International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

https://gssrr.org/index.php/JournalOfBasicAndApplied/index

Examining Risk in the Russian Economy through an Extreme Value Analysis of the Moscow Exchange (MOEX)

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Abstract

The Russian Federation has long had a reputation for being a volatile country due to its geopolitical actions. Many investors are hesitant to invest in Russia as they question the practicality of it. This research seeks to answer their concerns using the statistical concept of extreme value theory (EVT), which existing literature has failed to apply to Russia in recent years. EVT is a branch of statistics that models values away from the center of the distribution, known as "extreme values." In the context of this paper, this is an instances of heavy intraday stock loss. Essentially, EVT models can help answer the likelihood of losses and how much loss can happen. This research seeks to answer these concerns with an ex-post facto design in which data from Russia's main stock index, the Moscow Exchange, is downloaded and analyzed using the Massachusetts Institute of Technology licensed Python package Pyextremes. After comparison to the main stock indices of India, France, and the USA, it was revealed that there is a likely greater risk associated with Russia in comparison to the other countries. Recommendations are made for those associated with Russia and its stock markets to manage investments, diversify portfolios, and seek resistance to mitigate the potential risks more carefully. Future research is suggested to use EVT in a more long-term analysis and to address the limitations of this study.

Keywords: Block Maxima; Extreme Value Theory; Moscow Exchange.

Received: 8/10/2024
Accepted: 10/20/2024
Published: 10/30/2024

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1. Introduction

On February 24, 2022, Russia Invaded Ukraine in an act many around the world “immediately condemned,” noting it as an act of pure treachery [1:1]. Actions like these have established the Russian Federation, in recent decades, as one of the most volatile and unpredictable regions of the world. Whether it be the Annexation of Crimea in 2014 or the aforementioned Ukraine invasion in 2022, Russia is unquestionably an entity that has made questionable decisions in the past.

As Reuters (2023) [2] explains, because of these actions, the Russian economy has become volatile making the future of said economy difficult to predict. Additionally, a study conducted by the Guanghua School of Management in China furthered that Russia’s actions in Ukraine have shown a direct correlation with the volatility and risk of the Russian market [3].

Therefore, the millions living in and looking to invest in Russia and its stock market often face the following 2 predicaments: how risky is it for them to invest their money in Russia, and more specifically its stock market, and what conclusions can be made about the overall health of the Russian economy through these results. These are all important questions to be asked especially when “GPR [or geopolitical risk] can positively affect stock market volatility” otherwise saying that a country's actions on a geopolitical stage can directly increase their volatility or variability in stock returns [4:5]. The direct impact of a nation's political decisions on its stock market performance is well-documented, and given Russia's history of impulsive geopolitical actions, it proves the importance of conducting a thorough risk analysis of its stock market and economy to understand how at-risk the markets are to ensure informed investment decisions and mitigation of potential financial risks for millions.

This paper seeks to answer the previous concerns using the statistical risk prediction model known as extreme value theory (EVT). Ferreira and Haan [5], Dutch statisticians specializing in extreme value theory, describe EVT as a branch of statistics focusing on the "extreme" values within a dataset. These are values that deviate significantly from the dataset's center, capturing rare and unusual occurrences. In other words, the extreme values of a dataset are the outliers and extreme value theory is the study of said outliers. Examples of extremes in a dataset include the maximum amount of rainfall occurring in a single day, maximum earthquake magnitudes over multiple centuries of data, or even airplane crashes, among other examples.

EVT usually has two applications. First, researchers can use it to understand the probability of extreme events, which, often used interchangeably with extreme values, are the events that lead to the extreme values in a dataset occurring [6] . Moreover, through the second application, extreme value theory can be used as an analysis of how extreme a value can become. In simple terms, EVT helps researchers understand the likelihood of an outlier occurring and how much of an outlier it can become. Referring back to the previously described examples, through the first application of EVT, researchers can understand the probabilities of the different amounts of huge rainfall events or the number of plane crashes in a single year. With the second application, EVT can be used to understand how catastrophic future earthquakes can become and how “extreme” future rainfall can become.

Using the described applications of extreme value theory, this paper seeks to understand how at-risk the Russian economy and stock market are in comparison to other countries which are typically seen as less geopolitically risky.

1.1. Literature Review

The concept of EVT was first born in the 1920's by Leonard Tippett who studied the distribution of the largest values of samples coming from a normal distribution for different sample sizes [7]. Throughout the 1920s and 1930s, research by Sir Ronald Aylmer Fisher and Tippett found similar families of distributions for large values and realized that extreme values from different distributions can follow the same asymptotic distribution [7].

What this means is that the distributions of extreme values often follow similar distributions regardless of the specific numerical data associated with them. This is the fundamental idea of EVT. Explained by Fisher and Tippet alongside Soviet mathematician Boris Vladimirovich Gnedenko, this concept is referred to as the Fisher-Tippett-Gnedenko theorem. The theorem is homologous to the central limit theorem [8]. Where the central limit theorem is the idea that the means of many sample distributions will converge to a normal distribution regardless of the parent distribution, the Fisher-Tippett-Gnedenko theorem as explained by [7:2] states that the asymptotic distributions of the maximum, if non-degenerate, is restricted "to only three different families." Essentially, the distributions of the asymptotes, or the extreme values, in a dataset can always be described as one of three distributions, assuming that all of the probabilities are not at one point or degenerate. These families, known as the Gumbel, Weibull, and Frechet distributions, are all named after three of the largest contributors to the early beginnings of EVT. A standardized form of these distributions is known as the generalized extreme value (GEV) distribution, and since then, books such as Gumbel's [9] monumental 1958 book *Statistics of Extremes* have helped confluence the theoretical ideals of EVT into truly applicable standards used by many.

