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WILL SWITCHING FROM THE VAR TO THE EXPECTED SHORTFALL PROVIDE THE EFFICIENCY IN THE CAPITAL ADEQUACY? EVIDENCE FROM THE FX POSITIONS

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Abstract

The banks have to measure the market risk daily for the calculation of their capital adequacy. According to the Fundamental Review of Trading Book (FRTB) market risk revision, which was released in 2016 by the Basel Committee on Banking Supervision (BCBS), the expected shortfall (ES) will replace the value-at-risk (VaR) approach in order to capture the tail risks. In this paper, various risk management methodologies have been compared based on their performances using both the VaR and the ES. The data are based on three different currencies (USD/TRY, EUR/TRY, and EUR/USD) for the period from Jan 2nd, 2007 to Jan 4th, 2017. The methodologies have been applied to several portfolios of assets, ranging from a linear one (pure FX Position) to highly non-linear one (complex derivative securities on FX). The binomial backtest method is used for comparing backtesting performance and the empirical results indicate that the ES method, in lieu of the VaR methods, ensures the significant reduction in the capital adequacy for the semi-parametric models. In addition, the ES yields a considerable capital adequacy reduction compared to the VaR in linear portfolios. The reduction in loses strengths as the portfolios get more non-linear. These findings mainly highlight the importance of the convexity and the subadditivity features of the non-linear portfolios.

Keywords: Expected Shortfall, Value at Risk, Backtesting Methods, Risk Management, Capital Adequacy, FX Portfolios

JEL Classifications: C02, C14, C15, G31, G32

1. Introduction

The use of the Parametric (Variance-Covariance), the semi-parametric (Historical simulation), and the non-parametric (Monte Carlo simulation) methods are common practices in measuring the daily market risk for the calculation of capital adequacy. Especially following the Subprime crisis, the financial institutions have been in quest of upgrading their value at risk (VaR) methods due to an abnormal increase in their backtesting exceedance and failings in measuring the liquidity risk (Topaloglou, 2015). The modified methods (Filtered Historical Simulation, Age-Weighted Historical Simulation, Copula Monte Carlo, ES (Expected Shortfall), EVT, etc.) that take into account the volatility and the correlation that concentrate on the last days have come to the forefront thanks to the many advantages they offer as a result.

Banks have a key role in the financial system since they provide the financial instruments or the funding to facilitate the cash flow obligations of the institutions or the individual customers. Problems that arise in banks can devastate the economy by yielding an inadequate liquidity, even if all the institutions and the customers of the banks fulfill their obligations on time up until that point. Hence, we can suggest that the risk of banks being incapable of managing their own cash flow is a systematic risk. The systematic risk can be defined as a sudden shock that harms the entire financial system that could damage or even the economic activities. It has been observed that the systematic risk in the banking system could lead the countries' economies and even the global economy into recession. In that regard, Lehman's bankruptcy and the ensuing crisis have been a phenomenal case study of the banking world. To contain the damages of this crisis, the countries tried to save the banks that were in trouble about their capital adequacy. The countries have supported the banks during the crisis to ensure that the crisis does not have a spillover effect and that the banks continue their financial operations.

A systematic risk mainly occurs for two reasons: the panic behavior of the depositors or the investors; and interruptions in the payment systems. To avoid this kind of a systematic risk, the central bank executives of the G-10 countries worked together with international agencies and financial authorities at the end of 1974 and ultimately established the Basel Committee on Banking Supervision (BCBS). The Committee aims to reach its targets by setting the minimum standards for the regulation and the supervision of banks. It aims to set a common standard in the financial markets by establishing a common set of rules, techniques and approaches for risk management. Since the meeting of the BCBS Committee in 1975, the annulment has been held regularly three to four times a year. The BCBS, consisting of the representatives of some 30 countries, including Turkey, has the aim of strengthening the harmonization and the financial stability of member countries. The BCBS Committee shares its proposals, called the Basel Agreement, with the authorized representatives of the countries. Basel's first set of regulations was developed in 1988, and the second regulation was developed between 2004 and 2009. Last Basel regulation, mainly known as Basel 3, started to be developed in 2010. Since the beginning of 2007, the liquidity-related shortcomings have brought a fundamental change in Basel regulations. After the Lehman crisis, it has come to light that the liquidity risk has not been managed and analyzed effectively. The Basel Committee has made arrangements to measure the liquidity risks of positions that cannot be followed by securitization transactions and off-balance sheet accounts in 2008 and 2009 under Basel 2.5. Some modifications have been made in the calculation of the trading portfolio. Most importantly, the Stressed VaR calculation has been introduced under the scope of the Tail VaR.

