A Study of The Effect of Black Swan Events on Stock Markets – and Developing a Model for Predicting and Responding to them

Chinmay Phadnis[1], Sunit Joshi[2] and Dipasha Sharma[3]

Abstract

Black Swan events are rare and seemingly random in nature. In the famous paper by Nassim Nicholas Taleb, it is posited that Black Swan events cannot be reliably predicted, and it is instead important to be prepared for them at all times (Musgrave, 2009). This study aims to understand various Black Swan events in recent history from the point of view of equity markets, and performs a comparative study between different events across time and geography in order to understand if there are any standard early indicators. In this study, a total of seven global events have been observed within the selected period from FY 1997 to FY 2019. All events have been considered from the standpoint of their impact on S&P 500 index. Apart from assessing the sensitivity factor, the impact of each event was observed for any statistical similarity through a One-Way ANOVA test of their normalised values.

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Keywords: Black Swan event, prediction, S&P 500 index, comparative study

[1] Symbiosis Centre for Management and Human Resource Development (SCMHRD), Symbiosis International (Deemed University), SIU Pune, India
[2] Symbiosis Centre for Management and Human Resource Development (SCMHRD), Symbiosis International (Deemed University), SIU Pune, India
[3] Symbiosis Centre for Management and Human Resource Development (SCMHRD), Symbiosis International (Deemed University), SIU Pune, India

INTRODUCTION

According to Nassim Nicholas Taleb (Musgrave, 2009), while a Black Swan event is rare and seemingly random, there would be some clear indications, which can be observed with the benefit of hindsight.

For the purpose of this study, a Black Swan event has been defined as any period of seven consecutive days during which the difference between the maximum and minimum values of a particular stock exchange is greater than or equal to 10 per cent of the maximum value.

Given this criterion, seven Black Swan events have been studied across the world, chosen for their uniqueness and their ability to, at least in part, influence major equity markets.

It is crucial to be able to identify how much of data before the actual event is relevant to the event itself. It would be prudent to separate short-term and long-term indicators, with the effect of each measured and prioritised for developing an accurate and reliable algorithm. Short-term indicators, for the duration of this study, have been defined as those appearing a maximum of five days before the steepest decline in the values of the concerned stock index in the specific time frame, while long-term indicators have been defined as those appearing twenty to five days before the steepest decline in the values.

The other significant attribute to be measured was the extent of early warning plausible at any given point in time. In other words, we needed to establish how early it was possible and reliable to predict a Black Swan event before it actually occurs. While any early warning would be welcome, it is logical to want to maximise the time between the warning and the event while making sure that the required reliability is achieved.

Intuitive thinking might lead us to consider moderate time periods of twenty or twenty-five years, considering each set of those many years to be a phase in the macroeconomic history of the world.

Through trial and error, we decided to select the period from FY 1997 to FY 2019 for the purpose of this study. During this time period, a total of seven global events have been observed within the period under consideration. Notably, every event has been considered from the point of view of the S&P 500 index – meaning that the impact of every event has been considered from the point of view of the US stock market.

Following are the events in detail and the reason for their consideration. This information was largely sourced from an article on the history of Black Swan events (Faisal Khan, 2019):

1. Asian Market Real Estate Crisis (1997) – The most relevant example of the demonstration of the interdependence of Asian markets in the recent times has occurred in 1997 with the prominent East Asian and South East Asian emerging economies facing a sudden shock when the real estate price bubble burst, starting with Thailand. The property prices in Thailand had entered an era of rampant price rise for years at a stretch, on the back of strong internal growth and foreign investment. However, as is the case with a lot of developing economies, it became uncontrollably volatile to the point that the prices rose to absurd levels. This inevitably caused a property price crash due to the bursting of the bubble, wiping out close to 70 per cent wealth in the stock market of Thailand. Since the South East Asian economies were, and still continue to be, closely interconnected, a similar demand side shock to property prices was observed in economies like South Korea, Malaysia, Singapore and Indonesia. The crisis that had begun to

rear its head in the initial months of 1997 was the biggest drop in stock prices in the respective markets in generations. It had shown early indications, as much as a year prior to the actual crisis, but as is the case with a lot of examples we observed, the general investor erred on the side of optimism, causing the bubble to swell up even more and hence bursting more devastatingly. This crisis was exacerbated with the contractionary policy of the US Federal Reserve, thus cutting off liquidity across the financial world. The countries were bailed out by the International Monetary Fund (IMF) with short duration loans of over a 100 billion US dollars under a lot of rigid clauses, eventually causing the economies to bounce back in the coming five years to regain their initial momentum.

2. The Dot Com Bust (2000) – Nearing the new millennium, hopes were high for the rapidly growing phenomenon of the internet. This caused a frenzy in the then adolescent Silicon Valley, with investors willing to put their money behind anything that resembled an internet application. This went beyond the point of healthy optimism to the point of sheer wishful thinking, to be able to think that so many companies competing directly could survive in a competitive environment, even in the late twentieth century. The US stock markets swelled up with the infusion of so much capital into these organisations, with its value increasing more than five-fold in five years. The infamous NASDAQ peak at 5,048 was followed by a free-for-all, with investors dumping stocks of big and small companies alike. Unsustainable growth in prices can be identified as one of the primary reasons for this sudden drop, in which the markets inevitably readjusted themselves based on the inherent value being traded. This was a sustained drop as compared to other crises, which were more sudden in nature. Just as the unprecedented, unrealistic and hollow inflation in the stock prices took place over a period of five years, so did the eventual readjustment due to the gradual disillusionment of investors who had expected a double-digit growth in tech companies, which, incidentally, also followed a pattern of five years. Although as we observe, since that time, more robust and stable tech companies like Alphabet (Google) and Apple Inc. have showed that investment in technology is still as lucrative as ever, other so-called tech companies like WeWork have brought back the bitter taste of Dot Com Bust due to the unrealistic expectations of investors for larger-than-life personalities and ideas instead of a robust study of business fundamentals and a solid plan.