Now, from first impression, EVT may come off as a niche topic to those unfamiliar with the topic. However, it can be very practical and useful in many settings. A fascinating past application of EVT is finding the maximum estimated age that humans can live as EVT is the study of extremes and maximum ages are extremes [10]. EVT "has been traditionally used to quantify rare events like century floods, avalanches, market crashes, or more recently terrorism attacks" [11:2]. EVT is a procedure with an abundance of professional usage. Furthermore, one notably famous application of EVT was examining dikes in the Netherlands [12]. More specifically, this application determines how high the Netherlands' dikes should be built when knowing that the country often suffers from floods. The paper uses EVT and historical data on extreme floods in the Netherlands to predict the probability of the next extreme flood as well as the expected period in which it may occur. Using these results, they look to provide suggestions that maximize cost and safety. Next, specifically in finance and economic analysis, [13:61] was among the first to use EVT in this context finding that extreme value methods are up to "5 times better" than traditional risk analysis methods in stock market estimation. Additionally, as a cornerstone in financial analysis, [14] bridges the gap between theory and practical applications through its study of extremal events such as large insurance claims, stock market shocks, large financial fluctuations, and more. In a similar regard, [15] explores parametric modeling, and statistical interference for extreme values in its analyses of finance and insurance applications, like [14], but also other uses in other disciplines such as hydrology and environmental sciences. This previous literature helps establish the EVT as a practice also commonly used by financial professionals and quantitative analysts.

Although originally belonging to the branch of statistics, its applications go far beyond because EVT can be applied to nearly every single field imaginable. Thus, EVT is an incredibly versatile tool used in a huge variety of fields.

1.2. Extreme Value Theory in Comparison to Other Risk Prediction Methods

It should be noted that there are other methods to predict risk in financial markets. These can include value at risk (VaR), conditional value at risk (CVaR), and others [16]. Like EVT, they can all be used to measure the risk associated with investment portfolios or stocks and the initial inquiry of this paper consisted heavily of the understanding of those risk prediction techniques. But, in many aspects, EVT is much more accurate than the other methods. One reason is that it is significantly more established being around since the 1920s versus 1988 for VaR or 2000 for CVaR. Furthermore, EVT is first and foremost a statistical procedure that can be used in multiple industries while the other methods described were created for and used almost exclusively in financials Reference [17].In addition, as explained by the Bank of Canada [18], the difference between EVT and VaR is that VaR focuses on the central observations of the data to predict risk which often underestimates the number of extreme values in a dataset. Because EVT in a financial setting discusses massive intraday loss or crashes, an underestimation of extremes can be very dangerous when the market crashes, as it may lead to inadequate risk mitigation strategies and financial losses for investors and market participants [18]. Therefore, in the specific context of predicting extreme loss, EVT is not only more applicable but also more accurate. Lastly, the bank furthers that measurements such as VaR which are statistics themselves can be used to supplement EVT as EVT can be applied to the distributions of VaR and CVaR [18]. Due to these reasons, EVT is used for risk prediction in this study rather than a different measure such as VaR or CVaR.

1.3. Situating the Research Gap and Hypothesis

Now that the idea of extreme value theory has been established, it needs to be further understood why Russia has been chosen as the country in which analysis will occur. Beyond being an inherently geopolitically risky country, Russia has also surprisingly not been analyzed through EVT in recent years.

In the study titled *A Conceptual Model of Investment-Risk Prediction in the Stock Market Using Extreme Value Theory with Machine Learning* [19], a semi-systematic literature review was conducted on all the different countries and their respective stock markets to have had studies conducting EVT on these markets conducted in recent years.

Figure 1 below shows the countries and stock markets that have had EVT analysis conducted on them in recent years. As shown from the chart, Russia is notably absent from the list. Given its status as one of the most geopolitically volatile countries globally, as previously demonstrated, along with its recognition by the CIA [20] in 2023 as the 9th most populous nation and by the World Bank [21] in 2022 as the 8th largest economy in the world, conducting EVT analysis on Russia is imperative. Surprisingly, research has not been conducted yet which is why it is so incredibly paramount that it must happen soon; this research seeks to do just that. For investors and those in Russia wanting to know how risky their markets truly are, extreme value theory must be finally used upon Russia to truly understand and answer those concerns.

