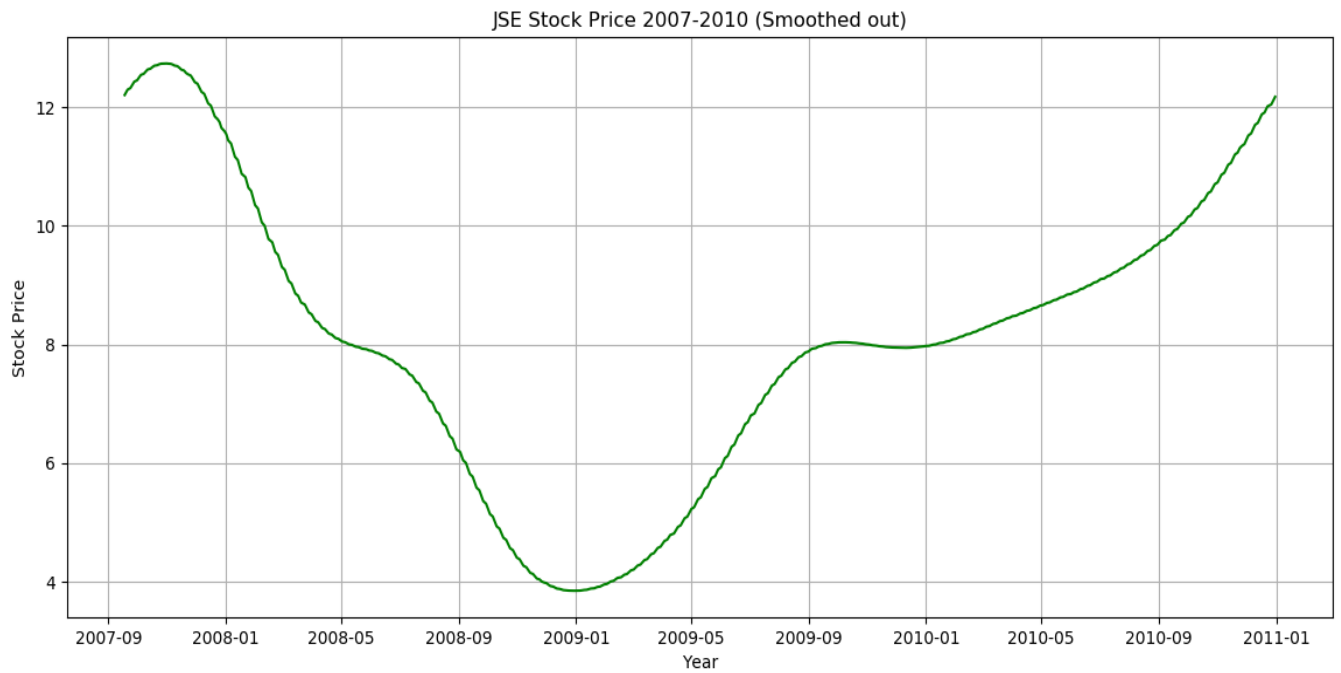


Figure 10: The JSE index between September 2007 to December 31, 2010, smoothed out.