3. Stock Market Crash after the 9/11 Terrorist Attacks – This is a Black Swan event due to sudden and unnatural circumstances, similar to the earlier discussion about wars and conflicts affecting the nature of the stock market, which is largely governed by emotions even in the modern era. Having just managed to regain a foothold since the dot com bust barely a year before, the already jittery markets were hit by a double blow due to a horrific terrorist attack on what was considered to be the centre of finance of the modern world, New York City. While the actual damage caused by the catastrophe cannot be understated, with New York's most recognisable business monument being destroyed and thousands of lives being lost in a few hours, the crisis was really brought into gear because of the lack of precedence and the simple shock of the world's most militarily powerful country being struck on its own soil by a terrorist organisation. This panic was felt across the world, but most in the United States, with the S&P 500 index falling by double digits in a week, wiping out more than a trillion dollars of investor wealth. Additionally, public spending increased in the defence sector for the United States in the succeeding years. However, since this crisis was the result of investor fear and panic instead of systemic faults inherent to the system, it is unrealistic to believe that it could have been

predicted. Having said that, since the inherent value of most stocks comprising the index was untouched due to this random event, the markets corrected themselves gradually to reach a level more indicative of their values. This entire process took less than two years, a pace much faster than the Dot Com crisis that took place a year earlier. Crises like these are the most challenging to predict because of their seemingly random occurrence. Observing global political and military trends is probably the most effective early indicator, if any.

4. Global Financial Crisis (2008) – This particular crisis is possibly the meaningful data point for our particular use, as this was the severe one to hit the US stock markets since the Great Depression almost a century ago, at least until the COVID-19 pandemic. As a matter of fact, this crisis also provides good lessons in order to understand and counter the current pandemic crisis, given the combination of its severity and recency. One important aspect about studying this period of financial distress is that it has been one of the widely studied and researched financial crises across the world in the recent times. We have a lot of in-depth insights about why and how it took place, how it spread and how the regulators fell short in their duty to maintain a steady financial system. Perusing the research before and after the crisis, it is possible to logically piece together the sequence of events leading up to the meltdown and the inevitable consequences of the same. The ripples of this quake were felt across the global financial markets, both small and large. Our focal point for the purpose of this study was the S&P 500 – a US stock market index that was affected the most by this Black Swan event if we consider the pre-COVID-19 world, and hence needed to be readjusted by a high sensitivity factor in order to separate the effect of proximity from the calculation of severity. Given the multiple single day falls in the market due to this crisis, four separate instances from this period have been studied.

5. European Crisis (2011) – Right on the heels of the 2008 crisis was the European banking crisis, which although much smaller in scale, exposed the systemic flaws in the debt market of the traditionally stable West European countries. This crisis offered a unique opportunity to observe how two different Black Swan events could occur in different geographies at different periods of time and one might still, in at least a partial way, be the effect of the other. It started with the unravelling of the Icelandic debt system, gradually spreading to Spain, Italy, Portugal and, the biggest disaster of all, Greece. The country required multiple bailouts from the European Central Bank and the IMF and just as it was beginning to crawl out of the ditch, it has possibly found itself, due to the global pandemic, requiring tremendous government spending in public healthcare and the loss of business due to necessary restrictions on travel and social distancing.

6. Brexit (2016) – Brexit is the seemingly simple name given to the United Kingdom's decision to leave the European Union. It was a decision taken through a nationwide referendum. While Brexit was devastating to the London stock market, we are measuring its impact on the US S&P 500 index. However, like the 1997 Asian crisis, the ripples did not cross the Atlantic Ocean, although moderate impact was felt in markets all around the world, including the one we observed.

7. COVID-19 (2020) – This ongoing crisis is shaping up to be the biggest jolt to the world economy in decades, definitely the biggest of the twenty-first century yet. Unlike most of the previous examples (barring the 2008 crisis), which were locally focused shocks, this one is expected to hit almost all countries in the world noticeably. Regarding the S&P 500, eight of the ten biggest single day drops in its value have been recorded in the year 2020 itself, with the crisis expected to get worse. The data on the crisis is not complete yet and hence has not been assigned a local magnitude (m), thus causing it to not be considered in the sensitivity map.

This study aimed at comparing various Black Swan events to see if there is any statistical similarity in the behaviour of a particular stock market in reaction to Black Swan events across the world. This was followed by the use of insights gained to develop a standard protocol for prediction of and response to a Black Swan event, depending on its severity and location.

LITERATURE REVIEW

This study primarily derived its knowledge and aimed at expanding on a study by Neil Johnson on the dynamics of Black Swan events understood through analysis of S&P's index. It is not an analysis of cause and effect between Black Swan events and equity markets, pitching one to be the cause of the other. It is simply an attempt to establish correlation between the two, hypothesising that the forces governing the economy have a significant impact on the markets, especially free float markets like equity (Johnson, et al., 2012).

A huge influence on this study was of the world-renowned book by Nicholas Nassim Taleb, namely *The Black Swan: The Impact of the Highly Improbable* (Musgrave, 2009). It comprehensively explains the need to address grave financial events that are highly unlikely, without considering them insignificant given the minuscule probability of their occurrence, simply because the impact is too drastic to ignore. It also states that it is more prudent to take preventive action, perpetually assuming that a Black Swan event might occur. This is because the study believes it is not practical to accurately predict events of this unlikely probability. Our study aims to identify if there is any merit in observing the sample data of Black Swan events in different geographies and evaluating the movements in equity markets that coincide with the arrival of events of such magnitude.

Another paper that distinctly impacted our understanding of the effect of Black Swan events on the money market was the study by Taylor and Williams, on the significance of counterparty risk and the effectiveness of the Term Auction Facility in reducing interest rate spreads. This study deals with the effects of Black Swan events in terms of policies and interest rates. While our study does not particularly focus on the correction measures by central banks or governments to deal with devastating financial events, it was necessary to understand the reasoning behind the actions taken by them in order to understand the dynamics and extent of impact these events tend to have on national economies (Taylor & Williams, 2009).

Additionally, since the applicability of our study needed to be verified in other mediums as well, we consulted the cited study to understand the effect on Black Swan events specifically on gold markets. Gold markets, in principle, move in a contrary direction to equity markets given the diverse nature of the two asset classes and their inherent risk dynamics. However, in the case of

Black Swan events, given their scale, there is a significant downward kink in the traded value of gold before it resumes its upward march, opposing the equity markets that tend to plunge (Bekiros, Boubaker, Nguyen, & Uddin, 2017).

Overall, we have identified that there has been considerable amount of research on the causes and impact of Black Swan events on various economies as well as different asset classes. We have, however, identified a research gap in terms of fundamental pre-indicators of Black Swan events. This study aims to expand the groundwork laid by Neil Johnson's study in its observation of equity markets in this specific context. We zeroed in on one equity market (S&P 500) and calculated the impact of various Black Swan events across the globe with respect to their impact on this reference point. It allowed us to establish a measure of interconnectivity in world markets in addition to the magnitude of the events, as well as to develop a measure to identify numerous early detection mechanisms by observing a singular equity market.