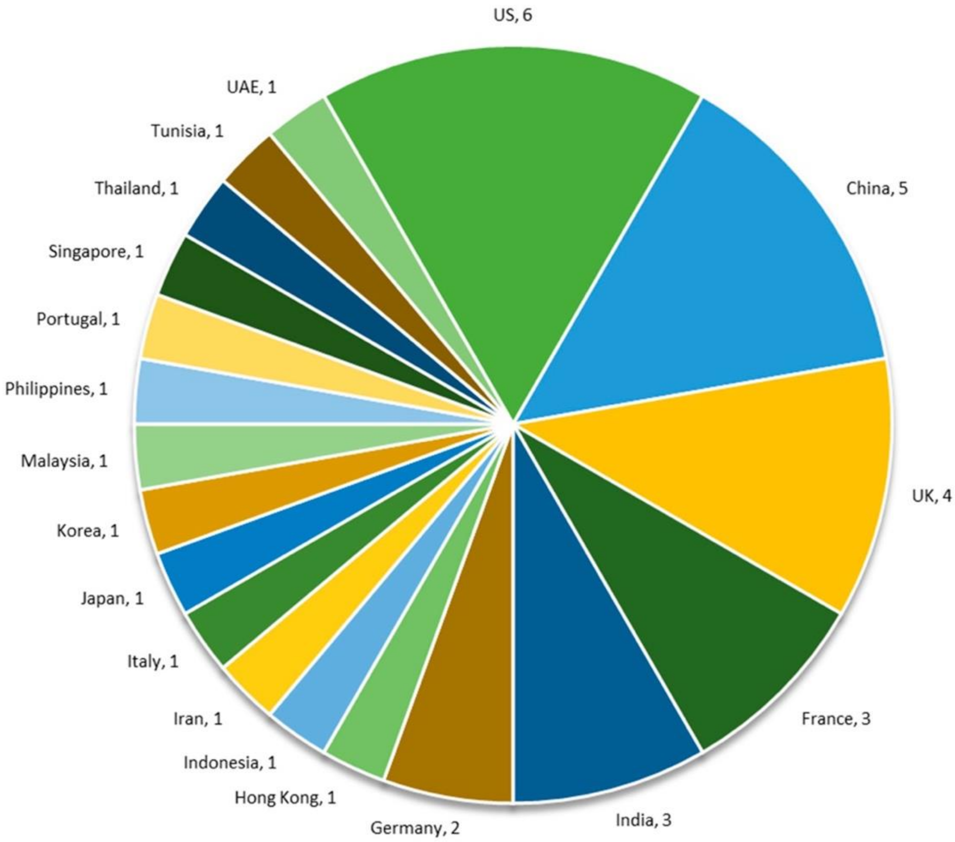

Figure 1: Countries Analyzed in Existing EVT Market Studies by Amount of Existing Literature [19]

Lastly, it should be noted that there have been evaluations of the Russian economy through the previously described risk prediction methods. Studies such as [22] and [23] have analyzed the Russian economy through VaR and CVaR. In fact [22] uses VaR and CVaR in an analysis of how the Russia Ukraine conflict influences the risk dynamics of energy futures contracts and concluded that the conflict does in fact lead to risk exposure supply crisis' and price escalation. There isn't a shortage of studies analyzing the risk of the Russian economy but rather a shortage of studies that analyze risk through EVT in recent years. One of the few examples of such is [24] which used EVT in Russia. However, because it was conducted roughly 15 years ago, its results potentially are outdated as Russia has gone through a plethora of noteworthy geopolitical and economic changes since Prime Minister Vladimir Putin's second term in 2012 [25].

From the previous studies described, one main theme arises. That is, previous studies have in fact identified Russia as a country of risk. For example, [23:16] wrote that through a CVaR analysis, Russia "was ranked [with the] highest risk" among China, South Africa, South America, Australia, Canada, and the United States. Therefore, it can be hypothesized that through an EVT analysis conducted using data from recent years, Russia will once again show the most economic risk in comparison to other countries.

2. Methods

This research will be conducted using an ex-post facto model. As Joy Rahman [26:29] from the University of Texas San Antonio explains, ex post facto means after-the-fact research, in which an already existing independent variable is used to "investigate a possible relationship between" the variables. An ex-post facto model is sufficient for this paper because an already existing independent variable, being the chosen countries of analysis and stock prices of its main index, are analyzed, through EVT, to show the risks associated with that market. It cannot be manipulated because there is no physical way a researcher can manipulate stock data that has already occurred. Unlike an experiment in which manipulation occurs and random assignment occurs, an ex-post facto design does not do either because conducting EVT on the data is simply an extension of conducting a study in which simple statistics of different variables such as the mean, median, and mode are compared amongst one another, albeit more complex. Also, unlike a meta-analysis, in which understanding from previous studies is synthesized and reshown, an ex post facto model in the case of this paper is the contextualization of different datasets, not studies. Thus, an ex-post facto model will be the most beneficial for the purposes of this study.

2.1. Data

Daily stock data from the main stock indices of Russia, the USA, France, and India were downloaded from Yahoo Finance into Microsoft Excel. These countries were selected as comparison points to Russia seeing as they have previously had extreme value theory conducted upon them as shown in Figure 1 and are often touted as less geopolitically active and risky than Russia [27].

Stock indices were selected as they encompass the top stocks in the country as well as reflect the overall economic health of the country [28]. Therefore, to have the most comprehensive measurement for both stocks as well as the economy, indices were downloaded into Microsoft Excel. For each of the listed countries, one of its main indices was downloaded. For Russia, its main index, the Moscow Exchange (MOEX) was downloaded. Likewise, for the USA, France, and India, their main indices, the Nasdaq, CAC 40, and NIFTY 50 respectively, were all downloaded [29]. Each index was downloaded from March 5th, 2013 until March 21st, 2024. This is because Russia's Moscow Exchange only has data available on those above dates. Hence, in order to have streamlined data, each index was downloaded from those dates as well.

Following this, the data had to be cleaned. Through Yahoo Finance, the date, opening price, closing price, high price, and low price, were all extracted into Excel. For this study, in which maximum intraday loss is measured through EVT, high prices and low prices are insignificant as they do not capture the intraday loss. For a day trader who tracks the stock prices in high-frequency periods, high and low prices may be useful, however, for the average investor, opening and closing prices are much more standardized and applicable. Next, all non-existent and error values were removed from the dataset so that errors would later be avoided in the analysis.

The final step before the data is fully ready to be used is that through Microsoft Excel, using the formula ((opening price - closing price)/closing price * 100), the daily percent change in the value of the index was calculated for there to be a statistic that can be used as a general comparison between the indices.