In 2010, the Basel III settlement adopted various regulations on the measurement, the monitoring and the reporting of the liquidity risk. In this revision, the measures such as the leverage ratio, the systematic risk, the minimum capital ratio and the counterparty credit risk have been updated. The new set of rules started to be executed in 2016 in some member countries and it is expected to be fully executed in 2019 in all member countries. Table 1 provides the overview of the market risk regulation in the BIS.

Value-at-risk is a measurement of the maximum potential loss that could be realized within a specific period for a given confidence level. It is a monetary value that could easily be interpreted (Jorion, 2006). Value-at-risk is useful in bringing together the types of risks induced by different factors such as equity risk, currency risk, interest-rate risk, commodity risk, etc. and representing all of these risks within a single number. The concept of VaR has been defined as the answer to the question of “how much can I lose at worst with probability x % in a given period?” (Benninga and Wiener, 1998).

Table 1. Overview of the Market Risk Regulation

Basel paper	Overview of the Market Risk regulation	Paper source
BCBS 1996	Supervisory framework for the use of 'backtesting' in conjunction with the internal models approach to market risk capital requirements	https://www.bis.org/publ/bcbs22.pdf
BCBS 1996	Amendment to the capital accord to incorporate market risks	https://www.bis.org/publ/bcbs24.pdf
BCBS 1997	Modifications to the market risk amendment	https://www.bis.org/publ/bcbs24a.pdf
BCBS 2005	International convergence of capital measurement and capital standards: A revised framework.	http://www.bis.org/publ/bcbs107.pdf
BCBS 2009	Revisions to the Basel II market risk framework (Stressed VaR, Effect of securitization transactions in banking portfolio on capital adequacy)	http://www.bis.org/publ/bcbs158.pdf
BCBS 2012	Fundamental review of the trading book (consultative paper 1)	http://www.bis.org/publ/bcbs219.pdf
BCBS 2013	Fundamental review of the trading book: A revised market risk framework (consultative paper)	http://www.bis.org/publ/bcbs265.pdf
BCBS 2014	Analysis of the trading book hypothetical portfolio exercise.	http://www.bis.org/publ/bcbs288.pdf
BCBS 2015	Fundamental review of the trading book: Outstanding issues (consultative paper 3).	http://www.bis.org/publ/bcbs305.pdf
BCBS 2015	Instructions for Basel III monitoring - Version for banks providing data for the trading book part of the exercise.	https://www.bis.org/bcbs/qis/biiiimplmoninstr_feb15.pdf
BCBS 2015	Instructions: Impact study on the proposed frameworks for market risk and cva risk	http://www.bis.org/bcbs/qis/instr_impact_study_jul15.pdf
BCBS 2016	Standards - Minimum capital requirements for market risk.(Expected Shortfall, Arbitrage disaggregation of Banking and Trading portfolio)	http://www.bis.org/bcbs/publ/d352.pdf

The VaR approach is an important part of the risk measurement and risk management processes in a financial institution. In risk management applications, (often times) the scenario analyses and the results of the stress tests are used as supplementary measurements for the VaR calculations. The most important reason for this is that the VaR calculations neglect the loss of a portfolio at the time of the worst case scenarios or namely the extreme market situations. Although, it is not very likely, there is always a probability of the tail events to happen in the financial markets. The three main disadvantages of a generic VaR model are neglecting the loss level in the worst case scenario, the assumption of the lack of change in positions within the entire backtest period, and the inability of recommending a future position of the portfolio. All VaR methods measure the level of risk of a portfolio as a smaller level than the sum of the risk levels of each factor in the portfolio due to the correlation effect among the risk factors. Despite all these disadvantages, the regulatory capital levels are still based on the results of the VaR analyses. Besides all these legal reports, VaR calculations are also used for the distribution of the financial resources and risk adjusted return on capital (RAROC) calculations (Jorion, 2006).

In 1996, the Basel Committee allowed the banks to use their internal models to calculate VaR levels. Hence, banks were able to calculate the adequate capital level based on their internal models instead of the Standard Model if they are authorized by the supervising organization. However, the Basel Committee requires all banks to use 10 days as holding period and the 99% for the confidence level within those internal models. The VaR techniques have been utilized in the last 20 years in practice despite their disadvantages (BIS, 2013). The main reason for the switch Expected Shortfall from VaR is that the VaR techniques do not give any information about what happens beyond the 99% risk level. At first, the 99% level seems quite high and more than enough, but the regulators decided that these VaR methods are inadequate for risk measurements in extreme events. The trading strategies and the product choices are constantly changing for most of the financial institutions. This makes the checks of exceeding the risk limits of the financial institutions, even harder for the regulators. Hence, the regulators announced their plans on switching to ES models for the required risk level calculations with the FRTB document in January 2016.

