Market risk of developed and developing countries during the global financial crisis

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March 2012

Online at https://mpra.ub.uni-muenchen.de/37523/
Market Risk of Developed and Developing Countries During the Global Financial Crisis*

Bülent Köksal † and Mehmet Orhan‡

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Abstract: This study compares the performance of the widely used risk measure Value-at-Risk (VaR) across a large sample of developed and developing countries. The performance of the VaR is assessed by both unconditional and conditional tests of Kupiec and Christoffersen, respectively, as well as the Quadratic Loss Function. Results indicate that the performance of VaR as a measure of risk is much worse for developed countries than the developing ones during our sample period. One possible reason might be the deeper initial impact of global financial crisis on developed countries than emerging markets. Results also provide evidence of decoupling between emerging and developed countries in terms of market risk during the global financial crisis.

JEL Classification Codes: C32; C51; G01; G32.

Keywords: Value-at-Risk (VaR), Developed Countries, Emerging Markets, ARCH/GARCH Estimation, Kupiec Test, Christoffersen Test, Quadratic Loss Function.

* The views expressed in this paper belong to the authors and do not necessarily represent those of the Central Bank of Turkey or its staff.
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1. Introduction

Risk management has become even more crucial after the 2007-2009 global financial crisis that hit the world economy.\(^1\) The risk will be reflected in the risk premium which is determined by the repayment capability of the borrower. Each borrower has to pay the “risk premium” based on his perceived risk. It is surprising to note that several developed countries are influenced from the crisis more adversely than the emerging market economies as reflected by the Credit Default Swap (CDS) rates (see Figure 1).

[Insert Figure 1]

It is interesting that the firms with expertise in risk management have collapsed while or after the global financial crisis.\(^2\) Mismanaged risk together with technological advances in the financial sector contributed to the global financial crisis. A special report published by the European Commission (2009) that examines the anatomy of the crisis states that “The crisis was preceded by long period of rapid credit growth, low risk premiums, abundant availability of liquidity, strong leveraging, soaring asset prices and the development of bubbles in the real estate sector. Over-stretched leveraging positions rendered financial institutions extremely vulnerable to corrections in asset markets. As a result a turn-around in a relatively small corner of the financial system (the US subprime market) was sufficient to topple the whole structure.” Many of the countries had to support their financial intermediaries because of the toxic assets in their balance sheets with significantly lower values.\(^3\) The cost of dealing with the consequences of the crisis created huge budget deficits and contributed to the low economic growth not only in small EU countries like Greece, Ireland, but also in more

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\(^3\) Toxic or troubled assets are the securities that suffer extreme illiquidity and difficult to value.
advanced economies like Spain, Italy and the UK. Basel II Accord provided guidelines in terms of capital requirements for a sound banking system but it was heavily criticized for boosting procyclicality of the banking sector. In response, the Basel Committee on Banking Supervision established revised global standards, known as Basel III.

VaR (Value-at-Risk) is devised as unit free risk measure which is very convenient for practical purposes. In its simplest form it is defined as the maximum expected loss of a portfolio at the given confidence level and holding period. VaR became more popular especially due to its simplicity (Giot and Laurent (2004)). As Berkowitz and O’Brien (2002) put “Value-at-Risk has become a standard measure of financial market risk that is increasingly used by other financial and even non-financial firms as well.” Its popularity increased after Bank for International Settlements and SEC address VaR as a measure to quantify risk as well as Basel Committee on Banking Supervision’s (1994, 1996) imposition of VaR use on financial institutions. The use of VaR in assessing risk is not limited to financial markets only. Giot and Laurent (2003), for instance, make use of ARCH to calculate VaR in commodities markets of aluminum, copper, nickel, and Brent crude oil. Naïve methods like variance-covariance and historical simulation could not survive because of their considerable shortcomings and there is a remarkable progress in computing more accurate VaR but in the expense of more complicated and sophisticated computation techniques that require more effort and time. Advances in the information technology enabled investors to perform VaR estimations that were not possible two decades ago.

This study compares the performance of the widely used Value-at-Risk (VaR) across a large sample of countries and provides evidence of decoupling between emerging and developed economies.

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countries in terms of market risk during the global financial crisis. Current literature about the
decoupling finds that emerging countries were isolated from the developments in the U.S.
financial markets at the beginning of the crisis but followed the rest of the developed
countries afterwards in terms of their reaction to the worsening situation in the U.S.
economy. Our study contributes to this literature by providing evidence of decoupling from
the perspective of Value-at-Risk.

The rest of the paper is organized as follows. Section 2 describes empirical methodology and
data. Section 3 describes the tests to evaluate VaR and discusses the results while Section 4
concludes.