RESEARCH METHODOLOGY

Secondary Data Analysis / Archival Study

A factor to be considered while defining the period of study for the algorithm is how far back into history one should go in order to get data relevant to today's prediction and response. While it is possible to get detailed stock data for the S&P 500 index from its inception as early as the year 1927, it will be unhelpful to consider data that old for prediction purposes, simply because the dynamics of the stock market have changed dramatically to the point that any data sourced from that time will only reduce the accuracy of prediction without providing any insight worth considering.

Thus, a recent time period of twenty or twenty-five years, which can be construed as a phase in the macroeconomic history of the world, was considered appropriate for the study, and we have identified the ideal period to be from FY 1997 to FY 2019.

There are a number of reasons for this, one of them being the fact that this is after the fall of the Soviet Union and hence the political structure of the world has remained stable in the grand scheme of things until recently with the rise of Chinese influence on political – and, by extension, economic – policies, particularly in the Asian region. Possibly as a result of a largely unipolar political structure, we have not had any major wars on a global scale barring the US invasion of Iraq, which in itself was much smaller in scale compared to most wars in the twentieth century. Naturally, the nature of the process was 'lookback', meaning all assumptions and inferences were derived from incidents that have occurred at some time in the past.

This means, in theory it is not possible to predict a completely unprecedented event through this method. However, no event is unpredictably sudden, barring a war of global proportions. Since there has been no such event in the period chosen, the period cannot be considered as a standard for all predictions. An interesting dilemma for developing a robust algorithm is whether we take into account major events like wars. While including them in the training naturally brings down the accuracy and reliability of the algorithm thanks to the rarity and unpredictability of these events, one might argue that a Black Swan event is inherently rare and the purpose of developing an algorithm to detect Black Swan events is to make sure they are detected, no matter how rare the occurrence.

The data for the S&P index was sourced from Yahoo finance (Yahoo Corporation, 2020). The reason for this is that we intended to check the effect of global events on any single market under consideration, rate each for the magnitude of its impact with relation to the market considered and incorporate that into the algorithm to prepare a sensitivity map for the particular market in relation to events taking place at different parts of the globe, with a sensitivity factor assigned to every country. The assignment could also be done by geography instead of country, with a group of interdependent countries that show similar trends towards local and global happenings being bunched together and assigned a single sensitivity factor. Note that the sensitivity factor is the market's reaction to an event of unit magnitude occurring in a particular country or geography. To put the above statement in a mathematical equation,

$$i = m * s$$

Where,

i = magnitude of impact on observed market,

m = universal magnitude of impact,

s = sensitivity factor between observed market and geography where impact has occurred.

This method gives us an understanding of not just the effect of a severe event on the market but also the interconnectivity between the two economies, given the unique sensitivity factors between any two countries or geographies. Additionally, the impacts of every event were observed for any statistical similarity through a One-Way ANOVA test of their normalised values, the results of which have been discussed under the results section.

In order to facilitate this, impact data prior to the sharpest decline of a day, impact in the immediate future since the event and impact in the further future was observed and normalised on a scale of 0 to 1, with the highest point within prior data as well as post data assigned a rating of 1 separately and the other points within the respective group (either prior or post) assigned a relative rating. The purpose of making this adjustment was to be able to compare data from two different eras with two different sets of absolute values.

Since we have defined a Black Swan event on the percentage change in the index value in a given period of time, the decision was made to demarcate the limits of the values within 0 and 1 and operate within those values.

For the purpose of the study, we found it useful to take twenty daily data points before the crisis, ten daily data points during the crisis including the day the crisis started and thirty daily data points after the ten-day period.

These three data sets were made for each crisis, and data from each of the data sets was studied together to check for statistical significance. *The null hypothesis was 'There is no significant difference in the means of the normalised values of pre-event data sets in the seven crises studied.'*

Each of these Black Swan events was assigned a score of 1 to 10 based on the severity felt by the local markets at the epicentre of the crisis. Similarly, each market was assigned a sensitivity score to denote the sensitivity of the S&P 500 to the events in the respective country. This was calculated by the drop in the average value of S&P 500 for a unit drop in the local markets at the epicentre of the crisis for a given short period in time. For events where the epicentre was the United States, the sensitivity score was naturally 1.

Table 1: Events and Their Impact

Event	Local Magnitude (m)	Sensitivity Factor w.r.t. S&P 500 (s)	Impact Magnitude on S&P 500 (I = m*s)
SEA Crisis	9	0.08	0.72
Dot Com bust	6	1	6
9/11 attacks	4	1	4
2008 Crisis	9	1	9
European Debt Crisis	7	0.24	1.68
Brexit	7	0.28	1.96

The period taken was fairly short – in this case only one day – to mitigate the possibility of multiple events affecting the drop in the value. This method allowed the establishment of an impact score to every crisis on the S&P 500 while also providing a sensitivity map for the other geographies studied.

Notably, the scores for COVID-19 have not been included in the above table because the crisis being ongoing at the time of conducting this study, impact of the pandemic could not be fully measured.

RESULTS AND ANALYSIS

Pre-Event Analysis

Table 2: Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1997	20	.9793	.01967	.00440	.9701	.9885	.93	1.00
2000	20	.9711	.01650	.00369	.9634	.9788	.94	1.00
2001	20	.9671	.02630	.00588	.9548	.9794	.91	1.00
2008	20	.9248	.06258	.01399	.8955	.9541	.78	1.00
2011	20	.9716	.02638	.00590	.9592	.9839	.89	1.00
2016	20	.9878	.00682	.00152	.9846	.9910	.98	1.00
2020	20	.9544	.04702	.01051	.9324	.9764	.87	1.00
Total	140	.9651	.03858	.00326	.9587	.9716	.78	1.00

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2008	20	.9248	.06258	.01399	.8955	.9541	.78	1.00
2011	20	.9716	.02638	.00590	.9592	.9839	.89	1.00
2016	20	.9878	.00682	.00152	.9846	.9910	.98	1.00
2020	20	.9544	.04702	.01051	.9324	.9764	.87	1.00

