

# **Measurement of Liquidity-Adjusted Market Risk by VaR and Expected Shortfall: Evidence from Turkish Banks**

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## **Abstract**

Due to its known weaknesses Value at Risk (VaR) has been modified to have a better market risk measurement model. 2007-2008 global financial crisis has increased the necessity to incorporate market liquidity into widely used models. This is to raise the required regulatory capital for trading portfolios since large marked-to-market losses have been observed to hit the global financial system. In line with the new coming regulations, this study applies a Monte-Carlo based approach on Turkish Banks' hypothetical trading portfolios to measure their total market risk. The results of designed risk measurement process are reported for VaR and Expected Shortfall (ES) models in comparative to their liquidity adjusted values. Finally, the results imply that the capital adequacy ratios of Turkish banks indicate a solid loss absorbency capacity although liquidity-adjusted market risk is relatively higher than the currently measured one. Nevertheless, possible deteriorations due to sudden extreme shocks on the banks' trading portfolios should be frequently analyzed on a more elaborate basis by taking market liquidity into account.

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## 1 Introduction

Both the recent global financial crisis and the announcement of JP Morgan Chase's multibillion dollar loss during May 2012 have shown once more that the marketable securities in banks' portfolios exposed to a huge market risk and it can result huge losses. Moreover, banks' intention to liquidate their financial assets to close their risky positions and/or to acquire liquidity can cause the market to deteriorate liquidity conditions in a sudden and severe fashion. This may further create a feedback loop between market and funding liquidity, thereby both cause liquidity problems and diminish capital due to large and fast losses. Especially under costly and restricted market conditions, the impacts of the market risk may become considerably high and severe. Although liquidity facilities provided by central banks can help the system for well-functioning, the presence of a banking system that is capable of funding itself through market sources is essential for maintaining financial stability.

In general, market risk and liquidity risk components are correlated. Without considering the market liquidity, the marking to market may underestimate the total risk and the deviations from the mid-prices of securities may impose significant risk on the system. (Bangia et al, 2006). In this context, considering typical characteristics of the past global crisis along with their damages, the interaction between market liquidity and funding liquidity risk should be integrated to total market risk in some extent for the sake of a better risk management. Indeed, building technical infrastructure incurring more prudent risk measurement methods is of great importance for a smooth-functioning financial system. The liquidity adjusted market risk measurement techniques are the subject of this study. In this context, the incorporation of market liquidity risk into VaR and ES models is elaborated. Likewise, the recent Basel III framework also points moving from VaR to ES model as well as to Liquidity-VaR model.

The consultation report prepared by Basel Committee on Banking Supervision (BCBS) points out that the methods to calculate the required capital against the market risk should be enhanced. The report highlights inadequacy of the VaR as the main method for calculating regulatory capital. VaR is the maximum loss of a financial asset or a portfolio at a specified time period with a certain probability. Due to both its convenience in calculating the portfolio risk and its advantage to produce a single figure as a proxy for market risk, VaR is commonly used by whole financial institutions. On the other hand, the Committee proposes ES model as an internal model-based approach to calculate capital against low probable but highly damaging situations and determine the risk weights for the standardized approach since VaR method is insufficient to capture

the “extreme event” (tail risk). In contrast to VaR, ES considers the tail events by averaging the losses above a certain threshold corresponding to a confidence level. In this regard, ES can be considered as a step forward in capturing tail risks.

BCBS reports both model-based and standard method in its report where the relationship between those two is of great importance. Each has pros and cons. Accordingly, BCBS consults on three proposals. First, a closer link between the calibration of the two approaches is established. Second, a mandatory calculation of the standardized approach by all banks is required. Third, introducing the standardized approach as a floor or surcharge for the models-based approach is considered. The Committee is proposing to break the model approval process into smaller, more discrete steps, including at the trading desk level. This will allow model approval to be “turned-off” more easily than at present for specific trading desks that do not meet the requirements. In this study the internal models-based approach is the subject of concern (BCBS, 2012).

Taking ES measurement method as an internal model approach brings significant prudence to the analysis of market risk. In the analysis, aforementioned two standard different market risk measures of VaR and ES are calculated along with their modified versions. In obtaining modifications, this study is based on exogenous intraday illiquidity approach. Hence, the exogenous liquidity component following Bangia et al (1999) based on a hypothetical government securities portfolio is used.