2. Empirical Methodology and Data

VaR is the maximum expected percentage loss possible at a given confidence level for some
specified investment horizon. More technically, VaR \((1-\alpha)\) is defined as the threshold that is
exceeded \(100\alpha\) times out of 100 trials on average. \(1-\alpha\) is the confidence level where \(\alpha \in
(0,1)\) is a real number. The cases where ex-post portfolio returns are lower than VaR estimates
are called violations. One main input to the VaR calculation is the confidence level, \((1-\alpha)\).
Once the confidence level is set, VaR must be calculated in such a way that the violations
should be equal to \(100\alpha\). For instance, if one wants to have the 95% confidence level, then
VaR must be computed in such a way that the loss worse than the VaR will be 5% of all cases
on average. That is, percentage of the losses greater than the suggested VaR will be 5 times
out of every 100 cases on average. Therefore, VaR is the unique number based on the time
series under focus.

See Akin and Kose (2008), Dooley and Hutchison (2009), Felices and Wieladek (2012), Fidrmuc and Korhonen
(2010), Frank and Hesse (2009), Kim et al. (2011), Kose et al. (2008), Saadi Sedik and Williams (2011), Uckun
The second input that is necessary to calculate VaR is the standard deviation or volatility of the returns. Modeling and forecasting volatility is crucial for investors who are interested in the forecast of the variance of a time-varying portfolio return over the holding period to calculate VaR. The long-run forecast of the unconditional variance would be irrelevant for these investors who hold the asset for a certain period only. In a seminal paper, Engle (1982) shows how to model the conditional variance of a time series. Bollerslev (1986) generalizes Engle’s work by allowing the conditional variance to be an ARMA process. These models are called GARCH (Generalized Autoregressive Conditional Heteroskedasticity) models. Most recent and advanced VaR methods make use of GARCH models to calculate the conditional standard deviation.

One issue that has to be addressed is to determine the specific GARCH model to estimate the conditional standard deviation since there have been quite a few models discussed in the literature. In his “Glossary to ARCH (GARCH)”, Bollerslev (2008) lists more than 100 entries. In a related work, Orhan and Köksal (2012) compare the performances of 16 different GARCH specifications for calculating VaR using the same data and sample period as the ones used in this study. Accordingly, we use the conditional variance model selected by that study as the best model which is the simple ARCH model with one lag where the errors follow the t distribution. Specifically, our model for calculating the conditional variance (and standard deviation) is as follows:

\[ r_t = \mu + \epsilon_t \]

\[ \mu_t = \beta_0 + \beta_1 \epsilon_{t-1} \]

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6 See Poon and Granger (2003) for an extensive survey.
8 GARCH model likelihoods are notoriously difficult to maximize. ARCH(1) model has the additional benefit of making convergences easier since the number of parameters to be estimated is smaller than other more complex models.
\[ \varepsilon_i = \sigma_i v_i \]

\[ \text{Var}(\varepsilon_i \mid I_{t-1}) = \sigma_i^2 \]

\[ \sigma_i^2 = \omega + \alpha_i \varepsilon_{t-1}^2 \]

where \( r_t = \ln(p_t / p_{t-1}) \), \( p_t \) being the closing price of a country index (as described in the next section) at the end of day \( t \), \( \mu_t = E(r_t \mid I_{t-1}) \) is the conditional mean, \( I_{t-1} \) denotes the information set available at time \( t-1 \) and \( v_t \) is a sequence of i.i.d. random variables with mean 0 and variance 1. We assume that \( v_t \) follow the standardized Student-t distribution which appropriately deals with the issue of fat tails of returns documented in the financial literature.

In this setting VaR is defined as:

\[ \Pr(r_t < \text{VaR}(1-\alpha)) = \alpha \]

Once the conditional variance terms, \( \hat{\sigma}_i^2 \), are estimated, VaR is defined as:

\[ \text{VaR}(1-\alpha) = \bar{r} - \hat{\sigma}_t \alpha \]

where \( \bar{r} \) is the mean return, and \( \alpha \) is the critical value of the t distribution with right-tail area \( \alpha \).

Although there are papers in the literature that calculate the VaR by utilizing GARCH models, to the best of our knowledge, this is the first study that compares the performance of VaR across a large sample of developed and emerging market economies by using data from the period that includes the recent global financial crisis.
We make use of the country indices for 44 developed and emerging market countries obtained from MSCI website. This website describes the construction of the indices as “To construct a country index, every listed security in the market is identified. Securities are free float adjusted, classified in accordance with the Global Industry Classification Standard (GICS®), and screened by size, liquidity and minimum free float.” For each country, we use a total number of 1887 daily returns starting from May 30th, 2002 to August 24, 2009 to estimate the conditional standard deviations for VaR calculations using a 1000-day rolling window. Because of the rolling-window methodology that we employ, our final sample includes 888 estimated values of conditional standard deviations for the period March 30th, 2006 - August 24, 2009 which overlaps with the global financial crisis. We calculate both in-sample and out-of-sample comparisons but report only the out-of-sample figures as the in-sample results are similar.