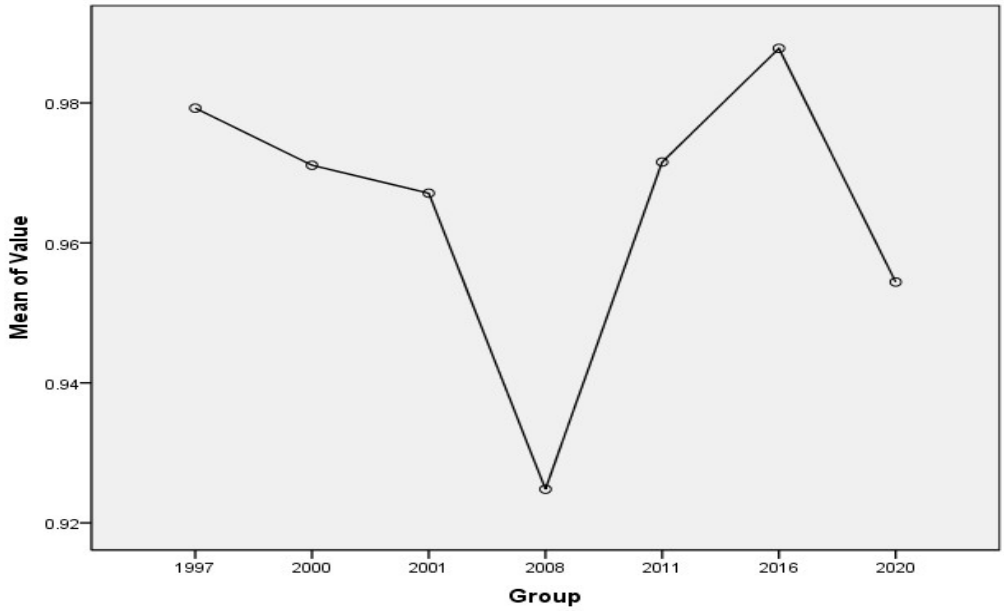
Table 3: Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
13.922	6	133	.000

Table 4: ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.051	6	.008	7.195	.000
Within Groups	.156	133	.001		
Total	.207	139			

Figure 1: Mean Plots



Event Analysis

Table 5: Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1997	10	.9792	.00979	.00310	.9721	.9862	.97	1.00
2000	10	.9449	.03739	.01182	.9181	.9716	.89	1.00
2001	10	.9722	.02271	.00718	.9560	.9885	.93	1.00
2008	10	.9411	.04068	.01287	.9120	.9702	.89	1.00
2011	10	.9710	.02636	.00833	.9521	.9898	.93	1.00
2016	10	.9817	.01772	.00560	.9690	.9944	.95	1.00
2020	10	.8834	.07160	.02264	.8322	.9346	.80	1.00
Total	70	.9533	.04827	.00577	.9418	.9648	.80	1.00

Event Analysis

Table 5: Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1997	10	.9792	.00979	.00310	.9721	.9862	.97	1.00
2000	10	.9449	.03739	.01182	.9181	.9716	.89	1.00
2001	10	.9722	.02271	.00718	.9560	.9885	.93	1.00
2008	10	.9411	.04068	.01287	.9120	.9702	.89	1.00
2011	10	.9710	.02636	.00833	.9521	.9898	.93	1.00
2016	10	.9817	.01772	.00560	.9690	.9944	.95	1.00
2020	10	.8834	.07160	.02264	.8322	.9346	.80	1.00

Table 6: Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
11.459	6	63	.000

Table 7:

ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.073	6	.012	8.637	.000
Within Groups	.088	63	.001		
Total	.161	69			

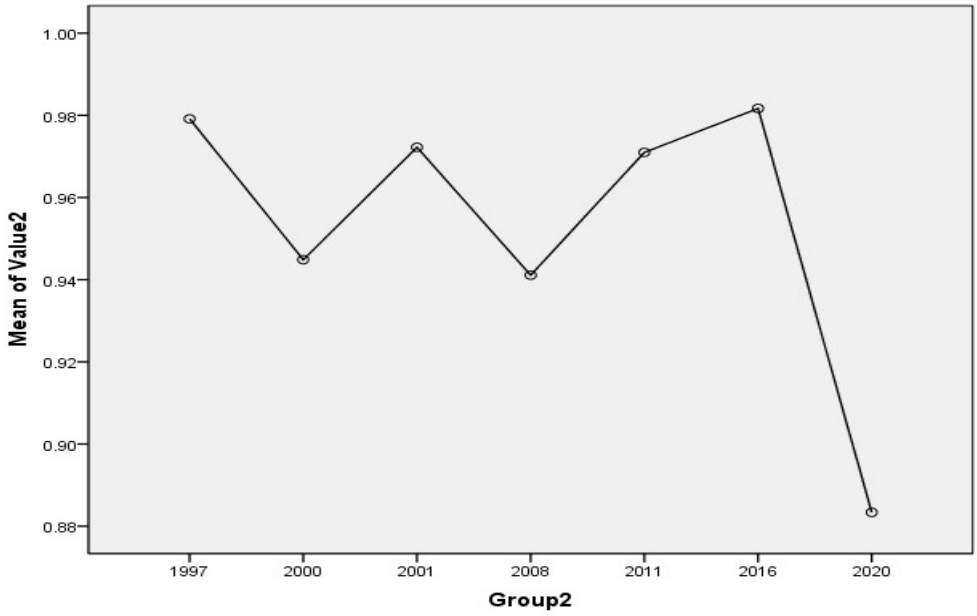


Figure 2: Means Plots

Post-Event Analysis

Table 6: Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1997	30	.9718	.01524	.00278	.9661	.9775	.94	1.00
2000	30	.9600	.02728	.00498	.9498	.9702	.89	1.00
2001	30	.9673	.01870	.00341	.9603	.9743	.93	1.00
2008	30	.8811	.05628	.01028	.8601	.9021	.75	1.00
2011	30	.9631	.02338	.00427	.9544	.9718	.92	1.00
2016	30	.9904	.00633	.00116	.9880	.9928	.97	1.00
2020	30	.9149	.06240	.01139	.8916	.9382	.76	1.00
Total	210	.9498	.04987	.00344	.9430	.9566	.75	1.00