Among the two types of market liquidity risks (i.e. exogenous and endogenous), this study considers exogenous illiquidity due to a couple reasons. First, exogenous liquidity risk is often large and important and it is relevant for all market players. Hence, from a policymaker perspective, it is believed that exogenous liquidity measures are able to capture market frictions. Second, in sharp contrast to the situation for endogenous liquidity, the data needed to quantify exogenous liquidity risk are widely available. This is because exogenous liquidity can be characterized by the volatility of the observed spread with no reference to the relationship of the realized spread to trade size. Yet, for endogenous illiquidity, there is no readily available data source for quantifying the relationships (between the trade size and both the quantity discount and the execution lag) and hence the study is forced to rely on subjective estimates in such case. Third, there is a lack of a unified approach in dealing with endogenous liquidity. Incorporating liquidity risk into market risk is not straightforward, mainly due to the fact that it is not directly observable, and its transmission into market risk is poorly understood. Lastly, dealing with exogenous liquidity risk is more appropriate for bond portfolio given that endogenous liquidity risk is particularly relevant for exotic/complex trading positions.

The rest of this study is organized as follows. The next two sections present the review of key literature and provide the methodology applied, respectively. The following section describes the data used in the analysis. Next, the assessment of the results is discussed. The final section summarizes the concluding remarks.

## 2 Motivation and Literature Review

During the recent financial global crisis, the liquidity crunch has played the key role for the banks. Counterparty credit risk turned out to be a large liquidity risk and the reflections of liquidity risk portion of market risk have been vividly observed. Since liquidity has very strong interrelation to other financial risks, market risk analysis cannot be done in isolation from market liquidity (Tian, 2009).

Market liquidity indicates the ability of a particular asset to be traded in the market in a considerably short time with a minimum loss of value. Market liquidity has three dimensions (Kyle, 1985) (i) tightness, (ii) depth, and (iii) resiliency. Amihud (2002) indicates that liquidity has a number of aspects that cannot be captured in a single measure. Each of the dimensions provides different information. In especially practical area, there is an approach to build market liquidity index that combines different aspects of liquidity and different types of markets (Kerry (2008), Pales and Varga (2008), Gersl and Komarkova (2009), ECB (2007) and Yildirim (2011)). These indexes generally use the tightness and depth dimensions where there is no agreement in the literature on quantifying resiliency.

Market risk is primarily concerned with describing uncertainty about prices or returns due to market movements. Bangia et al (1999) split uncertainty in market value of an asset, i.e. its overall market risk into two parts; uncertainty that arises from asset returns, which can be thought of as a pure market risk component, and uncertainty due to liquidity risk. In this regard, liquidity risk is a component of market risk which is shown to be priced in the market (Pastor and Stambaugh (2003), Archarya and Pedersen (2005), Sadka (2006)).

VaR is a probabilistic method of measuring the potential loss in portfolio value over a given time period and for a given distribution of historical returns. Calculating VaR is simple but requires the assumption that the asset returns follow a normal distribution. VaR methods are divided into two groups: Local valuation methods and full valuation methods. The latter covers the historical and the Monte Carlo simulation (Schweser, 2009). VaR approach as a market risk indicator focuses on capturing risk due to uncertainty in asset returns but ignores uncertainty stemming from liquidity risk. VaR methodology does not capture the tail risk adequately as it disregards extreme losses that might occur due to illiquidity as well. Furthermore, VaR is also criticized for not being a coherent risk measure. VaR is not a coherent risk measure because it violates the subadditivity criterion proposed by Artzner et al (1999)<sup>5</sup>. As McNeil et al (2005) discusses; subadditivity reflects the idea that risk can be reduced by diversification, the use of non-subadditive risk measures in a portfolio optimization problem may lead to

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<sup>5</sup> Subadditivity (diversification), Positive homogeneity (scaling), Monotonicity and Transition property. Subadditivity means that risk of a portfolio cannot be larger than the sum of risk measures of each component.

optimal portfolios that are very concentrated and that would be deemed quite risky by normal economic standards. Within this regard, Degen et al (2007) have shown that the lack of coherence can be an important problem for trading book risk measurement. Thus, a risk measurement based on VaR is not necessarily conservative.

