

# Identifying Black Swans in the Athens Stock Exchange

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## Abstract

The purpose of this study is to identify Black Swans in the Athens Stock Exchange during a thirty years period from 1985 to 2015. Using a large dataset of daily returns, we point out that extraordinary returns are not rare and that Black Swans in the Greek Stock Market are more frequent than expected. We also to show that these outliers have an extreme impact on an investor's long term return and finally that the normality assumption is not suitable in predicting the Black Swans phenomenon.

**JEL classification numbers:** G10; G15; G19

**Keywords:** Black Swans; Greek Stock Market; Normal Distribution

## 1 Introduction

During the last three decades the Athens Stock Exchange (henceforth ASE) has experienced numerous booms and busts. These large daily swings of the General Index of ASE have been caused by either financial or political events. These events may or may not be characterized as "Black Swans" depending on their special features. In this study we identify these extraordinary returns and show that - at least the majority of them - fulfill all the criteria of a "Black Swan". Moreover, we find out that these extreme returns outnumber the predictions of normality assumption and they impose a massive impact on investors' returns.

According to Taleb (2007) who has popularized the concept of "Black Swan", a "Black Swan" event has necessarily the three following features: 1) It falls outside the realm of regular expectations because nothing in the past can convincingly point to its occurrence 2) The event carries an extreme impact 3) Explanations for the occurrence can be found after the fact, giving the impression that it can be explainable and predictable. In short, a "Black Swan" event has three characteristics: Rarity, extreme impact and retrospective predictability.

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Determining whether an event qualifies as a Black Swan is theoretically a highly subjective issue. However, previous studies apply mainly technical approaches to define extreme returns. Such technical requirements define Black Swans as for example, monthly returns that are higher than or equal to 5% in absolute value (Estrada & Vargas, 2012), daily returns that are greater than or equal to 1.5% (Burnie & De Ridder, 2010) and finally, returns that fall outside three standard deviations from the mean (Estrada, 2009).

In this study we consider trading days of ASE starting from 1st January 1985, to 31 December 2015. We consider as outliers all daily movements which fall outside plus/minus three times standard deviations around the mean. Under the normal distribution, the occurrence of such events should be only 0,27% of total observations that is, 0,27% of returns belong to the tails of a Gaussian bell curve. The realized occurrence of such outliers in ASE is found to outnumber these predictions. We also show that these outliers had an extreme impact on the long term performance of the ASE General Index and are not to be neglected.

Academics and practitioners have assumed for more than four decades that the returns of stock markets follow a Gaussian – Normal distribution. Such an assumption have been used in many fields of finance: building optimal portfolio of financial assets, pricing and hedging derivatives and managing risk. However, real financial data tend to exhibit extreme price changes, as stock market experience extreme daily returns, that seem incompatible with the assumption of normality. The idea that outliers are observed far more often than what the normality assumption would predict is not new. In their pioneering works, Mandelbrot (1963) and Fama (1965), tested the normality of return of stocks and confirmed that a stable Paretian distribution with a characteristic exponent less than 2 describes stock market returns better than the normal distribution. Mauboussin (2006) quantifies the impact of these extreme returns on the long term performance of the S&P-500 index for a 27 years period (1978 -2005) and argues that the best 50 daily returns and the worst 50 daily returns have an extreme impact on the long term performance of the index. Furthermore, Burnie & De Ridder (2010) found strong evidence that the frequency of extreme day returns has increased over time. They also figured out that the magnitude of negative extreme day returns is greater than positive extreme day returns. Our paper is mostly related to Estrada who examines the impact of Black Swans on the long - term performance of developed (2008, 2009a) and emerging (2009b) stock markets. He pointed out that extreme trading days are more frequent than what is expected under the normal assumption and concluded that daily return data deviates from the normality assumption. He also concluded that Black Swans do have a massive impact on long - term performance.

The rest of the paper is organized as follows: first, we present the dataset, followed by the methodology and the results, then we demonstrate the impact of Black Swans on long term investors' return and we end up with the conclusions.

## 2 Data

We consider trading days of Athens Stock Exchange starting from 1st January 1985, to 31 December 2015. In total, the dataset consists of 7.692 observations - daily returns of the General Index. Table 1 presents the descriptive statistics of our sample. For the sake of comparison we split our sample to the three decades 1985-1994, 1995-2004, 2005-2015 and we also present the respective descriptive statistics for these sub-periods.