Post-Event Analysis

Table 6: Descriptive Statistics

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1997	30	.9718	.01524	.00278	.9661	.9775	.94	1.00
2000	30	.9600	.02728	.00498	.9498	.9702	.89	1.00
2001	30	.9673	.01870	.00341	.9603	.9743	.93	1.00
2008	30	.8811	.05628	.01028	.8601	.9021	.75	1.00
2011	30	.9631	.02338	.00427	.9544	.9718	.92	1.00
2016	30	.9904	.00633	.00116	.9880	.9928	.97	1.00
2020	30	.9149	.06240	.01139	.8916	.9382	.76	1.00

Table 7: Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
23.981	6	203	.000

Table 8: ANOVA Results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.260	6	.043	33.739	.000
Within Groups	.260	203	.001		
Total	.520	209			

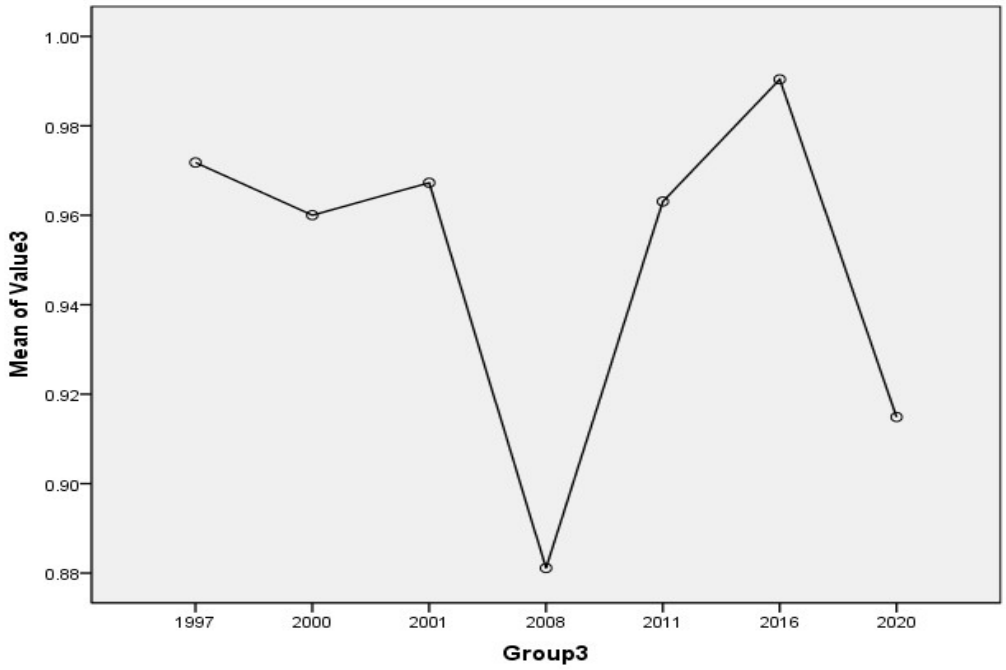


Figure 3: Mean Plots

FINDINGS AND DISCUSSION

Each of the seven selected events was taken into consideration because of its significance both at the local epicentre where the event actually took place as well as its ripple effect across the financial markets throughout the world. Since we were observing S&P 500 data, we primarily viewed the crisis from the lens of the US stock markets, although the same method could be applied to any market under consideration. In fact, in our particular case, a reverse effect may also be observed. The US stock markets have had an effect on global equity for years now, especially post globalisation, with investors from the United States investing in developing country stocks and the other way round.

Findings

1. We observed that there is a set of pre-shocks in the index values before the maximum drop in any given crisis. In each of the instances, we were able to observe between one and three minor drops in the pre-event data ranging until twenty days before the 'black day'. This could be due to the reaction of certain individual or institutional investors acting proactively or the pessimistic investors simply withdrawing their money before a crisis. Although this indicator has existed in every Black Swan event, it is not sufficient to determine whether a crisis is of Black Swan scale, as we have observed similar minor drops during the other scares as well, for instance the 2011 Fukushima nuclear plant crisis in which the markets experienced some minor shocks that were corrected without major damage.

2. Through assigning sensitivity scores, we were able to pin the effect of various world events on the equity markets in the United States. Although this study is sufficient to reliably predict a severe downturn in any one particular market, it is not a viable option to predict global crises, for the simple reason that there is no market in the world that is uniformly sensitive to all happenings anywhere across the globe. Instead, the purpose of this study is to keep a market as reference and localise the effect of all crises on that particular market. This benefits investors, as most retail investors are active in one equity market at a time (Barber & Odean).
3. Additionally, this study employs an observational approach towards the changes in values of the stock index, without questioning the reasons and implications of it on a fundamental scale. While this makes the study repeatable in different geographies, the approach might overlook some obvious fundamental indicators assisting in a more reliable and accurate prediction.

CONCLUSION

The current COVID-19 crisis was pitched against every other Black Swan event in modern history in this study, and it showed no significant similarity to any previous event – except to an extent to the 2008 crisis, at least from the perspective of the S&P 500 index. For all three stages – pre-event, event and post-event – the index has mirrored the trends of 2008, albeit on a much larger scale. We have observed an erratic fluctuation of values in the ten days of the event as well as thirty days post the event. The pre-event data from all the crises studied showed no significant difference in their stock values. To confirm if this is the case observed only in Black Swan events, the pre-event data of these events were checked for statistical similarity with other smaller downturns in the S&P 500 index. They showed significant differences in most cases, barring the Asian Crisis, which showed no significant difference. This may be because while the 1997 crisis was devastating for the South East Asian countries, its effect was not felt in the S&P 500 to a major extent, hence it mirrored smaller domestic downturns in the American market.

As explained in the literature review, this study primarily aimed to expand on the research by Neil Johnson's study (Johnson, et al., 2012), by implementing a similar approach towards the problem of studying Black Swan events, namely through observing equity markets. This study tries to fill up the gap of predictive analysis of the markets in order to identify actionable insights into a Black Swan event before its impact is felt.

The uniqueness of the study lies in its attempt to evaluate the interconnectivity between major markets in the world through the assignment of sensitivity scores for each market reference point – in this case, the S&P 500. Additionally, we have used statistical tools to reinforce our claims that various Black Swan events in history across various geographies have a statistical similarity even with the current COVID-19 crisis and hence can be used to generate actionable insights in order to identify early indicators in that regard.

Practical Implications

We have established a table that can be used to identify S&P 500's sensitivity to various world markets. Additionally, the insights generated through studying the previous Black Swan events have been tested on the current COVID-19 crisis and have generated statistically significant, accurate predictions. The results have been mentioned in the Results and Analysis section, as well as a detailed set of observations in the Annexure.