Due to such weaknesses of VaR, the ES methodology is also applied by regulators with the desire of overcoming the drawbacks of the VaR methodology. First, ES accounts for the severity of losses beyond the confidence threshold by considering the tail events by averaging the losses above a certain level. Second, it is always subadditive and coherent. Lastly, it is conceptually intuitive and has firm theoretical backgrounds. (Dunn (2009), Artzner et al (1999), Sy (2006), and Yamai and Yoshida (2005)). In this regard, ES can be considered as a step forward in capturing such liquidity effects under the assumption that these liquidity effects cause a tail loss. Thus, neither of these two major market risk measures, VaR and ES, directly takes into account the liquidity risk by itself.

Yet, a number of studies that focus on incorporating the liquidity risk into the market risk has surged recently. Data employed in these studies mostly belong to advanced economies. However, liquidity effects are expected to be more influential on emerging market economies since the depth of capital markets of emerging markets is much lower than those of advanced economies. In line with this, this study attempts to integrate market liquidity concept into market risk analysis for the Turkish Treasury securities market based on Monte Carlo simulation technique. Accordingly, the benchmark government securities are analyzed in terms of their market and liquidity risk since the government securities overly dominate the banks' trading portfolios of the Turkish banks.

Although standard market risk approaches fall short incorporating liquidity risk. There exist some recent researches dealing with liquidity risks in the context of VaR methodology. Bangia et. al. (1999) classified market liquidity risk into two categories: exogenous illiquidity and endogenous illiquidity. Exogenous illiquidity is the result of market characteristics hence it is common to all market players and unaffected by the actions of any participant. Within this context, for instance, there are differences between developed economies and emerging market economies in terms of exogenous liquidity. The market for liquid securities in developed economies is typically characterized by heavy trading volumes, stable and small bid-ask spreads, stable and high levels of quote depth. Hence, liquidity costs are usually negligible for such positions when marking to market provides a proper liquidation value. In contrast, securities of emerging markets or thinly traded bonds are comparatively illiquid and characterized by high volatilities of spread, quote depth and trading volume. In such case of imperfect liquid markets, liquidation of a portfolio may not be executed at mid-market prices and has to be adjusted for the value of the spread.

On the other hand, endogenous illiquidity varies across market participants and is mainly driven by the size of the portfolio: the larger the size, the greater the endogenous illiquidity given the relationship between the liquidation price and the

size of the portfolio held. Accordingly, knowledge of such relationship is crucial for an adjustment of VaR regarding to endogenous illiquidity. While dealing with endogenous liquidity risk, the researches mainly take into account liquidation strategies which aim to maximize the expected value of the portfolio and minimize the volatility of the expected cash flows. Overly, Almgren and Chriss (2000) combine the volatility risk and the liquidation costs that arise from permanent and temporary market impacts and find the best trading strategy in their attempt to calculate an adjusted VaR measure for a given risk aversion and time horizon.

Muller (2008) applies Monte-Carlo method for the stock portfolios by the following steps: (i) prices are simulated according to GBM w/1-day time horizon. (ii) simulated prices are used for obtaining returns with respect to corresponding initial prices. (iii) To estimate VaR, portfolio returns are put in ascending order and the observation corresponding to 1% of the whole sample is determined. (iv) spread is simulated according to a stochastic model, hence the time series of relative bid-ask spread for the portfolio is found and worst possible spread is estimated at the 99% confidence level. Muller (2008) finds that the difference in results between the VaR and L-VaR is not considerably large for illiquid portfolios. However, the difference is considerably high for liquid portfolios.

### 3 Data and Methodology

The analysis initiates by calculating the market risk of the proposed Turkish banks trading portfolio by using standard approaches of VaR and ES methods. The daily observations of 25 benchmark government securities traded in the secondary Turkish markets in the period of 1<sup>st</sup> of January, 2006 and 31<sup>st</sup> of December, 2011 are used. A particular security in the replicated portfolio remains to be a benchmark security for around 3 months at average. After December 31<sup>st</sup>, 2011 coupon bearing government bonds were included as a benchmark security in the market. However, coupon bonds were not included in this work since coupon bearing bonds have larger spreads that may cause fictitious jumps in risk measurement. The algorithm used in the study is presented below;

#### Step 1 - Scenario Simulation

The scenarios for the market risk factors are generated by applying Monte-Carlo simulation. Short term Turkish Lira (TL) interest rates are assumed to evolve according to Cox-Ingersoll-Ross (CIR) model;

$$dr_t = k(a - r_t)dt + \sigma_r \sqrt{r_t} dW_t^r$$

where  $k$  is the speed of adjustment,  $a$  is the long run mean of short rate (i.e., the level),  $dW_t^r$  is the increment of Wiener process,  $\mu$  is the mean of returns on currencies, and  $\sigma$  is the related diffusion parameter (Yildirim et al, 2012).