Table 1: Descriptive statistics

Period	Obs.	S.D.	Mean return	Min	Max	Skewness	Kurtosis	Jarque-Bera test
1985-2015	7.692	0,0192	0,054%	-16,23%	27,42%	0,410	11,419	1639.53* (0.000)
1985-1994	2479	0,0198	0,14%	-15,03%	27,42%	1,16	22,64	-
1995-2004	2498	0,0167	1,67%	-9,17%	7,96%	54,82	3,66	-
2005-2015	2715	0,0209	2,09%	-16,23%	2,54%	6,55	5,06	-

p-values in parenthesis, \*significance at 0.01

The mean return of our sample is 0,054% and the standard deviation (S.D) is 0,0192. The greatest fall of ASE was at the third of August, 2015 when the General Index lost 16,23% of its value. Contrary to that, the best day was the eleventh of December, 1987 when the General Index scored a 27,42% increase. Skewness and Kurtosis of our sample are 0,41 and 11,419 respectively, suggesting a very clear departure from a normal distribution. Moreover, the Jarque-Bera normality test indicates that the null hypothesis of normality should be rejected at standard probability levels. Inspection of table 1 further reveals a significant deviation among the three decades in terms not only mean return but also in terms of all other descriptive statistics such as skewness and kurtosis. An explanation of this deviation is the imposition of daily price fluctuation limits for the stocks traded at ASE. These limits were stricter during the period 1995-2004.

### 3 Methodology and Results

It is well known that when a random variable  $X$  follows the normal distribution, the great mass of observations lies within plus-minus three standard deviations  $\sigma$  around the mean  $m$ . In other words,

$$\Pr(m - 3\sigma < X < m + 3\sigma) \approx 99,73\% \quad (1)$$

In that sense, returns that lie out of that range can be considered rare events or “Black Swans”. To identify black swans we first follow the standard approach (Estrada, 2009) and initially assume normality of the distribution of daily returns. According to equation (1) only 0,27% of daily returns are out of the range of plus/minus three standard deviations and should thus be extraordinary rare (Black Swans).

Table 2 presents the descriptive statistics of our data that lie outside the range of equation (1), that is, out of the interval defined by three standard deviations around the mean. The lower bound (LB) of the interval is -5,73% whereas the upper bound (UB) is 5,83%. Therefore, under the assumption of normality, given that our dataset consists of 7.692 observations in total, it is expected that 21 daily returns should fall outside this interval. However, we identify 66 daily returns below the lower bound and 61 daily returns above the upper bound. In total we observe 127 extreme returns outside the range. These returns

are obviously rare but nonetheless exceed six times the predictions of normality assumption, that only 21 returns should exceed the given bounds. We also note that the minority of extreme returns occur in the second decade (1995-2004) where the ratio of observed to expected negative extreme returns is 4,2 and the respective ratio for positive extreme returns is 4,4.

Table 2: Descriptive statistics of data falling within plus/minus 3 standard deviations

		1985-2015	1985-1994	1995-2004	2005-2015
<b>Whole Sample</b>	<b>Mean Return</b>	0,054%	0,14%	0,06%	-0,03%
	<b>S.D</b>	0,0192	0,0198	0,0167	0,0209
<b>Left Tail</b>	<b>Mean – 3*S.D (Lower bound –LB)</b>	-5,73%	-5,80%	-4,96%	-6,29%
	<b>Expected extreme returns (below LB)</b>	10,3	3,3	3,4	3,7
	<b>Observed extreme returns (below LB)</b>	66	24	14	28
	<b>Ratio Observed / Expected</b>	6,4	7,2	4,2	7,6
<b>Right Tail</b>	<b>Mean + 3*STD (Upper bound –UB)</b>	5,83%	6,09%	5,09%	6,23%
	<b>Expected extreme returns (below UB)</b>	10,3	3,3	3,4	3,7
	<b>Observed extreme returns (above UB)</b>	61	23	15	23
	<b>Ratio Observed / Expected</b>	5,9	6,9	4,4	6,3

Table 3 presents the imposition of daily price fluctuation limits for the securities traded at ASE, since 1996. A limit of 8% was initially imposed in 1996 (plus/minus 8% daily fluctuation limit). There was an escalated increase of this limit from 2000 to 2008, when we have the implementation of a daily fluctuation limit of 30%, which is still valid today. It is worthy of mentioning that there was an imposition of the daily limit of 6% just for the trading day of 12<sup>th</sup> of September 2001, the first trading day after the terrorist attack of 11<sup>th</sup> of September 2001 in New York. September 11<sup>th</sup> 2001 was a Black Swan event with a tremendous effect in the global economy.