Recommendations

Although this requires further understanding by performing a similar exercise for other indices across the world to convincingly make a statement, we have found in our study that data from approximately fifteen days before the actual event provides a fair understanding of the possibility of a Black Swan event. As mentioned earlier, the sensitivity score was a ratio of the drop in the market under consideration (in our case S&P 500) to the drop in the markets at the local epicentre of the crisis. This method of analysis could be subject to scrutiny, as a drop in a market could be the result of multiple factors at once – some local and others global. However, we have observed that that the characteristics of the market before a Black Swan event provide a specific downturn unique only to the events of equivalent magnitude. Running an ANOVA test on any consecutive fifteen-day period compared with the events studied in this study will provide a p-value signifying its relationship with them. A statistical similarity observed is a warning sign, applicable at best five days before the biggest downturn. Regarding severe global financial crises not causing a significant impact on the market under observation, we found no significant patterns from the point of view of the foreign market under observation. Meaning that in our case, we found no significant changes in the patterns of the S&P 500 index, if the crisis had an epicentre elsewhere in the world in an economy decoupled from the American markets, as in the case of the South East Asian crisis. A possible work-around for this could be establishing a similar study from the point of view of multiple major markets around the world and conducting an analysis of each as if it was the epicentre. This would give us a better judgment of the magnitude for each of the crises individually, in turn helping reinforce the relative measurements.

Limitations

Since the calculations are normalised, that is, performed on a relative basis, they might not adequately consider the effect of events that have had an absolute impact on the values of the index. For instance, if a set of investors regularly withdraw and reinvest their fixed corpus in the market at different points in time, the effect of those transactions would not follow an increase or decrease pattern of the index proportionally. Instead its effect will remain steady in terms of absolute money injected into the market or withdrawn from it. In this case, our method is likely to understate or overstate this particular effect in conditions different than the base, with a bigger base causing overstating effect and a smaller one causing a corresponding understating.

The scope of the study is limited to the movements in the stock market, in this particular case the movement of S&P 500. The qualitative and quantitative factors governing the movement are beyond the scope of this particular study. Instead, this study deals with the combined effect of the factors on the movement of the stock index. The implications of this could be felt in a more pronounced manner after a couple of decades, when the dynamics of the equity market are completely different, at which point this study will become obsolete and a newer understanding of the dynamics must be applied.

The lookback nature of the study makes it so that all observations and hence all insights have been derived from historical precedence. To this end, while the other limitations of the study are a result of cost restrictions, time restrictions or simply a lapse in understanding, this particular one is a result of the inherent limitation of an error in predicting the future. As we continue to experience events that are unique and extreme in nature, the algorithm will keep getting better in terms of efficiency.

Annexure

Furnished below is the detailed inter-event comparison study in the three phases – pre-event, event and post-event scenarios.

Multiple Comparisons
Dependent Variable: Values (Pre-event)

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1997	2000	.00817	.01084	1.000	-.0254	.0417
		2001	.01216	.01084	1.000	-.0214	.0457
		2008	.05445*	.01084	.000	.0209	.0880
		2011	.00771	.01084	1.000	-.0259	.0413
		2016	-.00854	.01084	1.000	-.0421	.0250
		2020	.02485	.01084	.492	-.0087	.0584
	2000	1997	-.00817	.01084	1.000	-.0417	.0254
		2001	.00399	.01084	1.000	-.0296	.0376
		2008	.04629*	.01084	.001	.0127	.0799
		2011	-.00046	.01084	1.000	-.0340	.0331
		2016	-.01670	.01084	1.000	-.0503	.0169
		2020	.01668	.01084	1.000	-.0169	.0503
	2001	1997	-.01216	.01084	1.000	-.0457	.0214
		2000	-.00399	.01084	1.000	-.0376	.0296
		2008	.04230*	.01084	.003	.0087	.0759
		2011	-.00445	.01084	1.000	-.0380	.0291
		2016	-.02070	.01084	1.000	-.0543	.0129
		2020	.01269	.01084	1.000	-.0209	.0463
	2008	1997	-.05445*	.01084	.000	-.0880	-.0209
		2000	-.04629*	.01084	.001	-.0799	-.0127

		2001	-.04230*	.01084	.003	-.0759	-.0087
		2011	-.04675*	.01084	.001	-.0803	-.0132
		2016	-.06299*	.01084	.000	-.0966	-.0294
		2020	-.02960	.01084	.150	-.0632	.0040
	2011	1997	-.00771	.01084	1.000	-.0413	.0259
		2000	.00046	.01084	1.000	-.0331	.0340
		2001	.00445	.01084	1.000	-.0291	.0380
		2008	.04675*	.01084	.001	.0132	.0803
		2016	-.01625	.01084	1.000	-.0498	.0173
		2020	.01714	.01084	1.000	-.0164	.0507
	2016	1997	.00854	.01084	1.000	-.0250	.0421
		2000	.01670	.01084	1.000	-.0169	.0503
		2001	.02070	.01084	1.000	-.0129	.0543
		2008	.06299*	.01084	.000	.0294	.0966
		2011	.01625	.01084	1.000	-.0173	.0498
		2020	.03339	.01084	.053	-.0002	.0670
	2020	1997	-.02485	.01084	.492	-.0584	.0087
		2000	-.01668	.01084	1.000	-.0503	.0169
		2001	-.01269	.01084	1.000	-.0463	.0209
		2008	.02960	.01084	.150	-.0040	.0632
		2011	-.01714	.01084	1.000	-.0507	.0164
		2016	-.03339	.01084	.053	-.0670	.0002
Tamhane	1997	2000	.00817	.00574	.976	-.0105	.0268
		2001	.01216	.00734	.907	-.0118	.0361
		2008	.05445*	.01467	.024	.0045	.1045
		2011	.00771	.00736	.999	-.0163	.0317
		2016	-.00854	.00466	.824	-.0243	.0073
		2020	.02485	.01140	.563	-.0135	.0632
	2000	1997	-.00817	.00574	.976	-.0268	.0105