2.1. Conducting the Extreme Value Theory

After everything previously described has occurred, there is one final thing left before EVT can be conducted. That is, determining the type of EVT that must be conducted and is most effective for this study. Now, "in extreme value theory, there are two fundamental approaches: the block maxima (BM) method and the peaks-over-threshold (POT) method" [6:1]. Both methods have their uses and pros and cons. As shown in Figure 2, block maxima consists of dividing the observation period into non-overlapping periods of equal size and restricts attention to the maximum observation in each period. In contrast, POT extracts all data above a chosen threshold.

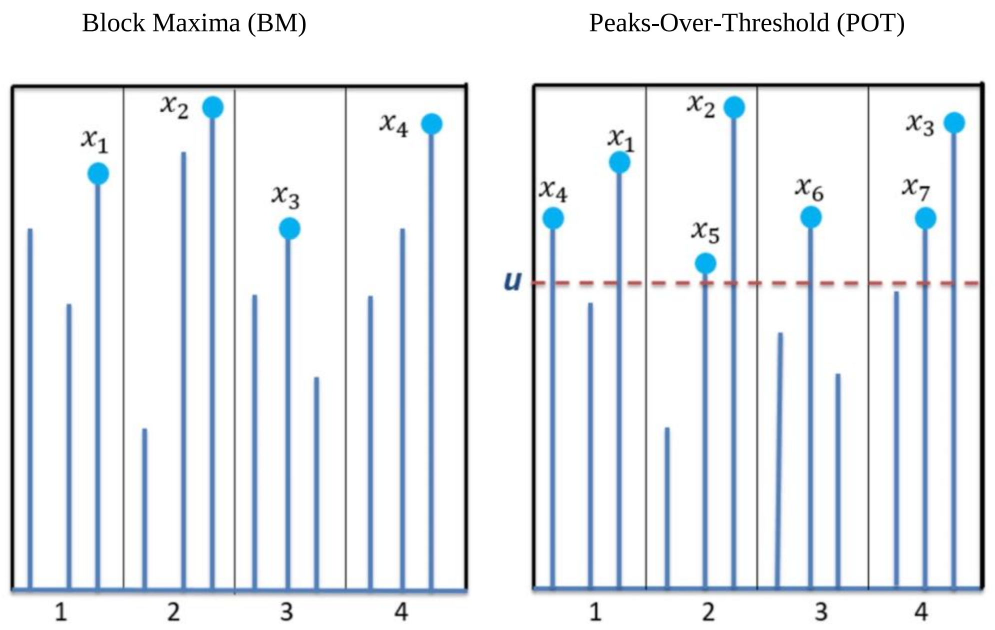

Figure 2: Block Maxima Evaluation vs Peaks-Over-Threshold Evaluation [31]

Additionally, although POT is preferred for quantile estimation, BM is preferred in instances where return level estimation is needed [30]. Block maxima will be the chosen type of EVT because peaks-over-threshold introduces bias as the researcher has to be the one to select the threshold, and an incorrect threshold can introduce instances with too many or too few extreme values. Also, for this study, return level estimation is needed. While this principle remains true for block maxima as well, it is significantly more impactful with peaks-over-threshold because the researcher directly defines what an extreme value is versus in what time sections the extreme value will be extracted.

Now, the extreme value theory can finally be conducted. It must first be established that EVT is traditionally conducted by hand because it has been around for so long that it had to have been developed without the aid of technology. Therefore, it must be understood why for the effectiveness of this study, EVT will not be conducted by hand. In contrast, the Massachusetts Institute of Technology licensed Python package Pyextremes will do the calculations of EVT. This is due to a combination of saving time as well as minimizing the risk of human miscalculations because of EVT's complexity. Using Pyextremes and the code in Figure 3 below, the extreme value theory was conducted upon each index selected above to extract the return values plot and exceedance probabilities.

Regarding specifications in the code, one of the only things to take note of is the block size being 30 days. Because the block maxima method was chosen instead of peaks-over-threshold, 30 days was a reasonable number of days that captured the extreme value in roughly one month as a comprehensible block size and fits within the 60-1000 point range of extracted extreme points explained in Fisher and Tippet's [32] initial inquiry. Also, in the code shown in Figure 3 below, block minima is written and the values extracted are low. This is simply another way of expressing block maxima but rather than extracting the maximum, which is the highest intraday percent change, the lowest is extracted for risk to be measured rather than success.

```
import pandas as pd
import numpy as np
from pyextremes import EVA

series = pd.read_csv(
    "File Name",
    index_col=0,
    parse_dates=True,
).squeeze()

model = EVA(series.astype(np.float64))

model.get_extremes(method="BM", block_size="30D", extremes_type="low")
model.plot_extremes()

model.fit_model()
summary = model.get_summary(
    return_period=[1, 2, 5, 10, 25, 50, 100, 250, 500, 1000],
    alpha=0.95,
    n_samples=1000,
)
model.plot_diagnostic(alpha=0.95)

print(summary)
```

Figure 3: Code Used to Conduct Extreme Value Calculations on Pyextremes

2.2. Pre-Examination

After running the code and extracting the extreme values, 4 graphs will be presented as the results of the extreme value analysis. These graphs are the Q-Q plots, P-P plots, probability density functions, and return value plots.

Before examining results, each graph must be explained and the most important one for the inquiry must also be examined. The Q-Q and P-P plots are used to determine how well the probability density plot and return values plot represent the raw data. For this study, it is not relevant as this research is not seeking to understand how well of a fit an extreme value theory model will have but rather how risky the markets in Russia are.

