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# Financial Crisis of 2007-2009 and Stress Test with Structural Changes for the Brazilian Financial Market

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**Abstract**

The financial crisis of 2007-2009 indicates the importance of analysis committed to measuring risk involving financial activities. Thus, the central objective of this work is to estimate parameters of a financial distress in daily return series of the Brazil's market index (Bovespa index) on the daily return series of the major companies' stocks in the Brazilian financial market, considering the period of international economic crisis and possible structural changes in the stress parameters. In this way, we capture the spillover effects using the methodology CoVaRand analysis of structural changes in Quantile Regression (QR). The results show that some of the reaction coefficient of the stock returns of companies operating in the Brazilian financial market had structural changes, as well as the value at risk of the market index decreased between the two periods. In general, the marginal contribution of financial distress in the market index generated a lower stress on the returns of companies stocks after the international crisis, possible indicating Basel III effects on Brazilian financial markets.

**Keywords:** Stress Test, Regulatory Impact Analysis, Structural Changes, Financial Crisis

**JEL Code:**C21; G30; G32

## 1 Introduction

In the last years, there was a fast advance of methodologies that aim to measure the risks to which the portfolios of many financial institutions and others firms operating in the markets are submitted.

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In a general way, those methodologies intend to provide quantitative support to the problem observed during the recent American crisis, which affected the global market.The traditional risk measurement, like Value at Risk (VaR) introduced by Leavens (1945), evaluates the maximum loss of a given portfolio, in a determined period.

Actually, we need of indicators that take into account the effects of negative externalities from astock returns on the others. That way, the indicators proposed by the CoVaRmethodology, which are described by Adrian and Brunnermeier (2011), have the advantage of conditioning the risk measures obtained by VaR to the worst losses also occurred in the other portfolios and financial market indicators. Arias, Mendoza and Perez-Reyna (2010) and Lima, Gaglianone and Oliver (2011) show many arguments by which the attributes of the risk measure provided by CoVaR make it possible to be used as a way of proper risk management in the financial markets.

However, the CoVaR model do not consider that structural breaks in the risk parameters motivated by changes in economic context, for example, can affect the spillover effects. Recently, the global economyhas seen one of the biggest crisis in history, in which the financial market had direct contribution. Thus, we question whether the economic crisis was able to alter the risk measures as stress test obtained by CoVaR model.

In this context, the question of structural change has been focus in several studies. Since the works of Chow (1960), Fisher (1970), Gujarati (1970a; 1970b), Dufour (1980) and Burrows and Cantrell (1990) a variety of tests and applications have been made, specially, to verify structural change in the conditional mean function. However, risk measures require evaluating at the negative extreme of the distribution, as well as an analysis whether the stress test on stock returns between different companies has changed over time.

By this way, in this work we propose to estimatethe stress test obtained by CoVaR model, with structural changes in quantile regression. Based in Qu (2008) and Oka and Qu (2011), we develop tests for structural break on daily return time series of the major companies operating in the Brazilian financial market, considering possible effects of the economic crisis 2007-2009 on changes in the risk parameters.

The innovation of this study is to incorporate structural changes in the CoVaR estimation to capture changes in the spillover effects, possible indicating Basel III effects on Brazilian financial markets.

Given the need for advances in the construction of types of measures for the risk management of domestic financial market, the present work evaluates as a distress in the series of financial returns of national market indicator impactsthe main returns of companies' stocks that operate in BM&FBovespa. For this, the methodology CoVaR with structural changes was applied to the daily quotations data of the 16 assets selected from January 2003 to August 2011.

The paper is organized as follows. Section 2 shows the relation riskmeasures, financial management and the estimated parameters obtained using the CoVaR model. Section 3 brings basic definition about CoVaR model, emphasizing the stress test measurement and the main equations to estimating the risk parameters with structural changes. Section 4 describes the dataset and section 5 and 6 contains the central results and final remarks.

## 2. Riskmeasuresand Financial Management

As mentioned before, the risks which affectfinancial marketsthrough stocks returns are also used to regulate those markets, with the purpose of them rule properly. The regulation focuses in most part, on estimations and measures of the risks to which financial markets are subject, that is, robust variance parameters relating to fluctuations of several types of stocks returns. The variance and its patterns, such as clustering, stochastic behavior, etc. is named volatility. It consists of a measure of the dispersion of the density probability function of the temporal stochastic process, given by the stock returns (TSAY, 2005).