3. VaR as a Measure to Assess Market Risk

Basel Committee on Banking and Supervision asked for the implementation of VaR as well as the out-of-sample backtesting (Escanciano and Olmo (2011)). There are basically two approaches that use back-testing to compare the performance of VaR calculations in the finance literature. The “unconditional” approach does not take the sequence of violations into account. Using this approach, Kupiec (1995) defines the following test statistic that follows the $\chi^2$ Distribution with 1 degree of freedom:

$$K = 2 \ln \left( \left(1 - \frac{F}{N}\right)^{N-F} \left(\frac{F}{N}\right)^F \right) - 2 \ln \left( (1-\alpha)^{N-F} (\alpha)^F \right)$$

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10 Rolling-window methodology requires 44 countries $\times$ 888 = 39072 estimations in total.
where \( N \) is the total number of trials and \( F \) is the number of violations. If a method is perfect in returning the VaR figures, \((F/N)\) will converge to \( \alpha \) as suggested by the null hypothesis, \( H_0 \), and \( K \) will be approximately zero. In the opposite case, the difference between percentage of violations and \( \alpha \) will be larger causing the test statistic to increase which means that the likelihood of null’s rejection will be higher.\(^{11}\) Kupiec Test assumes that the number of failures, \( F \), follows the Binomial Distribution with parameters \( N \) and \( \alpha \). Based on the selected level of \( \alpha \), rejection of the Kupiec test’s null hypothesis for a country implies that VaR is not very useful as a measure of market risk for that country.

Table 1, Panel A reports the Kupiec Test statistics for 5% and 1% significance levels as well as the proportion of violations for developed countries. Ideally, the proportion of violations should be approximately 0.1, 0.05, and 0.01, for VaR with 90%, 95%, and 99% confidence levels, respectively, and the Kupiec Test statistic should be close to 0. Panel B reports the number of rejections and non-rejections. Overall conclusion from Panel B is that # of rejections is much larger than the number of non-rejections implying that VaR as a measure of risk was not successful for developed countries during the crisis period.

[Insert Table 1]

The VaR methodology performed poorly particularly in Austria, Belgium, Canada, France, Italy, Norway, Spain and Sweden where the null hypothesis of the Kupiec test was rejected at all 90%, 95%, and 99% VaR confidence levels. VaR was a good measure of risk for Portugal, and Finland, followed by Singapore, Japan, and the USA.

[Insert Table 2]

Table 2, Panel A reports the performance of the VaR for developing countries. The null hypothesis was rejected at all significance levels for Hungary. There are slightly poor

\(^{11}\) Percentage of violations being less or greater than \( \alpha \) does not matter.
performances of VaR for Colombia, Israel, Mexico, Poland and Russia. Several developing
countries including Korea, Malaysia, Morocco, Peru, Philippines, Thailand and Turkey have
no rejections. It is possible to say that VaR has some value as measure of risk for Indonesia
and for emerging market giants China, Brazil, and India. Table 2, Panel B reports the number
of rejections and non-rejections for Kupiec test. Number of non-rejections is much larger than
the number of rejections. A comparison of Panels B in Tables 1 and 2 clearly reveals that there
was decoupling between emerging and developed countries in terms of market risk during the
global financial crisis.

The two shortcomings of the Kupiec Test are that it does not take into account of the
sequences of violations and it has limited power. To improve on the first shortcoming,
Christoffersen et. al. (2001) design a test which gives emphasis to the predecessor of a
violation. In case the violations are independent, the ratio of preceding violations and non-
violations should not be significantly different.

If we define $n_{ij}$ as the number of observations $i$ followed by $j$ ($i, j = 0,1$) where 1 indicates
a violation and 0 indicates a non-violation, then the test statistic

$$ C = 2 \ln \left( \frac{(1-\pi_00)^{n_{00}} \pi_01^{n_{01}} (1-\pi_11)^{n_{10}} \pi_{11}^{n_{11}}}{(1-\alpha)^N-F \alpha^F} \right) $$

where $\pi_{ij} = \frac{n_{ij}}{\sum_j n_{ij}}$, follows the $\chi^2$ distribution with 2 degrees of freedom. If there is
independence of the violations, then the numerator and denominator will be approximately
same and the test statistic will be close to 0.