The probability density plots examine the probability that a certain percent change will occur if a loss ensues. In contrast, the return value plots are used to understand how extreme a loss can be expected in a certain timeframe. Both have value however for this study, the return value plots will be analyzed. This is because what this study seeks to show is how risky it is to invest in Russia and how at-risk the Russian economy is rather than focusing solely on the likelihood of various percent changes in the event of a loss.

Lastly, the exceedance probabilities are calculated from Pyextremes using the code in Figure 4 below. Exceedance probabilities refer to the probability that a certain extreme value will be exceeded at least once a year. These are different from the probability values found in the probability distribution function. In context, the exceedance probability in this scenario is the probability that a certain percent loss will be exceeded at least once a year. Also, Pyextremes can extract the exact exceedance probabilities of the 5 most extreme data points extracted from the block maxima of each country. A least-squares regression line will be created using Microsoft Excel to represent the relationship between a certain amount of loss and the probability of that loss occurring for each country.

```
from pyextremes import get_return_periods

return_periods = get_return_periods(
    ts=series,
    extremes=series,
    extremes_method="BM",
    extremes_type="low",
    block_size="30D",
    return_period_size="30D",
    plotting_position="weibull",
)
return_periods.sort_values("return period", ascending=False).head()
```

Figure 4: Code Used to Calculate Exceedance Probabilities on Pyextremes

3. Results

In this section, the findings derived from the aforementioned extreme value calculations will be presented. More specifically, it will analyze the return values and exceedance probabilities of the Moscow Exchange (MOEX) in comparison to the Nify50, CAC 40, and Nasdaq. The return value plots will show the relationship between the return period and the corresponding predicted loss values. This helps allow for a better understanding of how often certain loss levels can be expected.

Furthermore, the analysis will look at the returned exceedance probabilities. These probabilities quantify the chance that intraday losses will exceed a specified threshold. By understanding both return value plots and exceedance probabilities, the analysis looks to finding a better understanding of the risks associated with extreme losses. As a result, these insights will hopefully empower stakeholders to make more informed decisions in their risk management so that they can be better prepared and informed in the event of an extreme loss.

3.1. Return Values Plot

Table 1: Percent Return Value of Evaluated Countries per Return Period

Return Period (Yr)	Russia	France	India	USA
1	-4.0879	-2.7069	-2.7567	-3.4019
2	-5.3346	-3.2881	-3.3207	-3.9698
5	-7.3419	-4.1633	-4.1446	-4.7078
10	-9.2007	-4.9225	-4.8384	-5.2617
25	-12.2242	-6.0786	-5.8639	-5.9916
50	-15.0367	-7.0866	-6.7322	-6.5429
100	-18.4019	-8.2268	-7.6896	-7.0939

For Russia and the MOEX, the USA and the Nasdaq, France and the CAC 40, and India and the NIFTY 50, the following return value plots are observed in Figure 5 and Table 1. There are a few things to note. In order to read the graph, the X-axis represents the return period, and the Y-axis represents the percent loss. So, to be able to read the graph, it would be as follows: In a period of X years, there is expected to be at least one instance of a daily loss of at least Y percent.

Looking at the Table 1 above and Figure 5 below, it is likely that Russia is a riskier country than India, France, or the USA. This is because Russia shows higher percentages of loss compared to the other countries in every single evaluated return period. For example, in 10 years, there is expected to be at least one day with losses of 9.2007% or more for Russia, while only 4.9225%, 4.8384%, and 5.2617% losses for France, India, and the USA, respectively. In additional return periods, the projected maximum losses in that time frame, or the return values, are more than double that of the other countries. This proves that it is likely that there is more risk associated with the Russian stock market and economy as the return values are consistently evident of higher amounts of loss than that of France, India, and the USA.

Additionally, as seen by the blue shaded area in Figure 5, because the confidence interval of the MOEX is wider than the other evaluated countries it can be concluded that there is greater volatility and uncertainty in the Russian Market because a wider confidence interval for return values can suggest that there is greater uncertainty surrounding the expected returns. For example, when looking at the confidence intervals in Figure 5, at the 10-year return period, the potential for loss climbs nearly 6 percentage points from a projected 9% loss to a nearly 15% loss. In contrast to the other countries with considerably smaller intervals, the chance for additional risks at the higher end of the confidence intervals is much less existent because simply put, the intervals are much smaller. These conclusions are noteworthy for potential and current investors in the Russian market as through the return values, the country is likely much riskier than the others meaning they should be wary of massive extreme losses.