The implementation of limits had obviously an impact on the magnitude of Black Swans in our sample. As Table 3 displays, during 1995 -2004, the decade with the lowest daily

fluctuation limits, we observed the lowest ratio observed/expected extreme returns in comparison with the other two sub-samples (1985-1994, 2005-2015). According to 2001 and 2005 ASE Regulations, securities had scalable maximum daily price fluctuation limits. The first price fluctuation limits were 12% (2001) and 10% (2005) respectively, on the starting price. If there were buy orders at the upper limit or sell order at the lower limit that had remained unexecuted at the best bid or offer prices for fifteen minutes, the daily fluctuation limits were extended to 18% (2001) and 20% (2005) respectively. However, the limit of 30% implemented in 2008 is well above the maximum return of 27,42% and had thus, no effect on the occurrence of Black Swans after 2008.

Table 3: Limits of daily prices fluctuation

Date of implementation	First Limit	Limit
3.5.1996	-	8%
1.8.2000	-	12%
1.6.2001	12%	18%
2.1.2005	10%	20%
4.8.2008	-	30% <sup>3</sup>

Table 4 presents some descriptive statistics of the ten best and ten worst daily returns. We calculated the average return of the ten best returns, which is 13,59% with a standard deviation of 4,8% and the average of the ten worst returns, which is -11,79%, with a standard deviation 1,6%. The 10th best return during 1985-2015 was 10,02% on the 13th of March 1990, and the 10th worst return was -9,24% on the 28th of January 2015.

Table 4: Statistics of ten Best (B10) and ten worst Returns (W10)

Period	Mean Return B10	Mean Return W10	MIN B10	MIN W10	STD B10	STD W10
1985-2015	13,59%	-11,79%	10,02%	-5,84%	4,8%	1,6%

In Tables 5 and 6 we closely inspect the 10 best and 10 worst returns of our dataset. For each return we describe the events that caused the extraordinary reaction of the ASE. One can observe that these reactions were caused by specific event. We divided these 20 extreme returns into four categories, according to the characteristic of each event: (a) black swans generated by domestic political events, (b) black swans generated by international

<sup>3</sup> According to 2008 Regulation securities traded in the "Big Capitalization" segment had Maximum daily price fluctuation limits of 30%. Securities traded in the "Middle & Small Capitalization" segment had scalable price fluctuation limits, with first limit +/-10% and after 15 minutes the limit was extended to +/-20%. A price fluctuation limit of +/-30% for all the securities traded in the "Main Market" was implemented with the Regulation of 2011.

political events, (c) black swans generated by domestic financial and economic events and (d) black swans generated by international financial and economic events.

Regarding the 10 ten best returns, which are presented in Table 4, we show that 4 of them were generated by domestic political events (they are described at the following Table in purple), 4 of them by domestic financial events (they are described at the following Table in green color), one by an international financial event (in red color) and one by an international political event (in brown color).

Table 5: Best 10 returns

<b>Date</b>	<b>Return</b>	<b>Description</b>	<b>Type</b>
11-12-1987	27,42%	Two days earlier, finance minister Panagiotis Roumeliotis announced measures supporting the Greek stock market.	domestic financial events
9-4-1990	14,74%	Greek political party “Nea Dimokratia” forms one-party governance after consecutive unsuccessful elections.	domestic political events
29-8-2011	14,37%	The presidents of EUROBANK and ALPHABANK announced an agreement for merge of the two financial institutions.	domestic financial events
3-12-1990	13,57%	The UN Security Council approves “Operation Desert Storm” against Iraq	international political event
28-9-1987	11,60%	Adoption of a stabilization program for the Greek Economy – reduction of discount rates	domestic financial events
9-12-1987	11,58%	The Minister of Finance, Panagiotis Roumeliotis announced measures in favor of the Greek stock market.	domestic financial events
3-2-2015	11,27%	The Greek authorities statements regarding the Greek government’s renouncement from its requisition for the Greek Public Debt haircut, raised expectations that a compromise between the Greek government and troika (IMF, ECB & EE) is very close.	domestic political events
2-11-1987	11,22%	The Greek Stock Market recovered from trading days during which ATHEX registered a large fall, following the N.Y.S.E. collapse on the 19th of October. The recovery was backed by the rise of European and American market indices.	international financial event
14-6-2012	10,12%	It was the penultimate trading day in ASE before national elections on the 17th of June. The building of a stable government was taken for granted.	domestic political events
13-3-1990	10,02%	The announcement of the national elections, which was published the previous day (12.3.90), signaled the end of a political instability period and the completion of the national unity Governance incumbency	domestic political events