However, the Expected Shortfall is the expected value of the loss beyond the given confidence threshold. In contrast to the VaR, the ES only uses the values beyond the confidence level (Jorion, 2006). Different terminologies have been used in the ES such as the expected tail loss, the tail VaR or the conditional VaR. The first step in the ES calculation is computing the VaR level. After that, the expected tail loss is computed. Hence, the uncertainty for the ES is more comparable to the VaR. The ES calculations are recommended by the FRTB document to overcome most of the disadvantages of the VaR calculations. Neiting (2011) proves ES and VaR methodologies should only be compared in terms of risk levels, but not in terms of the returns of the portfolios. Because, the ES considers the average value of the risk in the entire tail, whereas the VaR only takes into account a single value on the distribution.

In BCBS consultation paper (Basel Committee on Banking, 2014) the Basel Committee recommended the use of the ES models for the capital requirement calculations in the banks' internal models instead of the VaR models, however it did not recommend any changes for the backtesting methods. In addition, with the announcement of FRTB in 2016, the ES clearly became the standard model for the risk measurement calculations as opposed to the VaR methods. In this document, the Global ES is defined to be the average of the diversified ES and the undiversified ES for the identified risk categories.

In this paper, we use the main arrangements designed by the regulators for the ES models in the FRTB can be classified into two groups: i) For the daily required capital calculations, the Global ES has to be utilized in the banks' internal models. Furthermore, the ES should be calculated separately for every trading desk included in the internal model. ii) The confidence level of 99% of the VaR has been modified to 97.5% for the ES calculations. (BIS, 2016). To the best of knowledge, our paper is the first paper in the literature that considers the ES instead of the VaR approach to capture the tail risks. Specifically, our paper compares the portfolio performances using both the VaR and the ES. Our data are based on three different currencies (USD/TRY, EUR/TRY, and EUR/USD) for the period from Jan 2nd, 2007 to Jan 4th, 2017. For this purpose, we consider several models and portfolios of assets, ranging from a linear one (pure FX Position) to highly non-linear one (complex derivative securities on FX). Another contribution of our paper is that to use the binomial backtest method for implementing the backtesting performance.

Our findings illustrate that the ES method provides the significant reduction in the capital adequacy, especially for the semi-parametric models and the linear portfolios. It is interesting to observe that the reduction in loses its increases as the portfolios get more non-linear. Our findings mainly highlight the importance of the convexity and the subadditivity features of the non-linear portfolios.

The rest of the paper is organized as follows. Section 2 reviews the previous literature. Section 3 explains the data and the methodology. Section 4 provides the empirical findings. Section 5 concludes.

2. Literature Review

Mainly, the prediction of the financial risks is based on the predictions of the distributions of the financial assets or the portfolios using their historical returns. Measuring the risk of a financial asset is based on predicting the return, the volatility and therefore the distribution of the financial asset for time t+1 at time t. Hence, modelling the volatility and determining the parameters of the model is very important in the risk management models. Although, the first academic papers on VaR models started appearing in the 1990s, the mathematical models used in those models go to the earlier years. For example, Markowitz' portfolio selection theory could be considered as an early study that points out the importance of risk management in the financial portfolio analysis. A regulatory capital was calculated for the first time by the SEC in the year 1980. The historical return data have been used to calculate the potential loss of the financial institutions for a holding period of 30 days and at a confidence level of 95%. The haircut levels are adjusted according to these calculations. This has been the first step towards the calculation of the capital adequacy from the risk management point of view. According to Angelidis and Degiannakis (2007), models are categorized in three main classes: the Parametric Models, the Semi-Parametric Models, and the Non-Parametric Models. We adopt a similar categorization with a small change that will be clarified later in this section.

2.1. Parametric Models

The parametric VaR methods were developed first by the Morgan (1996). Using the variance-covariance matrix of the risk factors computed from different asset classes. They named this methodology as 'Riskmetrics' (Morgan, 1996). One of the main advantages of using the non-parametric models is the fact that we do not need to use the probability distribution functions of the risk factors (Cheung and Powell, 2013). The problem of calibrating the probability distribution is particularly hard under volatile market conditions.