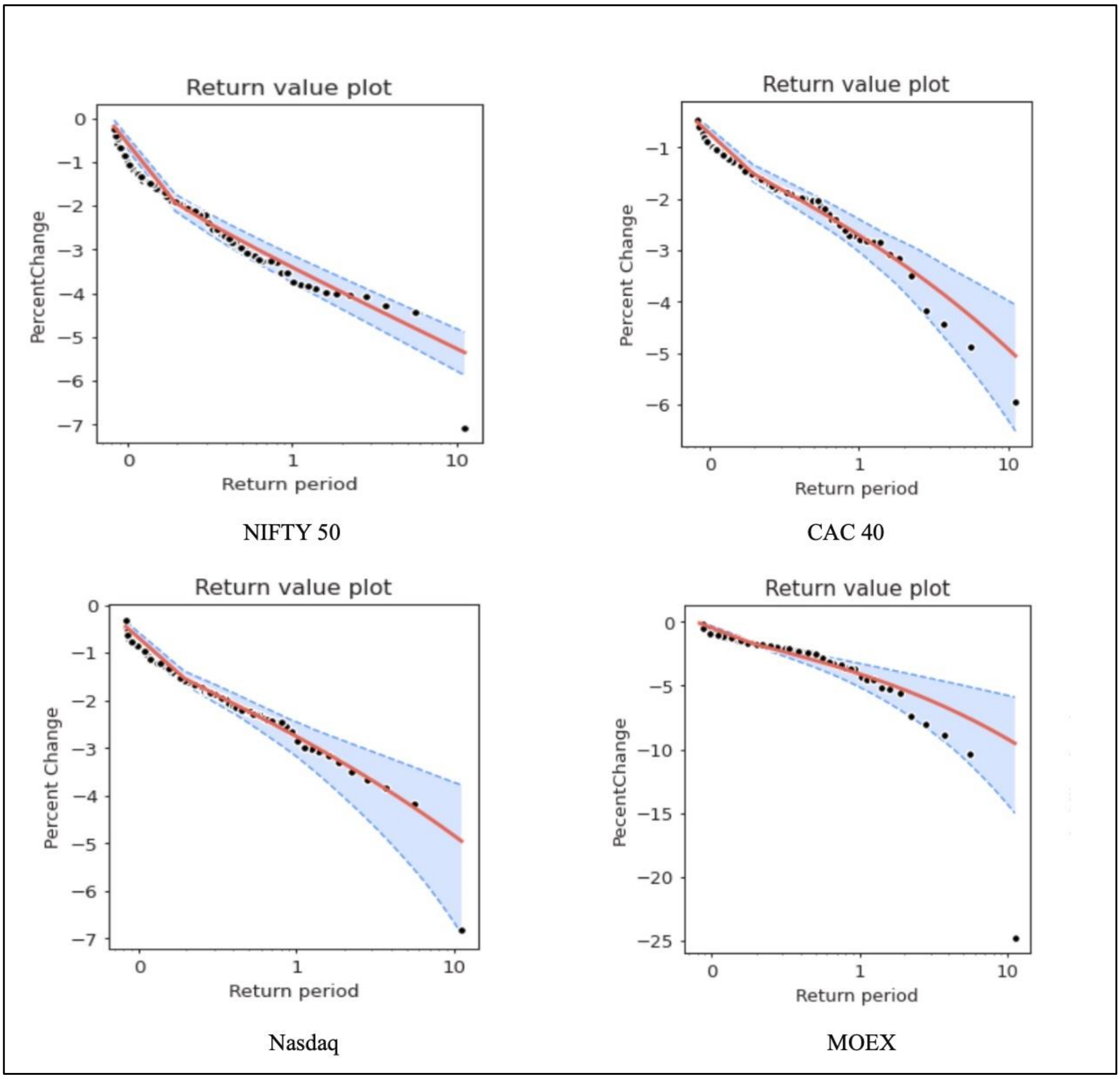

Figure 5: Return Value Plots of 4 Analyzed Countries

3.2. Exceedance Probabilities

Using Pyextremes, the exceedance probabilities for the five most extreme days of loss were extracted. Figure 6 displays these results along with a least-squares regression line, illustrating the relationship between exceedance probability and the expected percentage of intraday loss at each probability level. As previously explained, exceedance probability refers to the probability that a certain amount of loss will occur at least once a year. Accordingly, the graph below is read as follows: at a Y percent change in index price, there is an X percent chance that the aforementioned change will be exceeded in a year. Where the return value plot shows projected expected loss, exceedance probabilities show the probabilities of the associated loss. It should be noted that these are different than the probabilities from the probability density functions.