Regarding the 10 ten worst returns, which are presented in Table 6 we find that 4 of them were generated by domestic political events, 3 of them by domestic financial - economic events and 3 by international financial events. We also ascertained that all of these events had the attributes of a black swan event, which means, they were rare, they had extreme

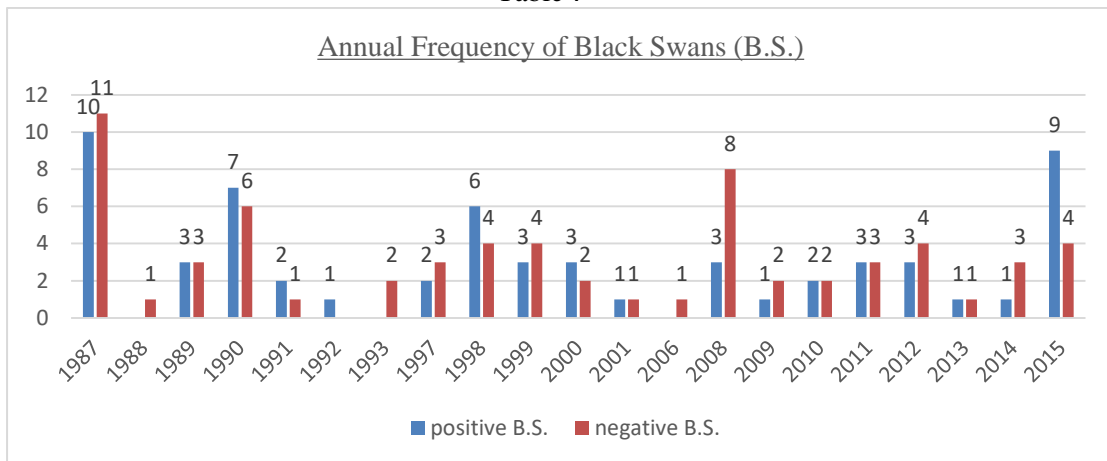
impact to the Greek stock market and a post hoc explanation for their occurrence had been presented.

Table 6: Worst 10 returns

Date	Return	Description	Type
03-08-15	-16.23%	Reopening of Athens Stock Exchange, 32 days after the imposition of capital controls at the Greek financial sector.	domestic financial events
07-12-87	-15.03%	At 26 <sup>th</sup> of November 1987 the Greek Government announces the imposition of an urgent fee on corporate profit and the reassignment of Greek Finance minister Costas Simitis. The Greek Stock Exchange reacts severely, the worst day being the 7 <sup>th</sup> of December.	domestic financial events
09-12-14	-12.78%	Prime-minister Antonis Samaras announces premature elections	domestic political events
26-10-87	-12.64%	Reopening of Greek stock exchange market, 5 days after the "Black Monday" caused by the NY Stock Exchange collapse	international financial event
26-11-87	-11.99%	Announcement of the imposition of an extra fee on corporate earnings	domestic financial events
24.08.15	-10,54%	On August 20th, Prime-minister Alexis Tsipras announced premature elections. The announcement caused a considerable slippage in ASE. At 24 of August was the worst day for General Index.	domestic political events
16.10.89	-10.05%	On Friday 13th of October 1989 Dow Jones Index slipped by 6.91%, causing a turmoil to the global markets. It was another "Black Friday" for the stock markets. ASE on Monday 16th followed and experienced a dramatic fall of 10.05%.	international financial event
4.11.87	-9.73%	A big strike of Greek banks employees was in progress from the previous day, troubling the financial sector and various Greek companies. At the same day, there was an announcement regarding an unexpected fall of GDP for the 2nd quarter of 1987 and a deterioration of Current Account deficit for the same quarter.	domestic political events
24.10.08	-9.71%	The previous day, stock markets had experienced a severe fall on the fear of a global recession. Dow Jones Index was plunged by 3.4%, while NIKKEI Index was tumbled by 9.6%.	international financial event
28.1.2015	-9.24%	The composition of the new Greek Government as well as ministers' public statements regarding "freezing" the privatization program, the banking sector and the HFSF (Hellenic Financial Stability Fund) caused a sell-off in the ASE, especially for the stocks of the banking sector. The prime minister's statement regarding the nationalization of systemic Greek bank institutes, drove the banking sector's index in ASE to a new historic low.	domestic political events