2.2. Semi Parametric Models

The Standard Historical Simulation (HS) method was first offered by Hendricks (1996), who analyzed the oil price historical return data by classifying them in two groups as the positive and the negative returns. Then, they computed the VaR values at the 99% confidence level in both directions. This method assumes that the distribution in the observed period will remain the same in the upcoming holding period. Dowd (1998) finds evidence that the historical simulation method offered by Maude (1997) that gives the better results compared to the parametric models. The HS methodology is considered to be the simplest technique among the full-valuation methods (Manfredo and Leuthold, 1998). Although a lot of different VaR techniques have been developed in the academic literature so far, only three of those methods have been adopted by the Basel Committee.

Another HS method is the 'Age Weighted Historical Simulation' model suggested by Boudoukh *et al.* (1998). This HS method also uses the historical return data. However, it gives more importance to the more recent values, and less importance to the less recent values by introducing a time decay factor. One of the main disadvantages of this method is the assumption of the volatility is stationary. This could lead to a misrepresentation of the market conditions when there happens a sudden change Dowd , 1998). On the other hand, it leads to lower capital requirements during the periods of the lower volatility for the P&L values of the risk factors (Pritsker, 2006).

Another HS method is the Volatility –Weighted HS Model that has been found by Hull and White (1998). This method focuses on the recent changes in the volatility level. Hull and White (1998) find the evidence towards the Volatility-Weighted HS beats the Age-Weighted HS both in terms of the profit and loss, and the backtesting performances. Sinha and Chamu (2005) compare all these three HS methods that we have introduced so far in the Mexican Financial Markets in a very high volatility period. They also concluded that the Volatility-Weighted HS gives the best results in this horse race.

One last HS method appeared in the academic literature is the Filtered Historical Simulation (FHS) method which was suggested by Giovanni *et al.* (1999), who observes that FHS performs better than the standard HS. Also Pritsker (2006) claims that the standard and the Age-Weighted HS methods can only be used when the portfolios under consideration do not have fat tails. It is important to note that in the modern financial world, the HS methods appear to be the most popular VaR methods in use. For instance, Perignon and Smith (2010) pointed out that 73% of the commercial banks use one of these HS methods.

2.3. Non-Parametric Models

Woller (1996) claims that the Monte Carlo (MC) Simulation method is the most efficient method for pricing the complex derivative securities. Monte Carlo Simulation technique also assumes that the historical returns are normally distributed. The interaction between the volatility factors are modelled based on this assumption (Linsmeier and Pearson, 1996). Caflisch (1998) confirmed the hypothesis that the MC method is the most efficient model in pricing complex derivative securities although it turns out to be rather slow (Woller, 1996). Larcher and Leobacher (2005) show that the MC methodology can also be used for the VaR calculations. All of the HS methods mentioned above and the MC method fall under the category of the semi-parametric and the non-parametric models (Angelidis and Degiannakis, 2007). The main advantage of all these models is that they do not need to assume anything about the distributions of the risk factors (Cheung and Powell, 2013).

3. Data, Models, and Methodology

3.1. Data and Models

In this paper, the data used is daily data starting from Jan 2th, 2007 up to Jan 4th, 2017. The period is chosen intentionally to include the subprime crisis years. There are many windows with different volatility patterns within the chosen time period. This allows the researcher a chance to compare the VaR versus the ES in different market conditions. The data used for the interest rates, the currency, and the volatility levels have been obtained from the Bloomberg EOD API service. For the required VaR and the ES calculations, we use the above mentioned data set starting from a year earlier. Hence, these items start from Jan 2nd, 2006 and end at Jan 6th, 2017. The currency data are taken from the free market database of the Bloomberg. The interest rate data come from the yield curves obtained via the Nelson-Siegel method, which is applied to the deposit market rates. The volatility data are the implied volatility data that have been constructed from the option prices using the Vanna-Volga technique.

The currencies appearing in the portfolios of this study are chosen to be the most commonly used ones in the local markets, i.e. the USD/TRY and the EUR/USD currencies. For linear portfolios, a simple FX position that consists of 1M in the USD/TRY and 1M in the EUR/TRY is created. As we go to more non-linear portfolios, vanilla type at-the-money options have been synthetically created. To accommodate highly non-linear portfolios, the paper makes use of barrier options where all the barriers are designed to be up-and-in options; the levels of the barriers are put to be 0.1 bps above the spot rate; and the strike levels are chosen to be 0.02 bps above the spot rate, which closely follows the at-the-money-forward rate. The type of the options is created by the call options on the USD/TRY and the put options on the EUR/USD. The maturities used for all the options are 1M, 3M, and 6M.