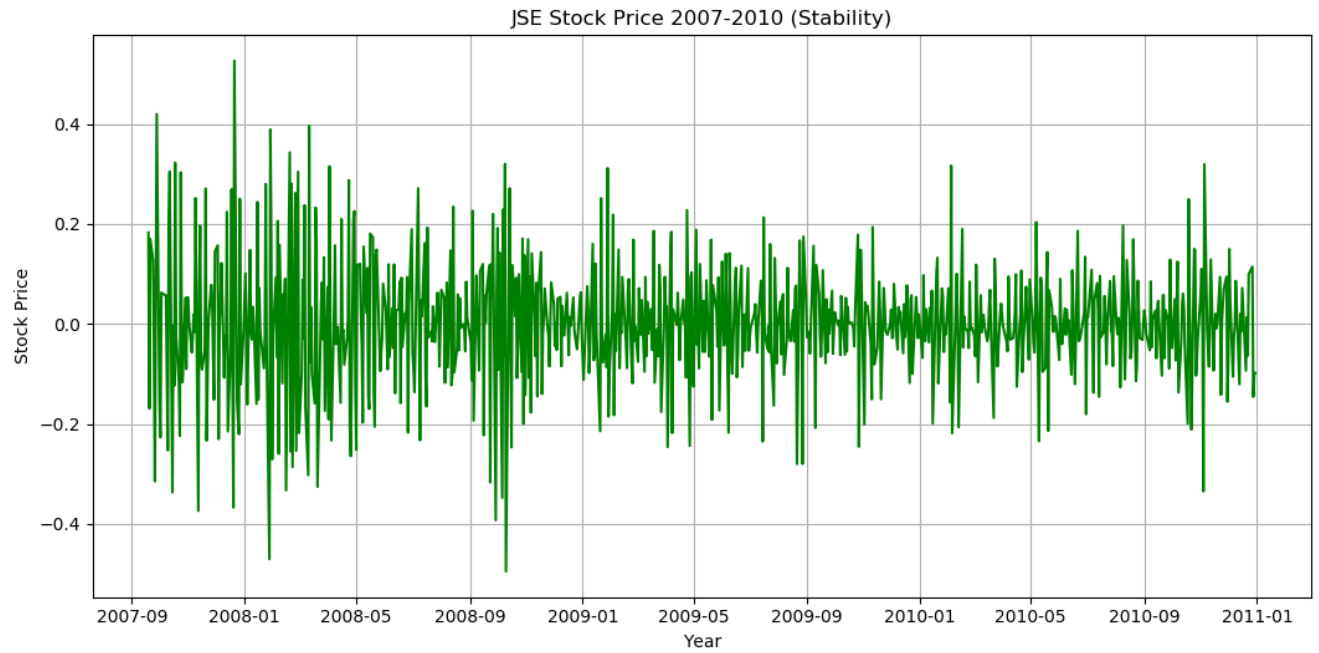


Figure 11: The JSE index variation/stability between September 2007 to December 31, 2010.

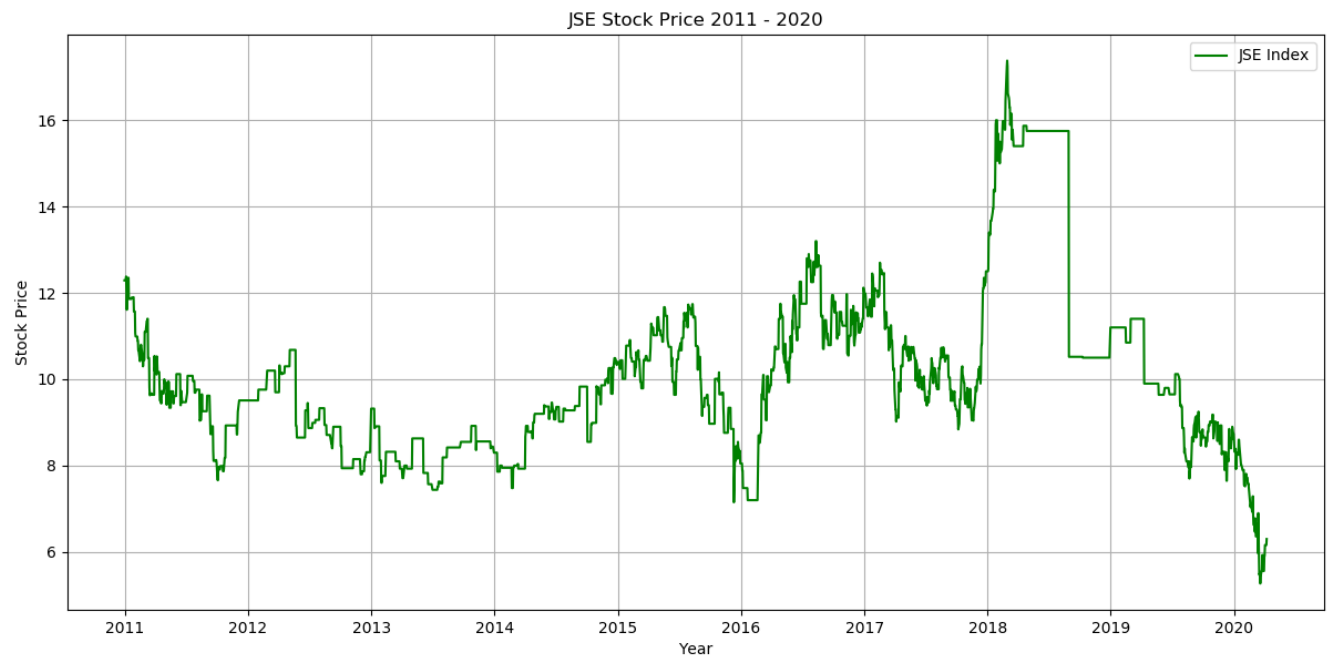


Figure 12: The JSE index from 2011-2020. The data between 2018 and 2019 was almost non-existent for some reason, but the key part here is the downfall in value between 2011 and 2012, showing that the world cup was only a temporary boost to the economy of South Africa, or at least for this stock index.