[Insert Table 3]
Table 3 reports the results from the Christoffersen Test for all countries. Note that the test rejects the appropriateness of VaR for Canada, Denmark, France, Greece, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and UK at all levels of significance. Developing countries for which VaR performs poorly seem to be Colombia, Czech Republic, Hungary, India, Mexico, Morocco and Poland. The only country with non-rejections at all confidence levels is Turkey. Table 3, Panel B tabulates the number of rejections and non-rejections for the developed and developing countries separately. Overall conclusion from Table 3 is that the developing countries still have less rejections than the developed ones, but the difference is somewhat smaller when compared to the Kupiec test results reported Table 2.

The last comparison we make is based on the Quadratic Loss (QL) function. Tests based on the number of rejections at different confidence levels give an idea about the performance of VaR as a measure of risk, but they do not take the magnitude of performance loss into account. Therefore, we make use of a loss function in order to assess the magnitude of the poor performance of the VaR. Define the QL (Quadratic Loss) function as:

$$QL_t = \begin{cases} 1 + (r_t - VaR_t)^2 & \text{if } r_t < VaR_t \\ 0 & \text{otherwise} \end{cases}$$

for t\(^{th}\) day’s VaR. Since there were no convergences for some cases, we calculate the Average Quadratic Loss (AQL) for each country and for each VaR confidence level to make comparisons.

[Insert Table 4]

Next we rank countries based on these averages. Table 4, Panel A shows these ranks in parentheses just below the country names. Among the developed countries, Hong Kong has the minimum average quadratic loss followed by Finland, Portugal and Singapore. The
highest average loss belongs to the securities markets of Norway, Canada and Italy. USA, Japan and Germany have relatively low AQLs.

Regarding the developing countries, the minimum AQLs belong to Israel and China followed by Colombia and Russia. The worst performing securities markets in terms of VaR as a measure of risk are Hungary, Poland, and Brazil. The VaR performs well for Russia and China but it performs poorly for Brazil and India.

Table 4 Panel B, reports the mean AQL for developed and developing countries at each VaR confidence level. The mean figures for developing countries are smaller than the ones for developed countries, providing some additional evidence for the decoupling discussed above.

4. Conclusion

This study examines the performance of Value-at-Risk (VaR) as a risk measure across a large sample of developed and emerging countries by utilizing unconditional and conditional tests of Kupiec and Christoffersen, respectively, and the Quadratic Loss Function. There are three main conclusions from our study. First, the performance of VaR as a risk measure was worse for developed countries than the developing ones during the global financial crisis. One possible reason might be that the developed countries have been affected from the crisis more adversely when compared to the emerging countries. Second, our results reveal some evidence of decoupling between emerging and developed countries in terms of market risk during the global financial crisis. Finally, as the rejection of the appropriateness of VaR for many countries indicates, alternative measures of risk should be used together with VaR and the performance of these risk measures should be regularly evaluated to improve the assessment of risks in a market. It would be interesting to see whether our conclusions
continue to hold when other measures of risk together with different methodological choices are implemented.
References


**Figure 1.** Credit Default Spread Indices (01/01/2007=100)

- **Developed Countries**: Austria, Belgium, France, Germany, Greece, Italy, Japan, Portugal, Spain, Sweden.
- **Emerging Countries**: Brazil, Chile, China, Colombia, Czech Rep., Hungary, Indonesia, Israel, S. Korea, Malaysia, Mexico, Peru, Philippines, Poland, Russia, S. Africa, Thailand, Turkey.

*Source.* Bloomberg

*Note.* CDS Index=100 for 01/01/2007 for each country. The rest of the index is calculated based on percentage changes in CDS spreads. Then average index is calculated for developed and developing countries that have data starting from January 2007.
### Panel A.

<table>
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**, and * denote rejections at the 1%, and 5% levels, respectively. F/N is the proportion of violations. The critical values for 1%, and 5% significance levels of the Chi-Square Distribution with 1 degree of freedom are 6.64, and 3.84, respectively.

### Panel B.

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*: Insufficient number of convergences for Egypt.

**, and * denote rejections at the 1%, and 5% levels, respectively. F/N is the proportion of violations. The critical values for 1%, and 5% significance levels of the Chi-Square Distribution with 1 degree of freedom are 6.64, and 3.84, respectively.
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+, **, and * denote rejections at the 1%, and 5% levels, respectively. The critical values for 1%, and 5% significance levels of the Chi-Square Distribution with 2 degrees of freedom are 9.21, and 5.99, respectively.
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</tbody>
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#### Panel B.

<table>
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<th>VaR</th>
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</tr>
<tr>
<td>99</td>
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</tbody>
</table>