3.2. Portfolio Details

Since all the options in the study are synthetically created, a model needs to be used for each pricing. The model chosen for pricing the vanilla type FX options (Garman and Kohlhagen, 1983), the model used for pricing the single barrier options (Rubinstein and Reiner, 1991), and the model used for digital options (Rubinstein and Reiner, 1991). All these choices of models are listed together in Table 2 that provides the option pricing models of the option portfolios.

Table 2. Option Pricing Models

PRODUCTS	OPTION PRICING MODELS
VANILLA FX OPTION	BS-Garman-Kohlhagen (1983)
SINGLE BARRIER OPTION	BlackSholes-Merton&Rubinstein(1991)
VANILLA DIGITAL OPTION	Reiner&Rubinstein(1991)
BARRIER DIGITAL OPTION	Reiner&Rubinstein(1991)

While comparing the backtesting performances of the VaR and the ES techniques, seven different types of portfolios have been utilized. The simplest portfolio consists of a pure FX position. The second type of portfolio includes only vanilla type options. The third portfolio only includes the barrier options. The study also considers portfolios that consist of vanilla digital options and barrier digital options. As one can see, the portfolios chosen get more and more non-linear as they included more and more complex derivative securities. The last two types of portfolios investigated include all the above mentioned derivative securities and all the above mentioned products. The portfolios studied are summarized in Table 3 that represents the portfolio definition of the products.

Table 3. Portfolio Details of the positions

PORTFOLIO	PORTFOLIO DETAILS
FX POSITION PORTFOLIO	FX POSITION
FX OPTION PORTFOLIO	FX OPTIONS
STANDART KI PORTFOLIO	SINGLE BARRIER OPTION
VANILLA DIGITAL PORTFOLIO	VANILLA DIGITAL OPTION
DIGITAL TOUCH PORTFOLIO	BARRIER DIGITAL OPTION
ALL DERIVATIVE PORTFOLIO	FX OPTION,SINGLE BARRIER,VANILLA DIGITAL,BARRIER DIGITAL
ALL PRODUCTS PORTFOLIO	FX POSITION,FX OPTION,SINGLE BARRIER,VANILLA DIGITAL,BARRIER DIGITAL

3.3. Theoretical Comparison

In theory, any plausible risk measurement techniques have the following five properties: normalization, monotonicity, convexity, positive homogeneity, and subadditivity (Hult *et al.* 2012). In terms of these features, there are two more theoretical reasons for switching to the ES from the VaR. First, one should assume that the returns of the underlying assets are normally distributed to guarantee the subadditivity of the VaR measurement. One does not need such an assumption for the ES measure (Embrechts and Wang, 2015). It has to be kept in mind that this assumption gets further and further away from reality as the portfolio of interest contains more and more complex derivative securities. Secondly, a similar argument can also be constructed against the convexity of the VaR measurement. Again, the convexity becomes a more important issue as the portfolio of interest gets more non-linear.

The early versions of the Basel regulations do not focus on this phenomenon since at the time the amount of highly complex derivative securities in the actual portfolios of the banks are not on a visible level. It becomes undeniably important in the subprime crisis period. As a result, BIS (2009) wanted to introduce VaR + Stressed VaR to handle this phenomenon. Since, this does not solve the problem entirely, FRTB (2016) decided to make the switch to the ES from the VaR.

4. Empirical Findings

The backtesting performance of the VaR and the ES have been studied on four different models: the Standard Historical Simulation (HS), the Age-Weighted Historical Simulation (AWHS), the Volatility-Weighted Historical Simulation (VWHS), and Monte-Carlo Simulation (MC). The exceedance of the profit and loss (P&L) levels are calculated by the binomial backtesting method, which is described in detail in the Appendix.

The following tables are colored in bold and dark grey and a dark grey-colored cell represents a year where the number of days of exceedances of the minimum required level set by the Basel Committee is between 4 and 7. This can be interpreted as the model needs attention. A bold colored cell represents a year where the number of days of exceedances of the minimum level set by the Basel Committee is more than 7. This means that the risk measurement technique cannot be used. For the results of this comparison in detail are provided in Tables from 4 to 10. Table 5 represents the Backtesting exceedance table of all risk models as the FX position portfolio. Table 6 represents the backtesting exceedance table of all risk models as the currency option portfolio. Table 7 provides the backtesting exceedance table of all risk models as the single barrier option portfolio. Table 8 reports the backtesting exceedance table of all risk models as the vanilla digital option portfolio. Table 9 provides the backtesting exceedance table of all risk models as the binary digital option portfolio. Table 10 represents the backtesting exceedance table of all risk models as the derivative portfolio. Finally, Table 11 provides the backtesting exceedance table of all risk models as the "all products portfolio".