Table 7 presents the annual occurrence of Black Swans in our dataset. As mentioned above, ASE during the whole sample period experienced 127 outliers. The year with the greatest number of extreme returns is 1987, when we observed 21 outliers. On the contrary we have 10 years in between this 30 years period where we don't have the appearance of any outliers.

Table 7



The following three figures illustrate the extreme returns that occurred in each of the three decades of our sample period (1985-1994, 1995-2004, 2005-2015). It is obvious that during 1987 ASE experienced a great amount of extreme returns, particularly during the last quarter, possibly due to the N.Y.S.E crash on the 19<sup>th</sup> of October. We also notice the appearance of a significant number of extreme returns during the years 1989 – 1990, a total number of 19 outliers, due to the domestic political turmoil at this period of time.

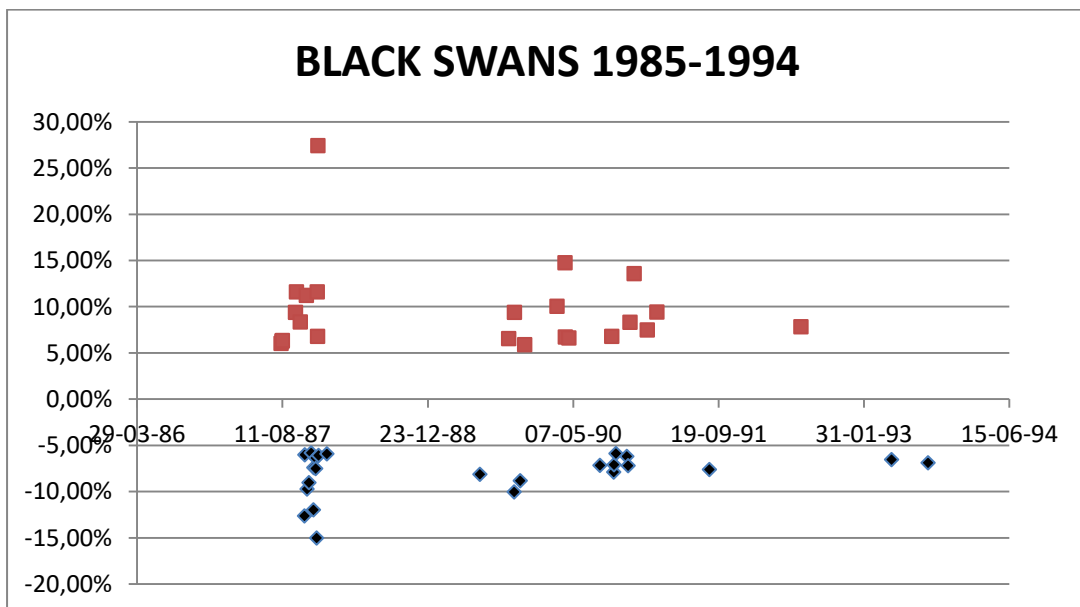


Figure 1



Between 1995 and 2004 ASE experienced 29 outliers, representing the 22,8% of the total number of extreme returns of the whole sample period. As we can see from 1996 to 2000 we don't have any extreme return over 8%. As we have already presented, this is due to ASE Regulations provisions regarding daily price fluctuation limits. From 1996 to 2000 ASE applied daily price fluctuation limits of 8% and in 2000 price fluctuation limits were adjusted to 12%. Price fluctuation limit is defined as the price range within which the prices of the securities are permitted to fluctuate during the course of a trading session of the market. The price fluctuation limits of the securities is expressed as percentage of deviation from the starting price.