Volatility is not an observable measure and is assumed as a measure of risk in financial markets since Markowitz (1952). Furthermore, it could be decomposed into implicitvolatility and stochastic volatility. The first one refers to that calculated over the life of the derivative contracts, ofcalls and puts, for example. The stochastic volatility is obtained by using of statistical models applied to historical data of stock returns.

However, according to Elton and Gruber (2007), Fabozzi, Modigliani and Ferri (1994) and as the object of this research work, maybe more important than obtaining robust estimates of volatility, are the efforts to estimate how more substantive losses in stocks returns arecorrelated.In this sense, among the mainsafetyprocedures for the international financial system, described first time in a set of agreements of the Basel Convention[3], in 1988, compromises with financial institutions to createand obtain volatility indicators, in an attempt to understand how those markets works appropriately.

The Basel Convention was the most important mark inside the regulatory process of global financial markets and it had three accords: 1988, 2002 and 2010, respectively. Documented as well, as Basel I, II and III.Studies as from Raghuram (2005) and Shadab (2002) have already reported the danger of fast growth without limits of financial markets on the real side of economies, but only after the American Crisis, the implementation of safety procedures todealwithfailures come from financial and monetary markets.

An advance in the so-called Regulatory Impact Analysis (RIA)[4], constituted by principles of efficiency, accountability and transparency, which seek to encourage the development of markets and, at the same time, make them answersome expectations of society, is denominated autoregulation. It is a process within many biological systems, resulting from an internal adaptive mechanism that works to adjust that system's response to incentives. In financial markets it consists of a type of regulation proposed by financial institutionsthemselves, when they measure and generate quantitative and qualitative indicators of their investments, by providing efficient mechanisms of risk management.Those mechanisms are constituted of models, for instance, the models VaR, among many others. In other words, in this type of regulation, financial institutions create their risk management mechanisms which can be based on parameters quantifications and forecasts on the behaviors of some variables which can be important for their management, and whose methodologies can be robust, shared and approved by the regulation agent.

[3]Regarding the regulation of FIs, in 1988, the central banks of G10 countries signed the Basel Accord. In line with this accord, the central banks would be responsible for establishing minimal limits of paid-up capital and net equity to which FIs would be subject. In Brazil, the Basel Accord was present through the resolution number 2,009 dated 08.17.1994 from CMN, and aimed to adjust SFN to solvency and liquidity standards proposed in the accord.

[4] Consists of a systemic approach to critically assessing the negative and positive effects of proposed and existing regulations and non-regulatory alternatives. See more about it in OECD (2008) and The Treasury (2013).

One of the contributions given by autoregulation is the recent third edition of Basel Accord. Among other proposals, the third edition of the accord came to prevent the increase of banks'patrimony based on the additional credit provision, i.e., the excessive use of securitization of receivables. Besides the increase of operations which help to reduce the Basel Index (BI) (LOUTSKINA, 2011).

Furthermore, the attempt is to reclassify the operations which provide coverage in new roles amongst those of high risk to the system. For example, as in the case of market makers, during the process of the capital opening of companies, Initial Public Offerings (IPOs), in which immediately create, in a chain arrangement markets, new ones, where financial derivatives[5] negotiation are potentially harmful to the system. By other hand, the governmental operations, which contaminate portfolios' risks, consequently, press the decisions of central banks; and those which, generally, have less marginal contribution for the systemic risk.

The idea is to separate the financial activities in order to improve the characterization of the activities known as speculative dealing, and the matched-book ones. The banks of the countries which joined the agreement organized by 27 countries, among which the Brazilian financial institutions will have to triplicate, or better, more than this, from 2% to 7%, the index of so-called high quality capital over the shareholders' equities, in order to try to avoid that new financial collapses could deeply affect the economy. Even with Brazil figuring in a relatively better position regarding these aspects, when it is compared to European financial institutions, the proposals contained in the Basel III should bring in some changes. This is our purpose: test structural changes in parameters of $\Delta$CoVaR, which represents institutional changes, therefore spillovers' changes in Brazilian financial markets.

In practical terms, one of the problems faced in estimation of parameters, regarding financial market, is that the volatility comes up more frequently as a variable form over the time (clusters), compare with the constant form. It may occur with higher or lower variability, evolves continually in time and reacts differently of positive and negative values of stochastic process of returns, i.e., losses and gains. This occurs because the reactions of agents in face probabilities of losses are different of their reactions in face of gains of same proportion.