	2001	.00399	.00694	1.000	-.0189	.0268
	2008	.04629	.01447	.085	-.0033	.0959
	2011	-.00046	.00696	1.000	-.0234	.0224
	2016	-.01670*	.00399	.006	-.0301	-.0033
	2020	.01668	.01114	.965	-.0211	.0545
2001	1997	-.01216	.00734	.907	-.0361	.0118
	2000	-.00399	.00694	1.000	-.0268	.0189
	2008	.04230	.01518	.189	-.0088	.0933
	2011	-.00445	.00833	1.000	-.0315	.0226
	2016	-.02070	.00608	.053	-.0415	.0002
	2020	.01269	.01205	.999	-.0272	.0526
2008	1997	-.05445*	.01467	.024	-.1045	-.0045
	2000	-.04629	.01447	.085	-.0959	.0033
	2001	-.04230	.01518	.189	-.0933	.0088
	2011	-.04675	.01519	.098	-.0978	.0043
	2016	-.06299*	.01408	.005	-.1120	-.0140
	2020	-.02960	.01750	.890	-.0868	.0275
2011	1997	-.00771	.00736	.999	-.0317	.0163
	2000	.00046	.00696	1.000	-.0224	.0234
	2001	.00445	.00833	1.000	-.0226	.0315
	2008	.04675	.01519	.098	-.0043	.0978
	2016	-.01625	.00609	.260	-.0372	.0047
	2020	.01714	.01206	.978	-.0228	.0571
2016	1997	.00854	.00466	.824	-.0073	.0243
	2000	.01670*	.00399	.006	.0033	.0301
	2001	.02070	.00608	.053	-.0002	.0415
	2008	.06299*	.01408	.005	.0140	.1120
	2011	.01625	.00609	.260	-.0047	.0372

	2020	.03339	.01062	.103	-.0035	.0703
2020	1997	-.02485	.01140	.563	-.0632	.0135
	2000	-.01668	.01114	.965	-.0545	.0211
	2001	-.01269	.01205	.999	-.0526	.0272
	2008	.02960	.01750	.890	-.0275	.0868
	2011	-.01714	.01206	.978	-.0571	.0228
	2016	-.03339	.01062	.103	-.0703	.0035

Multiple Comparisons

Dependent Variable: Values (Event)

	(I) Group2	(J) Group2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1997	2000	.03428	.01673	.937	-.0187	.0873
		2001	.00693	.01673	1.000	-.0461	.0599
		2008	.03805	.01673	.554	-.0149	.0910
		2011	.00817	.01673	1.000	-.0448	.0611
		2016	-.00253	.01673	1.000	-.0555	.0504
		2020	.09578*	.01673	.000	.0428	.1488
	2000	1997	-.03428	.01673	.937	-.0873	.0187
		2001	-.02736	.01673	1.000	-.0803	.0256
		2008	.00376	.01673	1.000	-.0492	.0567
		2011	-.02612	.01673	1.000	-.0791	.0269
		2016	-.03682	.01673	.661	-.0898	.0162
		2020	.06150*	.01673	.010	.0085	.1145
	2001	1997	-.00693	.01673	1.000	-.0599	.0461
		2000	.02736	.01673	1.000	-.0256	.0803
		2008	.03112	.01673	1.000	-.0219	.0841
		2011	.00124	.01673	1.000	-.0517	.0542
		2016	-.00946	.01673	1.000	-.0624	.0435
		2020	.08885*	.01673	.000	.0359	.1418

	2008	1997	-.03805	.01673	.554	-.0910	.0149
		2000	-.00376	.01673	1.000	-.0567	.0492
		2001	-.03112	.01673	1.000	-.0841	.0219
		2011	-.02988	.01673	1.000	-.0829	.0231
		2016	-.04058	.01673	.382	-.0936	.0124
		2020	.05773*	.01673	.021	.0048	.1107
	2011	1997	-.00817	.01673	1.000	-.0611	.0448
		2000	.02612	.01673	1.000	-.0269	.0791
		2001	-.00124	.01673	1.000	-.0542	.0517
		2008	.02988	.01673	1.000	-.0231	.0829
		2016	-.01070	.01673	1.000	-.0637	.0423
		2020	.08761*	.01673	.000	.0346	.1406
	2016	1997	.00253	.01673	1.000	-.0504	.0555
		2000	.03682	.01673	.661	-.0162	.0898
		2001	.00946	.01673	1.000	-.0435	.0624
		2008	.04058	.01673	.382	-.0124	.0936
		2011	.01070	.01673	1.000	-.0423	.0637
		2020	.09831*	.01673	.000	.0453	.1513
	2020	1997	-.09578*	.01673	.000	-.1488	-.0428
		2000	-.06150*	.01673	.010	-.1145	-.0085
		2001	-.08885*	.01673	.000	-.1418	-.0359
		2008	-.05773*	.01673	.021	-.1107	-.0048
		2011	-.08761*	.01673	.000	-.1406	-.0346
		2016	-.09831*	.01673	.000	-.1513	-.0453
Tamhane	1997	2000	.03428	.01222	.321	-.0145	.0831

	2001	.00693	.00782	1.000	-.0228	.0367
	2008	.03805	.01323	.294	-.0151	.0912
	2011	.00817	.00889	1.000	-.0262	.0426
	2016	-.00253	.00640	1.000	-.0261	.0211
	2020	.09578*	.02285	.044	.0019	.1897
2000	1997	-.03428	.01222	.321	-.0831	.0145
	2001	-.02736	.01383	.766	-.0778	.0230
	2008	.00376	.01747	1.000	-.0578	.0654
	2011	-.02612	.01447	.861	-.0780	.0257
	2016	-.03682	.01308	.268	-.0860	.0123
	2020	.06150	.02554	.483	-.0333	.1563
2001	1997	-.00693	.00782	1.000	-.0367	.0228
	2000	.02736	.01383	.766	-.0230	.0778
	2008	.03112	.01473	.681	-.0231	.0854
	2011	.00124	.01100	1.000	-.0376	.0401
	2016	-.00946	.00911	1.000	-.0418	.0229
	2020	.08885	.02375	.068	-.0045	.1822
2008	1997	-.03805	.01323	.294	-.0912	.0151
	2000	-.00376	.01747	1.000	-.0654	.0578
	2001	-.03112	.01473	.681	-.0854	.0231
	2011	-.02988	.01533	.781	-.0853	.0256
	2016	-.04058	.01403	.244	-.0939	.0127
	2020	.05773	.02604	.606	-.0379	.1534
2011	1997	-.00817	.00889	1.000	-.0426	.0262
	2000	.02612	.01447	.861	-.0257	.0780

		2001	-.00124	.01100	1.000	-.0401	.0376
		2008	.02988	.01533	.781	-.0256	.0853
		2016	-.01070	.01004	.999	-.0469	.0255
		2020	.08761	.02413	.076	-.0058	.1810
	2016	1997	.00253	.00640	1.000	-.0211	.0261
		2000	.03682	.01308	.268	-.0123	.0860
		2001	.00946	.00911	1.000	-.0229	.0418
		2008	.04058	.01403	.244	-.0127	.0939
		2011	.01070	.01004	.999	-.0255	.0469
		2020	.09831*	.02332	.036	.0048	.1918
	2020	1997	-.09578*	.02285	.044	-.1897	-.0019
		2000	-.06150	.02554	.483	-.1563	.0333
		2001	-.08885	.02375	.068	-.1822	.0045
		2008	-.05773	.02604	.606	-.1534	.0379
		2011	-.08761	.02413	.076	-.1810	.0058
		2016	-.09831*	.02332	.036	-.1918	-.0048

* The mean difference is significant at the 0.05 level.