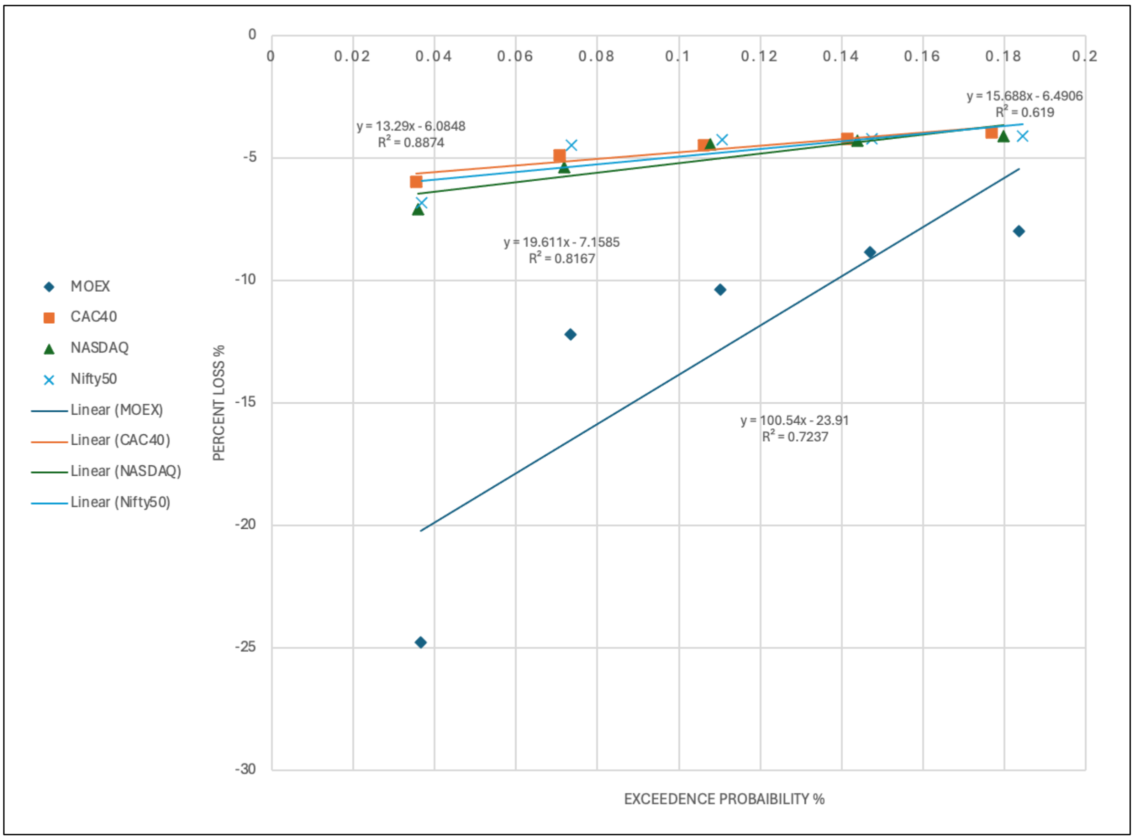

Figure 6: Exceedance Loss vs Percent Loss Graph for Analyzed Countries

Through these results as well, it is abundantly plausible that Russia is significantly riskier than the other countries examined in this study. Using the calculated linear regression equations from Figure 6, Y = 100.54(X) - 23.91 for Russia, Y = 19.611(X) - 7.1585 for the United States, Y = 13.29(X) - 6.08408 for France, and Y = 15.688(X) - 6.4906 for India, the corresponding percent loss is calculated at the 0.05% exceedance probability. For example, there is a 0.05% chance that there will be at least one day in a year with an 18.883% loss in Russia, 6.17795% for the US, 5.41958% for France, and 5.7062% for India. At the same probability of occurring, the expected loss is nearly triple that of the next closest country symbolizing the epitome of risk.

When examining the graph from Figure 6, the positioning of Russia's regression line below those of the other countries serves as a representation of the larger risks investors face in the Russian stock market. This is because, at similar probabilities of extreme events occurring, the potential losses in Russia are significantly more severe compared to other markets.

One may see the graph and think that Russia will be safer when the percent change is closer to zero, as, with a higher slope, the line should expect to cross the lines of the other countries. However, one must be careful not to extrapolate the results. The regression lines represent the relationship between exceedance probability and the corresponding percent loss on specifically extreme values and not the whole dataset. When one seeks to generalize the results to a larger range of values, results may be incorrect and invalid. Therefore, when analyzing the results of exceedance probability, one must only examine it at the given intervals.

4. Discussion

As the data reveals, because the return values of Russia have a much larger magnitude than that of the other countries included in this study, it can be concluded that when an extreme event occurs, the MOEX is at greater risk of greater loss. Take, for example, a 5-year return period, in that time frame there is expected be at least one instance of intraday loss of roughly 7.34% or more. In contrast, in this same time frame, this same projected loss for France, India, and the United States is only about 4.16%, 4.14%, 4.71%, respectively. To illustrate the importance of these losses, if the MOEX's all-time trading high of $4261.82 from 10/10/2021 is taken, at a 7.34% return value, prices can fall by more than $312 dollars. As this is the projected loss for only a 5-year return period, the impacts can get much worse as the return period increases. Moreover, because investors often have many thousands of dollars invested in the MOEX, the empirical loss simply gets larger and larger.

Additionally, there is likely more volatility due to wider confidence intervals in the MOEX return value plot. When looking at the confidence interval in Figure 6, represented by the blue area directly around the return value, it is visually clear that the margin of error is larger for the MOEX than in other countries. This suggests more variability in the true return value of the MOEX. And, while this may mean that the retune value of the MOEX is lower than projected, if the return value is higher than projected, the impacted may be disastrous as the projected return value of the MOEX is already significantly larger than the other countries. If this value is skewed towards the higher magnitude end of the confidence interval, than the projected loss will become more extreme and monumental.

Next, while examining the relationship between exceedance probabilities and percent loss, because the regression for the MOEX is significantly below the regressions for the Nifty50, CAC40, and NASDAQ, is highly indicative of possessing more risk in its extreme values. Taking the example of the corresponding percent loss at the 0.05% exceedance probability level, it is alarming that there is the same percent chance of an 18.883% loss in the MOEX, a 6.17795% for the Nasdaq, a 5.41958% for CAC40, and 5.7062% for the Nifty50. While a 0.05% chance of this occurring seems small, the fact that at that probability, the associated loss is roughly 3 times as severe means that the MOEX likely has significantly larger tail risk.

As previously explained, EVT has 2 applications: determining how extreme an extreme value can be and what the likelihood of extreme values occurring. The return value plot addresses how extreme a value or loss can become in a given period and the exceedance probabilities help explain the likelihood of loss that meets a certain threshold. Both the return values and exceedance probabilities point towards Russia attributes more risk.

Because of this, it is critical for investors to make informed decisions when considering investments in Russia and the potential for extreme losses should not be overlooked. Investors should conduct thorough risk assessments and consider diversification strategies to mitigate potential financial risks. It is also recommended that they more closely and regularly examine their portfolios and investments when Russian stock is included to have more awareness in the event of a loss. This can allow investors to be more prepared in the event of extreme loss. Lastly, diversification of investment is suggested because financial experts tend to suggest a diversified portfolios because they mediate risk without sacrificing a significant amount of future returns [33].