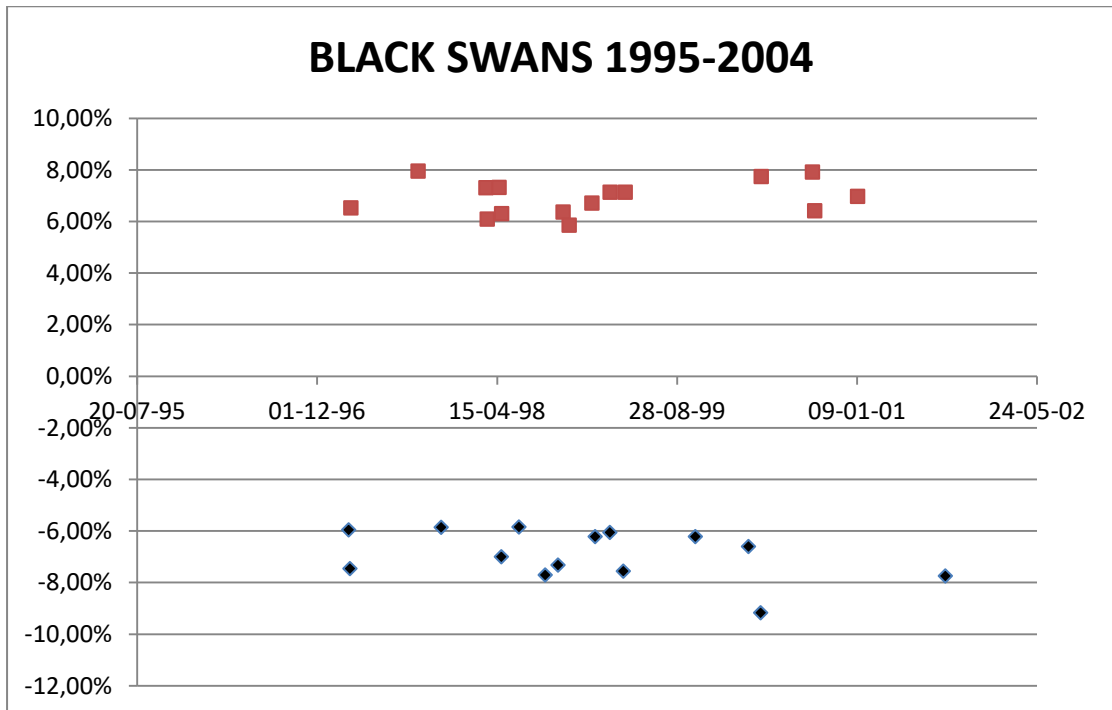


Figure 2

Finally, during 2005 -2015 ASE experienced a great number of extreme daily returns, 51 in total. In 2008, the year of the global financial crisis, ASE experienced 10 extreme returns and during 2015, the Greek stock market experienced 13 outliers in total, due to the domestic political and financial instability and of course the imposition of capital controls.