Multiple Comparisons

Dependent Variable: Values (Post-Event)

	(I) Group3	(J) Group3	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1997	2000	.01178	.00924	1.000	-.0167	.0402
		2001	.00453	.00924	1.000	-.0239	.0330
		2008	.09066*	.00924	.000	.0622	.1191
		2011	.00871	.00924	1.000	-.0197	.0372
		2016	-.01860	.00924	.957	-.0470	.0098
		2020	.05690*	.00924	.000	.0285	.0853
	2000	1997	-.01178	.00924	1.000	-.0402	.0167
		2001	-.00725	.00924	1.000	-.0357	.0212
		2008	.07888*	.00924	.000	.0504	.1073
		2011	-.00306	.00924	1.000	-.0315	.0254
		2016	-.03037*	.00924	.025	-.0588	-.0019
		2020	.04512*	.00924	.000	.0167	.0736
	2001	1997	-.00453	.00924	1.000	-.0330	.0239
		2000	.00725	.00924	1.000	-.0212	.0357
		2008	.08614*	.00924	.000	.0577	.1146
		2011	.00419	.00924	1.000	-.0243	.0326
		2016	-.02312	.00924	.277	-.0516	.0053
		2020	.05238*	.00924	.000	.0239	.0808
	2008	1997	-.09066*	.00924	.000	-.1191	-.0622
		2000	-.07888*	.00924	.000	-.1073	-.0504
		2001	-.08614*	.00924	.000	-.1146	-.0577
		2011	-.08195*	.00924	.000	-.1104	-.0535

		2016	-.10926*	.00924	.000	-.1377	-.0808
		2020	-.03376*	.00924	.007	-.0622	-.0053
	2011	1997	-.00871	.00924	1.000	-.0372	.0197
		2000	.00306	.00924	1.000	-.0254	.0315
		2001	-.00419	.00924	1.000	-.0326	.0243
		2008	.08195*	.00924	.000	.0535	.1104
		2016	-.02731	.00924	.074	-.0558	.0011
		2020	.04819*	.00924	.000	.0197	.0766
	2016	1997	.01860	.00924	.957	-.0098	.0470
		2000	.03037*	.00924	.025	.0019	.0588
		2001	.02312	.00924	.277	-.0053	.0516
		2008	.10926*	.00924	.000	.0808	.1377
		2011	.02731	.00924	.074	-.0011	.0558
		2020	.07550*	.00924	.000	.0471	.1039
	2020	1997	-.05690*	.00924	.000	-.0853	-.0285
		2000	-.04512*	.00924	.000	-.0736	-.0167
		2001	-.05238*	.00924	.000	-.0808	-.0239
		2008	.03376*	.00924	.007	.0053	.0622
		2011	-.04819*	.00924	.000	-.0766	-.0197
		2016	-.07550*	.00924	.000	-.1039	-.0471
Tamhane	1997	2000	.01178	.00571	.617	-.0065	.0301
		2001	.00453	.00441	1.000	-.0095	.0185
		2008	.09066*	.01065	.000	.0557	.1256
		2011	.00871	.00510	.873	-.0076	.0250
		2016	-.01860*	.00301	.000	-.0284	-.0088
		2020	.05690*	.01173	.001	.0184	.0954
	2000	1997	-.01178	.00571	.617	-.0301	.0065
		2001	-.00725	.00604	.996	-.0265	.0120

	2008	.07888*	.01142	.000	.0421	.1157
	2011	-.00306	.00656	1.000	-.0239	.0177
	2016	-.03037*	.00511	.000	-.0472	-.0136
	2020	.04512*	.01243	.017	.0049	.0854
2001	1997	-.00453	.00441	1.000	-.0185	.0095
	2000	.00725	.00604	.996	-.0120	.0265
	2008	.08614*	.01083	.000	.0508	.1215
	2011	.00419	.00547	1.000	-.0132	.0215
	2016	-.02312*	.00361	.000	-.0349	-.0114
	2020	.05238*	.01189	.002	.0135	.0913
2008	1997	-.09066*	.01065	.000	-.1256	-.0557
	2000	-.07888*	.01142	.000	-.1157	-.0421
	2001	-.08614*	.01083	.000	-.1215	-.0508
	2011	-.08195*	.01113	.000	-.1180	-.0459
	2016	-.10926*	.01034	.000	-.1435	-.0750
	2020	-.03376	.01534	.493	-.0824	.0149
2011	1997	-.00871	.00510	.873	-.0250	.0076
	2000	.00306	.00656	1.000	-.0177	.0239
	2001	-.00419	.00547	1.000	-.0215	.0132
	2008	.08195*	.01113	.000	.0459	.1180
	2016	-.02731*	.00442	.000	-.0418	-.0128
	2020	.04819*	.01217	.007	.0086	.0878
2016	1997	.01860*	.00301	.000	.0088	.0284
	2000	.03037*	.00511	.000	.0136	.0472
	2001	.02312*	.00361	.000	.0114	.0349
	2008	.10926*	.01034	.000	.0750	.1435
	2011	.02731*	.00442	.000	.0128	.0418
	2020	.07550*	.01145	.000	.0376	.1134

2020	1997	-.05690*	.01173	.001	-.0954	-.0184
	2000	-.04512*	.01243	.017	-.0854	-.0049
	2001	-.05238*	.01189	.002	-.0913	-.0135
	2008	.03376	.01534	.493	-.0149	.0824
	2011	-.04819*	.01217	.007	-.0878	-.0086
	2016	-.07550*	.01145	.000	-.1134	-.0376

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