[5] See more about derivatives of call and puts in Wilmott (1998).

One of the causes pointed out in the explanation of this fact is the so-called leverage effect[6]. Another common problem associated to the processes in which exists volatility, is the distribution of leptokurtic data, i.e., processes with heavy tails. In summary, all these characteristics and stylized facts about the behavior of volatility promote a wide-ranging debate and many efforts on how to obtain it,as accurately as possible.

## 3 CoVaR Model

The information which may be more relevant under the viewpoint of the regulation of markets is supported in the work of Adrian and Brunnermeier (2011) and, consequently in the present work. It is refer to the identification of marginal contribution of the risk existing in stock return series of a private company or portfolio for others, in relation to systemic risk and vice versa. As suggested by such authors, the estimation of CoVaR for quantileregressors – whose properties of robustness can be seen in Lima, Gaglianone and Oliver (2011) for the VaR case – makes this measure feature among the measures recently developed with an utmost degree of precision.

In this sense, Adrian and Brunnermeier (2011) define the contribution of a determined institution for the systemic risk such as the difference between conditional CoVaR of the company asset that is under financial distress and CoVaR of returns of the asset on the median, i.e., quantile 50%. The prefix "Co", which was incorporated to VaR by the authors already mentioned, has wider coverage and it can be referred to conditionality, co-movement, contribution and contagion.

For this reason, it is a more robust and wider methodology than VaR, due to the possibility of capturing three fundamental aspects: the systemic risk, the contagion effect and stress test. Besides CoVaR, there is $\Delta$CoVaR, whose purpose is to measure the marginal contribution of a private institution for the global systemic risk. It consists of an assessment of the performance of portfolios by the difference of returns of the main companies that operate in financial market and market returns.

[6] The leverage effect include the fact that, in moments of fall in the prices of roles, the companies keep their liabilities constant in short term, making the ratio liabilities/patrimony grow up. That said, the company in question becomes more leveraged, which can grow the degree of uncertainty regarding its future and, consequently, the volatility of its price role in the market.

The regression estimated by quantiles, whose method was initially proposed by Koenker and Bassett (1978) is a type of regression used to carry out estimates based on several quantiles of a sample, i.e., through this method it is possible to obtain estimates approximated both of the median as of any other quantiles desired, from the dependent variable in analysis.

This way, it can be a tool to obtain better information. They are not provided when it is used the Ordinary Least Squares Method (OLS), which, differently, provides estimates approximated of the conditional mean of the dependent variable based on determined values of the explanatory variables. In studies that use economic or financial data such as in this one, the models of quantile regression have been widely used, because they conduct to a more complete statistical analysis of stochastic relations among random variables (KOENKER, 2005).

This method has been spread in studies over the past few years, emerging as an approach for the statistical analysis of data through linear models, by expanding themselves in direction of non-linear models, widening, therefore, the possibilities of regression methods (KOENKER and MACHADO, 1999). Buchinsky (1998) and Koenker and Basset (1978) consider that one of the advantages of using the quantile regression to estimate the median, instead of OLS, is that the quantile regression result can be more robust, in response to outliers, for example, or distributions of residues which do not present normality.

In Lima, Gaglianone and Oliver (2011) the parameters of model VaR estimated through quantile regressions presented important properties concerning robust estimates. That was important in order to decide how to obtain the estimations of the several measures provided from the model CoVaR. Denoted by $CoVaR_q^{j|i}$, CoVaR, in this case, is VaR of the financial stock of company *j*, conditioned to some event C($X^i$) to the stock of company *i*. In other words, $CoVaR_q^{j|i}$ is nothing but the *q*-n-to-default quantile of conditional probability distribution function. In this work, the quantiles analyzed were 1%, 5%, 10% and 50%, which mean the distribution median and the other ones the negative extremes of stockreturns distribution represent a financial distress scenario:

$$\Pr\left(X^j \leq CoVaR_q^{j|C(X^i)} | C\left(X^i\right)\right) = q \qquad (2)$$

Thus, the proposal of Adrian and Brunnermeier (2011) was to generate a measure which could promote the monitoring of behavior from the stock returns of the companies and identify those characterized by the impact caused from a higher negative externality (higher spillover effect) on the system and/or for the other stocks. Even as the individual risk measures do not contain the information on externalities to they are subject, the marginal contribution was estimated, i.e., $\Delta CoVaR$ of the returns of stock*i* on asset*j* in a situation of financial distress. Therefore, it was possible to show how potential losses from *i* are transmitted to *j* and how the stockreturns of companies suffer impacts of the main domestic index, as well as in which way they contribute to a distress in the returns of it.