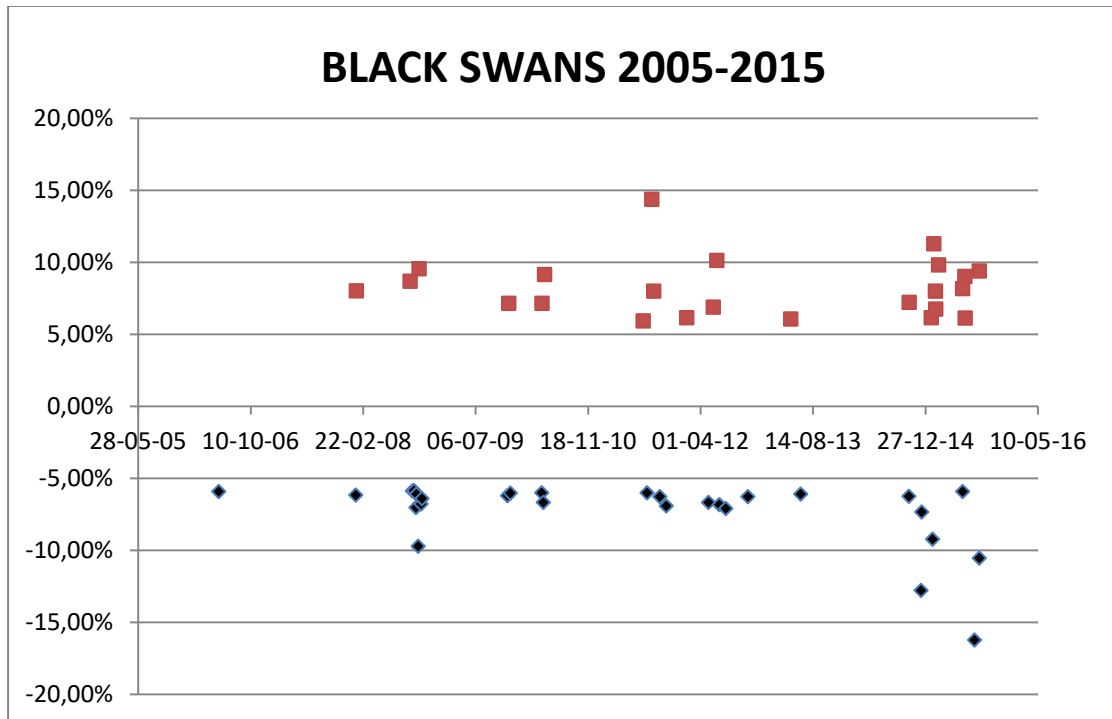


Figure 3

#### 4 Effect of Black Swans on return

Finally we demonstrate the impact of the 10 and 5 best (worst) returns on long term investors' return. Although extreme outliers represent only 1.67% of our sample, their impact on investors' return is rather extreme and should not be neglected. To demonstrate their effect, we follow Estrada (2009) and estimate their impact by calculating an investor's annual compound return assuming that he invested €100 at the beginning of our sample period and held it invested till the end of it. Table 7 presents our calculations on five cases: actual annual compound return, annual compound return without the five best and ten best returns of our sample, annual compound return without the five worst and ten worst returns of our sample. We demonstrate the respective calculations for the whole sample but also for the three decades 1985-1994, 1995-2004 and 2005-2015. All estimates account for capital gains but not for dividends.

Table 8: Compound returns

Period	Actual	Without 10 Best	Without 10 worst	Without 5 Best	Without 5 worst
1985-2015	9,22%	4,85%	13,74%	6,60%	11,85%
1985-1994	35,73%	20,42%	51,04%	26,22%	44,62%
1995-2004	12,33%	4,68%	21,18%	8,25%	17,06%
2005-2015	-12,86%	-20,52%	-4,54%	-16,93%	-7,58%

Table 8 reveals that these outliers had a really extreme impact on investor's return. Note that, although our sample is consisted of 7.692 days, where the best 10 returns represent only 0,13% of our sample, the impact of these 10 daily returns on investors' portfolio performance is rather extreme. An investment at the beginning of 1985 delivered a compound return of 9,22% at the end of 2015. Excluding the best 10 days reduces the compound return by 48% to 4,85%. Similarly, avoiding the worst 10 days increases the compound return by 49% to 13,74%. After excluding the best 5 returns, which account only for the 0,065% of our sample, the compound return is reduced by 28,5% to 6,60%. Similarly avoiding the worst 5 days increases the compound return by 28,5% to 11,85%. In that line, the extreme impact of outliers is evident also in the three sub-samples of Table 8, in which excluding either ten or five extreme returns alters the compound return considerably.

## 5 Conclusions

In this paper we used a large dataset of daily returns of the Athens Stock Exchange to examine the Black Swan phenomenon, that is, rare, extraordinary returns having retrospective predictability. Contrary to the predictions of normal distribution, we found that Black Swans are far more often in ASE than assumed. We identified 127 possible Black Swans in total, which is a significant departure from normal distribution and we studied further the top and lowest ten. It was found that indeed the best ten and worst ten returns of our dataset have all the features of a Black Swan and can thus be identified as such. We also presented that the imposition of daily fluctuation limits effected the frequency and the magnitude of extreme daily returns. Finally, we pointed out that these daily extreme returns have a significant importance on the long term performance of ASE and correspondingly on investors' returns.

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