Table 4. FX Position Backtesting Performance of risk measures

	Historical Standard(VaR)	HS Age Weighted(VaR)	HS Volatility Weighted(VaR)	MC(VaR)	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)
2007	6	8	8	1	6	3	8	0
2008	**11**	7	**13**	1	**11**	5	**13**	2
2009	0	1	0	0	0	0	0	0
2010	3	4	5	0	3	3	5	0
2011	2	4	5	0	2	3	4	0
2012	2	3	0	3	2	3	0	2
2013	3	7	4	2	2	4	5	2
2014	4	3	6	3	3	2	3	2
2015	4	5	7	4	3	3	6	3
2016	3	3	3	2	2	3	2	2
Total	38	45	51	16	34	29	46	13
%					-10.53	-35.56	-9.80	-18.75

Table 5. Currency Option Portfolio Backtesting Performance of risk measures

	Historical Standard(VaR)	HS Age Weighted(VaR)	HS Volatility Weighted(VaR)	MC(VaR)	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)
2007	7	9	6	1	8	5	7	2
2008	**10**	8	**10**	1	**10**	5	**11**	2
2009	0	2	0	0	0	0	0	0
2010	4	4	5	0	4	3	5	0
2011	2	4	2	0	2	3	2	0
2012	2	3	1	3	2	3	2	2
2013	3	8	3	2	2	3	2	2
2014	4	4	5	3	3	2	4	1
2015	5	5	7	3	5	4	6	3
2016	2	3	1	2	2	2	1	2
Total	39	50	40	15	38	30	40	14
%					-2.56	-40.00	0.00	-6.67

Table 6. Single Barrier Option Portfolio Backtesting Performance of risk measures

	Historical Standard(VaR)	HS Age Weighted(VaR)	HS Volatility Weighted(VaR)	MC(VaR)	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)
2007	7	6	6	1	8	4	6	2
2008	6	7	8	1	6	6	7	1
2009	0	2	0	1	0	2	0	2
2010	2	3	3	1	2	3	3	2
2011	5	6	7	3	2	5	4	2
2012	0	2	0	0	0	0	0	0
2013	9	7	**13**	2	9	7	**13**	2
2014	3	4	3	2	3	4	4	2
2015	4	6	8	2	4	5	8	1
2016	4	3	5	1	3	3	4	1
Total	40	46	53	14	37	39	49	15
%					-7.50	-15.22	-7.55	7.14

Table 7. Vanilla Digital Option Portfolio Backtesting Performance of risk measures

	Historical Standard(VaR)	HS Age Weighted(VaR)	HS Volatility Weighted(VaR)	MC(VaR)	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)
2007	4	6	7	2	3	2	7	2
2008	**11**	8	**11**	2	**10**	8	**13**	3
2009	0	2	0	1	0	0	0	1
2010	5	5	3	0	5	3	3	0
2011	3	5	4	0	3	3	4	0
2012	2	3	1	3	2	3	2	3
2013	1	5	1	3	1	3	1	3
2014	2	3	3	3	3	2	3	3
2015	7	6	8	4	6	4	8	4
2016	1	4	1	4	1	1	0	3
Total	36	47	39	22	34	29	41	22
%					-5.56	-38.30	5.13	0.00

Table 8. Binary Digital Backtesting Performance of risk measures

	Historical Standard(VaR)	HS Age Weighted(VaR)	HS Volatility Weighted(VaR)	MC(VaR)	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)
2007	7	6	6	2	8	3	6	2
2008	5	5	5	4	4	3	5	4
2009	0	3	0	2	0	1	0	3
2010	1	3	3	2	1	2	2	2
2011	3	7	4	3	3	3	3	3
2012	0	2	0	2	0	0	0	0
2013	7	8	**11**	2	9	5	**12**	2
2014	4	4	3	2	3	3	5	2
2015	2	6	1	3	3	3	2	3
2016	3	5	5	5	2	3	4	4
Total	32	49	38	27	33	26	39	25
%					3.13	-46.94	2.63	-7.41