The equation (3) shows the definition of $\Delta CoVaR$. It exhibits the marginal contribution of *i* to *j*, which is determined by the difference between the value at risk if *j* in the quantile q, conditioned to the value at risk of *i* in the same quantile and the value at risk of *j* in the quantile*q,* conditioned to the value at risk of *i* in the median:

$$\Delta CoVaR^{j|i} = CoVaR_q^{j|X^i=VaR_q^i} - CoVaR_q^{j|X^i=VaR_{50\%}^i}, \qquad (3)$$

where$CoVaR_q^{j|X^i=VaR_q^i} = VaR_q^j|VaR_q^i$; $CoVaR_q^{j|X^i=VaR_{50\%}^i} = VaR_q^j|VaR_{50\%}^i$. These terms show the definition of $\Delta CoVaR$. On the basis of the interaction and specification between the assets*i* and *j*, from this approach, it is possible to obtain three measures of risk management: systemic risk, stress test and contagion effect. However, this article will emphasize only stress test, including structural change in this risk measure.

### 3.1 Stress Test with Structural Change

The stress test, which is a direct contribution of the work of Adrian and Brunnermeier (2011), can be defined as the marginal contribution to the vulnerability of the stock returns of company *i*, conditioned to a financial distress in the system (market returns). Therefore, it is different from the similar concept presented by Markowitz (1952). According to the convention used in this work, the stress test shows the negative externality of the lower quantiles of stockreturns of a particular company which operates in domestic financial market on the “stock market returns”.

However, the traditional approach introduced by Adrian and Brunnermeier(2011) does not consider that any events can generate structural changes on the parameters of stress test. In the literature, we found classical studies as Chow (1960), Gujarati (1970a; 1970b) and Fisher (1970) on the statistical validation of structural changes in the parameters of economic models, for example, motivated by changes in economic (crisis and advances in productivity) and policy context (war and end of dictatorships). These studies were made tests for structural changes in linear regressions.

Recently, Qu (2008) and Oka and Qu (2011) developed tests for structural changes in quantile regression, because the changes, according to authors, can be different among the quantiles of the conditional distribution. In our case, we intend incorporate structural changes in the CoVaRestimation.

We consider the last international economic crisis between 2007 and 2009, highlighted by NBER, as a division of a period that generated potential changes in the coefficients of the CoVaR model. Thus, we have, basically, two periods: before and after crisis.

In domestic case, it is possible to score the stocks of the companies' that suffer the highest negative impacts, estimated by the worst losses in the stock market returns (captured by Ibovespa), in which the stress test is presented as another monitoring and management measure. For the estimation of $\Delta CoVaR^{i/M}$, it is firstly necessary to estimate $VaR$ of the stock returns of company *i*conditioned to the value at risk of stock market return, M. Therefore, we calculate this equation usingquantile regression with structural changes, in which *D* represents the crisis indicator (*D*=0, if before crisis, and *D*=1, if after crisis). By taking into account the definition of $VaR$, we have the following:

$$VaR_q^i|X^M = \hat{X}_q^{i,M} \quad (4)$$

where:

$$\hat{X}_q^{i,M} = \hat{\alpha}_q^M + \hat{\theta}_{0q}D + \hat{\beta}_q^M X_q^M + \hat{\theta}_{1q}DX_q^M \quad (5)$$

The term $\hat{X}_q^{i,M}$ denotes the value estimated for stock returns of company *i* in the quantile*q*conditioned to thestock market returns in the quantile*q*.

In this scenario, the definition of value at risk of the company stock*I* conditioned to system M, $CoVaR^{i|X^M}$, to the *q*thquantile of distribution is given by the equation (6):

$$CoVaR^{i|X^M=VaR_q^M} = \begin{cases} \hat{\alpha}_q^M + \hat{\beta}_q^M VaR_q^M, if \hat{\theta}_{0q} = \hat{\theta}_{1q} = 0 \\ \left(\hat{\alpha}_q^M + \hat{\theta}_{0q}\right) + \left(\hat{\beta}_q^M\right) VaR_q^M, if \hat{\theta}_{0q} \neq 0 \; and \hat{\theta}_{1q} = 0 \\ \left(\hat{\alpha}_q^M\right) + \left(\hat{\beta}_q^M + \hat{\theta}_{1q}\right) VaR_q^M, if \hat{\theta}_{0q} = 0 \; and \hat{\theta}_{1q} \neq 0 \\ \left(\hat{\alpha}_q^M + \hat{\theta}_{0q}\right) + \left(\hat{\beta}_q^M + \hat{\theta}_{1q}\right) VaR_q^M, if \hat{\theta}_{0q} \neq 0 \; and \hat{\theta}_{1q} \neq 0 \end{cases} \quad (6)$$