These recommendations can be generalized to those living in Russia as well. However for them, there are a few unique recommendations to consider. Because the indices can often represent both the economic health of the country along with that health of country's stocks comprised in that index, it is recommended that they should seek skill development in areas of the economy resistant to change to avoid suffering impacts to their employment and livelihood when extreme events occur [28]. Individuals should also receive advice from financial professionals before making large purchases and investments to understand the risks accompanying the economy.

Additionally, the implications of these findings highlight the importance of understanding volatility in financial markets and the economy. This is particularly true in regions with heightened political and economic uncertainty like Russia. Using extreme value theory, this research provides valuable insights for both institutional and individual investors by quantifying the risks associated with extreme losses.

Moreover, while other nations have been extensively analyzed using EVT to better understand and mitigate the impact of extreme financial events, Russia has been notably absent from recent studies despite being recognized as one of the most geopolitically volatile and economically significant countries. This study addresses that gap by offering a framework to evaluate extreme losses. By applying EVT to recent data, this research builds upon the findings of previous studies, such as [23], which identified Russia as a high-risk market using other methods. This enhanced understanding through multiple risk prediction models will enable investors with more confidence to make informed decisions and prepare for scenarios of high loss, ensuring they adopt more effective risk mitigation strategies. As a result, the study aims to provide both international investors and Russian citizens with the information needed to navigate the country's volatile economy.

4.1. Limitations and Future Directions

There are a few limitations with the research that may inhibit the conclusions found. One such limitation is the fact that in theory, extreme value theory is conducted on specifically independent and identically distributed variables. Obviously, it is difficult to generalize stock data to independence as there is some inherent dependence on external factors such as previous stock prices, interest rates, or general economic situation, for example. In fact, in most real-world examples "it is virtually impossible to have such independent data" needed for EVT analysis [7:2]. The failure of stock data to be truly independent can lead to conclusions derived, in both this study and other described EVT applications, from EVT analysis being potentially flawed. However, because as past precedent sets, for the majority of most EVT applications, the independence and identical distribution factor is ignored. Future research can potentially look to orthogonalize the stock data in an attempt to remove the causality between economic aggregates that can affect stock prices and the prices themselves.

Another important limitation to take note of is the fact that this research was conducted using block maxima instead of peaks-over-threshold. As previously explained, EVT has 2 methods of application: block maxima and peaks-over threshold. This is of note because, as explained by researchers at the econometric institute at Erasmus University, the peaks-over-threshold method makes better use of the extreme values in comparison to block maxima when done correctly [6]. In other words, because block maxima extract the most extreme instance in a set block size, if there are several large extreme events occurring with high frequency in the same block, block maxima will ignore some data points. By choosing block maxima, any risk of an inadequate or flawed threshold selection that may occur with POT is removed, however it may also fail to incorporate the entire dataset. Therefore, it is a limitation of this study that the block maxima technique was used instead of POT. If it were selected, it is very well likely that the results would be different. While the results may be similar, it is suggested that future research applies POT in order to account for the limitation in this study and obtain greater confidence that an EVT model can highlight risk in the Moscow Exchange.

Additionally, because the analysis was only conducted with three countries in comparison to Russia, results may be disproportionately skewed towards showing comparatively additional risk in Russia. This is because India, France, and the USA are all countries established to have less risk than Russia, be it geopolitically or otherwise. While they do serve as effective benchmarks of comparison to Russia, had other countries with potential risk been selected, results may show that Russia is at less relative risk in comparison to them. There are many countries with similar geopolitical risk to Russia so for future research, it may be beneficial to replicate this study on those countries for a wider scope of analysis.

A final limitation of the study is that stock indices may not be the best indicator of economic performance. While it is sufficient in understanding the impact on the stock market, a broader economic measure such as exchange rates or GDP may be better for understanding the effects on the economy through EVT as shown through studies like [34] which uses EVT to estimate the tail risk of daily current exchange rates. While index stock market data is a good representation of the economy through its summarization of market performance and health, metrics such as real GDP can also show insights into the health of the economy specifically. Future research focused more upon macroeconomic country health rather than market health for investors can use EVT to analyze risk in those aggregates as well.

5. Conclusion

With discretion of the limitations of the study described above, the results of this study show that through an EVT analysis of Russia's MOEX stock index in comparison to the primary stock indices of other countries, the original hypothesis, that an analysis of the Russian economy using recent data will continue to associate Russia with more risk, is supported. To obtain better confidence in the results of this paper, future research can seek to address the prior limitations. This means that future research should use the peaks-over-threshold (POT) method instead of BM, conduct analysis with more countries and specifically more at-risk countries, and find the associated results of an analysis using broader economic measures such as GDP or exchange rates.

Finally, this study analyzed risk in the short term through intraday loss. It is urgent that future research be conducted in the long term as well to better understand the risks associated with the Russian market over many years through sustained loss rather than on-day loss. Future research using EVT on the Russian market can look at a time period longer than the 11 years analyzed in this study by potentially using a different economic indicator, use a block size larger than 30 days, and have results analyzed on intra-month or intra-week loss rather than intraday loss.

Beyond the distinction of the Russian Federation being a country of risk, this paper is a call to action. It is a call to action for those living in Russia and seeking to invest in its economy to be aware of the risks they face and adjust their strategies accordingly and a call to action for future researchers to address the limitations of this study to provide clearer insights to the millions potentially facing disastrous economic hardship so that for them the risks can hopefully be mitigated.

Acknowledgements

I would like to express my deepest gratitude to my instructor, Mrs. Jill Ceneskie, for her invaluable support. I would also like to extend my appreciation to Mr. Roland D'Amato, and Andrew Langan for their guidance throughout the research process.

6.Conflict of Interest

The author declares that he has no conflict of intrest.

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