### Step 2 - Valuation and Spreads

Zero coupon bonds are revalued based on the simulated interest rate scenarios. Though we have the term structures for each of the maturities, we revalue the securities according to the acquired rates, the results reported for 1-week and 1-month are calculated with the time conversion from 1-day VaR as:  $VaR(99\%) (m \text{ days}) = VaR(99\%) (1\text{-day}) \times \sqrt{m}$ . The analysis includes only the zero-coupon bond portfolios since the zero coupon bonds are the dominating bonds of the Turkish banks' trading portfolios. The relative spread series are analyzed considering their historical evolution. The intraday data for the spreads are in rates, then they are converted into prices.

$$\text{Relative Spread} = \frac{BA - BB}{(BA + BB)/2} \quad \text{where BB: Best Bid and BA: Best Ask.}$$

### Step 3 - L-VaR and L-ES

VaR and ES models are modified by incorporating liquidity market risk in line with Bangia et al (1999).

**L-VaR:** According to parametric VaR the steps are as follows (Bervas, 2006):

$$\text{Lowest return expected at } t: R_t^* = \ln\left(\frac{P_t^*}{P_t}\right) = \mu - 2.33\sigma.$$

$P_t$  is the asset price at  $t$ , and  $P_t^*$  is the worst price expected at a confidence threshold of 99%.

$$\text{VaR at } t: VaR = P_t(1 - e^{\mu - 2.33\sigma})$$

Worst relative spread at  $t$ :  $\mu' + 2.33\sigma'$  (we apply historical VaR)

$$\text{Exogeneous Liquidity Cost (ELC): } \frac{1}{2} P_t(\mu' + 2.33\sigma')$$

$$\text{Liquidity adjusted VaR (L-VaR)} = VaR + ELC = P_t(1 - e^{\mu - 2.33\sigma}) + \frac{1}{2} P_t(\mu' + 2.33\sigma'),$$

where 2.33 is the standardized normal distribution quantile for the %99 VaR confidence level.

**L-ES:** Liquidity adjusted ES (L-ES) = ES + ELC.

ELC = Average of relative spreads beyond the VaR level which is  $\mu' + 2.33\sigma'$ .

### Step 4 - Volatility and Normality

Bangia et al (2006) relaxes two assumptions; (i) constant volatility assumption: EWMA/GARCH could be used to calculate volatility. Loebnitz (2006) applies a sensitivity analysis for different volatility levels. (ii) Normality assumption:  $\alpha$  is

set to be very conservative between 2.0 and 4.5. This is an adjustment for fat tails. Extreme returns are considered as leptokurtic distributions. We use constant volatility and do a sensitivity analysis in line with Loebnitz (2006).

#### 4 Estimation Results

In line with the Muller (2008) study VaR values are computed for both L-VaR and L-ES through Monte Carlo simulations. We take the return observation corresponding to the % 1 of the whole simulated sample for the VaR and the average of the observations beyond the VaR level for the ES. Then the losses in returns are translated to the losses in TL amounts as mentioned in step 3. Finally, we report the results as negative values. The Chart 1 and 2 present the VaR, L-VaR, ES and L-ES models with the 99th percentile spread and proxy spread, respectively. Proxy spread is the spread corresponding to 99<sup>th</sup> percentile plus a penalty factor.

The results reported are for a hypothetical portfolio with the key aspects of the Turkish banking sector trading portfolio. We assume a portfolio of non-coupon bearing Government Securities and extend the VaR and ES methodology with the information gathered from the government securities' spread data. As seen from the charts below, the liquidity risk incorporated market risk is much higher than the solo market risk measure. The horizontal axis values are the TL losses out of 1000 TL portfolio. Clearly, adding liquidity component to the VaR and ES of the government securities portfolio comes out with harsher loss figures. Moreover, expected shortfall method outcomes with liquidity penalty express much more conservative figures in terms of the maximum loss of the portfolio on a probabilistic basis.