Using equation (6) we have four situations for stress test before and after the economic crisis: CoVaRdid not show statistically significant changes neither the intercept nor the reaction/response parameter (slope); only statistically significant changes on the constant; only on slope coefficient; in both parameters.

Formally, the following expression define the stress test, in which, empirically, it is possible to measure and score the companies' stocks that are more negatively correlatedwiththe market as a whole in a financial distress scenario, by pointing out the companies' stocks that may be more representative in this sense before and after changes on the context economic. Supposing a significantstructural change (specifically, on reaction parameter), we would have two risk measures for a given company stock:

$$\begin{aligned} Before\ Crisis: \Delta CoVaR_b^{i|M} &= \hat{\beta}_q^M \left(VaR_{bq}^M - VaR_{b50\%}^M\right) \\ Afeter\ Crisis: \Delta CoVaR_a^{i|M} &= \left(\hat{\beta}_q^M + \hat{\theta}_{1q}\right)\left(VaR_{aq}^M - VaR_{a50\%}^M\right) \end{aligned} \quad (7)$$

In the case of stress test, the work highlighted two instability measurements to the companies' stocksof domestic market, including:

Assessment of how a low stocks returns in the national financial system are correlated with the low companies' stocks returns; Analysis of how a change in economic context is correlated with the stress test of companies' stocks returns.

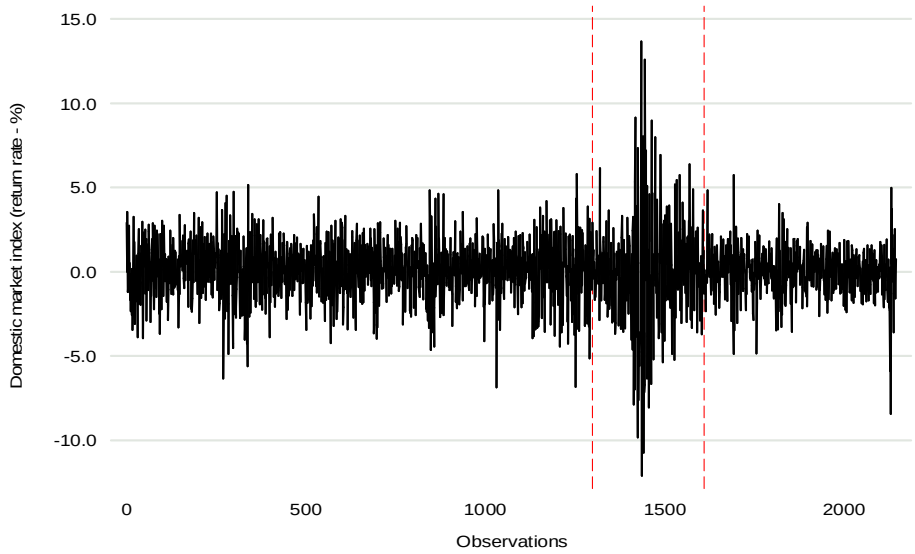
These two types of measures allow the scoring of the companies'stocks which are most impacted by worst losses in domestic stock market returns, as well as it is possible to estimate the company stock more directly are correlated with changes in the economic context.

## 4. Database

According to the delimitation of the economic crisis organized by National Bureau of Economic Research[7] (NBER), we note that the duration of the last economic crisis in the U.S. was between December 2007 and June 2009. Assuming the great influence of this country over the global economy, we developed tests for structural breaks in the equation (7), obtained through the CoVaRmethodology.

To avoid possible disturbances caused by the economic crisis between 2007 and 2009, we discard this period for the stress test estimation. In Figure 1we can see that the Ibovespa returns had a greatervariationin the period of American crisis thanobserved in the time series sample. Thus, the structural break test aims to identify the characteristics of the strong economic decrease in the Brazilian financial market before and after the American crisis period, testing the hypothesis of a significant change in the reaction coefficient of financial distress in the stock market returns on the stock returns of majorscompanies of the BM&FBovespa.