Table 9. Derivative Portfolio Backtesting Performance of risk measures

	Historical Standard(VaR)	HS Age Weighted(VaR)	HS Volatility Weighted(VaR)	MC(VaR)	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)
2007	4	5	6	0	4	5	5	0
2008	6	4	8	1	4	7	7	1
2009	0	1	0	0	0	0	0	0
2010	3	2	3	0	2	2	3	0
2011	0	0	0	0	0	2	0	0
2012	0	2	0	2	0	2	0	2
2013	1	2	1	2	1	2	1	2
2014	1	1	2	1	1	3	3	1
2015	1	2	4	2	1	6	4	2
2016	0	2	0	2	0	1	0	2
Total	16	21	24	10	13	30	23	10
%					-18.75	42.86	-4.17	0.00

Table 2. All Products Portfolio Backtesting Performance of risk measures

	Historical Standard(VaR)	HS Age Weighted(VaR)	HS Volatility Weighted(VaR)	MC(VaR)	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)
2007	4	5	6	0	4	5	5	0
2008	6	4	8	1	4	7	7	1
2009	0	1	0	0	0	0	0	0
2010	3	2	3	0	2	2	3	0
2011	0	1	1	0	0	2	1	0
2012	0	3	0	2	0	2	0	2
2013	1	2	1	2	1	2	1	2
2014	1	1	2	1	1	3	3	1
2015	1	3	4	2	1	5	4	2
2016	0	2	0	2	0	1	0	2
Total	16	24	25	10	13	29	24	10
%					-18.75	20.83	-4.00	0.00

It is clear from almost all these tables that the HS and the VWHS are unusable in the periods of high volatility such as the year 2008, regardless of the risk measurement technique. The other models, i.e. the AGHS and the MC, did not have any problem even in the year 2008. On the other hand, for the HS and the AWHS models, switching to the ES from the VaR almost all the time (with the exception of the year 2014, and only in the large portfolio) brings the significant reduction in terms of the number of critical years. Table 11 also represents the reduction of capital adequacy values provided by the VaR vs. the ES.

Table 3. Reduction of Capital Adequacy Value: the VaR versus the ES

Product/Model	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)
Overall_Currency	67,804.81	-23,738,231.91	-473,484.69	-1,290,172.08
Currency_Option	821,377.13	-11,942,348.24	776,912.19	-919,039.18
Single_Barrier_Option	611.10	-75,985.91	572.03	-5,704.53
Vanilla_Digital	14,652,021.99	-154,943,582.16	21,148,769.97	-14,706,479.38
Binary_Digital	-24,069,167.95	-90,993,323.35	-4,866,853.15	12,199,856.71
DERIVATIVE_PORTFOLIO	-8,595,157.94	-163,539,504.99	17,059,400.81	10,326,498.88
ALL_PORTFOLIO	-8,527,353.13	-179,618,551.79	16,585,916.12	11,472,684.54
Average Reduce PL in TRY	**-25,649,863.99**	**-624,851,528.35**	**50,231,233.28**	**17,077,644.96**

In addition, the required capital levels under these models turn out to be significantly less using the ES technique (See Table 12). However, the required capital level via the ES happens to be a little higher under the VWHS and the MC methods. Depending on the type of portfolio perspective, the reduction in the capital adequacy becomes more and more visible as the portfolios get more and more complex. Under the HS model, one starts seeing the reduction only after the portfolio gets complex. Under the AWHS although the reduction is always there, the amount of reduction increases as the portfolio gets more complex. This can be considered as the evidence that the rate of reduction in the capital adequacy violations is closely connected to how convex is the product under consideration. Table 12 reports the reduction of the backtesting exceedance rate provided by the VaR versus the ES.

Table 4. Reduction of backtesting exceedance rate: the VaR versus the ES

Portfolio/Model	Historical Standard(ES)	HS Age Weighted(ES)	HS Volatility Weighted(ES)	MC(ES)	Average
FX Portfolio	-10.53%	-35.56%	-9.80%	-18.75%	-18.66%
Currency Option	-2.56%	-40.00%	0.00%	-6.67%	-12.31%
Single Barrier Option	-7.50%	-15.22%	-7.55%	7.14%	-5.78%
Vanilla Digital	-5.56%	-38.30%	5.13%	0.00%	-9.68%
Binary Digital	3.13%	-46.94%	2.63%	-7.41%	-12.15%
Derivative Portfolio	-18.75%	42.86%	-4.17%	0.00%	4.99%
All Portfolio	-18.75%	20.83%	-4.00%	0.00%	-0.48%

The values show the percentage of the rate of reduction in the required capital levels as one goes from the VaR to the ES. The capital increase/decrease rates in the backtesting performance are summarized above in connection with the transition from the VaR models to the

ES model with a product/model basis. The dominance of light grey cells is a strong indication of a higher performance of the ES over the VaR under various circumstances, portfolios and underlying models. Basically, using the ES approach instead of the VaR provides a higher efficiency in the capital adequacy. Interestingly, the efficiency of the ES approach increases as the portfolios get more non-linear due to the convexity and the subadditivity features of the non-linear portfolios. In short, our results indicate that banks and financial institutions can use our evidence of a less capital adequacy for providing an extra fund in other financial and non-financial activities.