The analysis is simplistic in its kind that includes one kind of security only. Adding more securities and considering the correlations, the results could be much more severe. The results indicate that around 7 percent of the value of government securities could be expected to be gone in 1-month. However, zooming out to the whole system, considering the relatively small amount of the securities portfolio in banks the found losses are not large to hit the Turkish banking system (Table 1). In Turkey banks mostly collect deposit and allocate their funds on the loans. In the recent years though wholesale funding has increasing tendency, still more than 50 percent of the total liabilities (including the equity) is deposits. As seen from the Table 1, held for trading securities constitute the very small portion of the total assets. The combined total of the securities are around 22 percent of the whole assets (including the ones which are not marked-to-market). Although the nature and the size of the marketable securities do not point out a warning, the dynamic structure of the trading portfolios and the changing risk factors require that banks should take the market liquidity component of market risk into account especially in their bottom up stress tests. So that banks could be relatively more robust to the volatile market environment.



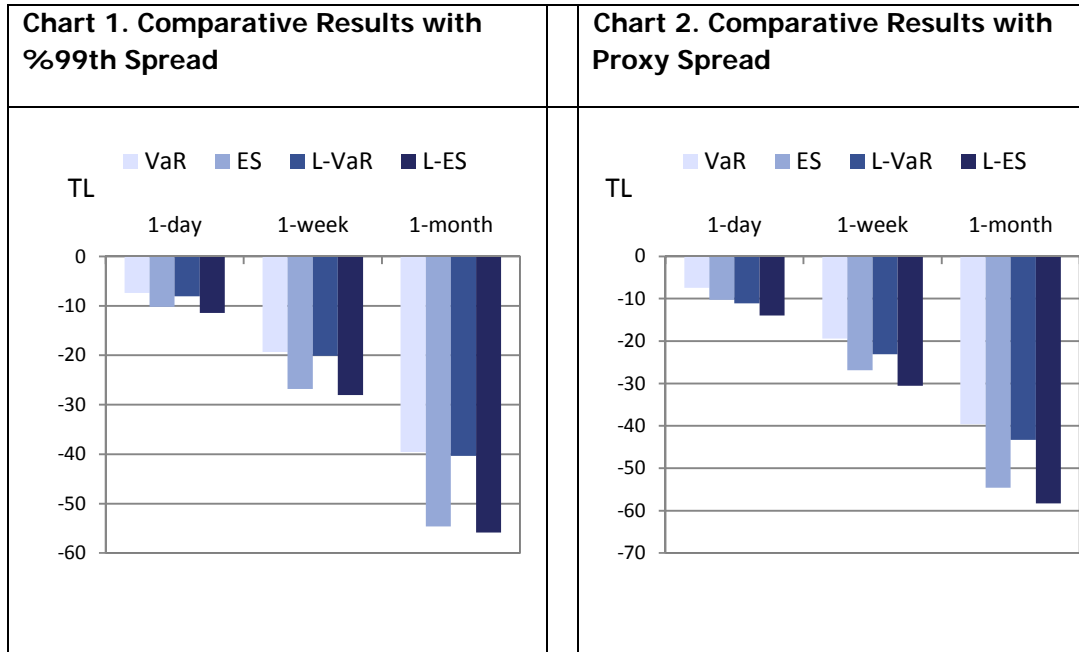


Table 1: Securities Portfolio as a Portion of Turkish Banks' Total Assets

Date	Held for Trading (%)	Available for Sale (%)	Held to Maturity (%)	Total Assets (million TL)
Jan-12	0.85	15.47	7.19	1,213,671
Feb-12	0.87	15.65	6.95	1,221,097
Mar-12	0.84	15.73	6.66	1,228,939
Apr-12	0.77	15.30	6.51	1,255,592
May-12	0.77	15.21	6.50	1,270,603
Jun-12	0.79	15.06	6.47	1,273,739

Source: BRSA-Interactive Monthly Bulletin

## 5 Concluding Remarks

Market liquidity risk is called crucial for the banks' total market risk analysis and it should be integrated into market risk models in order for banks to build a better resistance for unexpected financial risks. For a more conservative risk analysis monitoring market risk by both VaR and ES models is of great importance for the banks and for the entire financial system. This study implies

that the current position of the banks do not imply an alarm for the Turkish Banks; however, rapidly changing market conditions urge banks to conduct further analysis in risk management.

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