5. Conclusion

The Basel Committee focused on market risk regulation in the last decade to calculate of the tail risk. Measuring tail risks have become much more important than ever as a consequence of the increase in the complexity of products used by the banks. In this paper, the backtesting performances of the VaR and the ES techniques are compared under four different models. All these models have been applied both on linear and non-linear products for a period of ten years, for the period from 2007 to 2017.

In terms of the models used for scenario analysis, switching from the VaR to the ES brings a lot of reduction in the number of days of exceedances of the critical levels and the amount of required capitals. The difference is particularly clear under the standard HS and the AWHS models, and the improvement gets clearer in the periods of high volatile regimes. In terms of the product types, a high rate of reduction in the number of capital adequacy violations has been achieved in transition from the VaR models to the ES models. However, this rate of reduction somewhat decreases as the product complexity intensifies, i.e. when the products become non-linear. For instance, from the VaR to the ES, the capital need has reduced at a higher rate in the vanilla type products, such as the vanilla currency and the vanilla digital options. On the other hand, the reduction rate has been lower in more complex derivative securities; such as the single barrier and the binary digital options. Our paper also motivates that the rate of reduction in the level of the required capital is related to the convexity of the portfolio of interest. In other words, the rate of reduction decreases as the convexity of the products in the portfolio increases.

It is expected that the banks will encounter different risk capital results depending on their products in their portfolios, the model they use in transition from the VaR to the ES. Though one cannot claim that the ES technique is better than the VaR, but it is clear that there are many advantages of using the ES over the VaR under various circumstances. In the future papers, the backtesting performances should be tested not only in the currency risk category, but also in other common risk categories, such as the equity, the fixed-income, and the commodity risk. The tests also need to be enlarged to a wider set of financial securities.

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Appendix. Details of the Backtesting Models

Backtesting (model verification test) can be defined as being subject to a test for the purpose of testing the parameters and accuracy or the VaR model used. While conducting this test, the portfolio's PL values are compared with the then current VaR values. There are 2 types of approaches in the comparison of PL values. Marked to Market PL method that is based on obtaining the values of risk factors included in the portfolio by calculating their market values based on the just value, if any, or, if such a value is not available, based on the fair value approach. Marked to Model approach enables to obtain the Profit/Loss value by comparing a portfolio's theoretical present value with the same portfolio's theoretical present value on the next day. Basel (2016-FRTB) document sets forth that Liquid positions could be valued with Marked to Market model, while Illiquid positions with fair value or marked to model approaches. Below, we explain the model verification tests of Marked to Market or Marked to Model methods while there is a PL distribution (See Table A1).

Binomial Test, or, Kupiec method is one of the statistical methods that can be used for the quantification of the tail distribution in the Profit/Loss distribution. Binomial method can be defined as a frequency test of exceeding values. Binomial test is the basic backtest methodology where Profit/Loss values are compared with VaR and VaR exceeding is indicated in the most prominent way. Binomial Backtesting can be tested by means of the Binomial distribution or normal distribution. Where we define the daily calculated PL values as i, Hs= PLİ>VaRi the exceeding numbers during a year are determined. Total business days within 1 year are used in determining the value for average and deviation figures. The calculations are done as follows: Average Deviation = N*(1-α) =Ad, Standard Deviation = Square root (α*(1-α)*N) =Sd, Z=(Hs- Ad)/ Sd.

Table A1. Critical Values and the Safety Zones

Zone	Number of exceptions	Increase in scaling factor	Cumulative probability
Light Grey Zone	0	0	8.11%
	1	0	28.58%
	2	0	54.32%
	3	0	75.81%
	4	0	89.22%
Dark Grey Zone	5	0.40	95.88%
	6	0.50	98.63%
	7	0.65	99.60%
	8	0.75	99.89%
	9	0.85	99.97%
Bold Zone	10 or more	1	99.99%