**Figure 1: Ibovespa Returns (Domestic Market Index) between 01/02/2003 and 08/26/2011 – Brazilian Financial Market**




Source: Authors elaboration.

*Note: The red dash lines represent the periods of economic crisis in U.S.*

[7] Available at: www.nber.org/cycles.html.

For this analysis we considered the selected companies used to calculate the IBovespa of the first quarter of 2011 (from May to August). Regardless, another requirement for the participation was the consistent availability of information on daily quotations of the stocks in the investigated period. In the Appendix, the Table A1 describes the stocks from the companies, as well as the descriptive statistics of the stock returns of those companies and the domestic market index.

The time series sample usedwas selected by the fact that follows: after some years of strong economic instability and many monetary reforms, the Brazilian post-1999 inflation has shown more controlled and stable, as well as the national currency has kept the same. The data sample used for the analysis was obtained directly in the system Economatica® and it was built with 1,756 daily observations on the closing prices of each stock between 01/02/2003 and 08/26/2011.

The sixteen companies considered represent in September 2012 about 50% of the market value of each company in terms of total market value of all companies of BM & FBovespa.

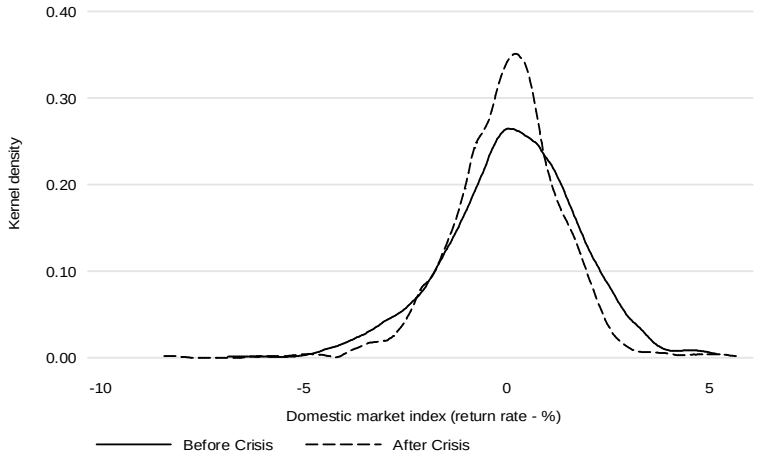
## 5. Analysis Results for Brazilian Case

This section presents the results of the stress test, a risk measure, in a context of structural change in the parameters, in which the objectivewas to identify the companies' stocksofBM&FBovespa that were most correlated with the return of domestic financial market (Ibovespa) in asituationof crisis. Our focus was to study the specific effects on the negative extreme of the distribution, because the tails of distributions has important information about distress periods of the stocks returns.

The economic crisis that began in late 2007 in the U.S. had a negative impact on the world economy. In Brazil, the effects of the crisis were felt in output growth in the last quarter of 2008 and, especially, in 2009, during which there was a negative real GDP growth of 0.33%. In the Brazilian financial market, the impact occurred faster than the real economy, since mid-2008 the indicator of the domestic market, Ibovespa, had a large increase in the variability of their returns (see Figure 1).

In order to identify possible changes in the Brazilian financial market after this period of international crisis, the Figure 2 shows the distribution ofIbovespa returns before and after this period.Remember that this illustration was done disregarding the crisis period itself, due to the objectives of this work that intends to evaluate just the consequences of economic crisis on stress test indicator.

**Figure 2: Distribution of Ibovespa Returns (Domestic Market Index) Before and after International Economic Crisis**




Source: Authors elaboration.

As we can see in Figure 2, the distribution of the domestic index returns in both periods has some differences, highlighting the returns curveafter the crisis was relatively flat. This information corroborates the fact that the post-crisis environment, the variability of the return on the domestic market decreased approximately 11%. Furthermore, Figure 2 indicates the existence of possible changes in the tails of the distribution after crisis, especially at the tail end of the negative distribution. With this information, we have a signal of the importance of analyzing the risk measures, such as the stress test, considering a context of structural changes in the parameters.

Table 2 shows the results for the structural change test for the parameters of CoVaR model. This test, based on Qu (2008) and Oka and Qu (2011), was calculated for the percentiles 1, 5 and 10 of all stocks companies'returns of the sample. The null hypothesis of this test admits that there was not change on parameter between the periods.

**Table 2: Structural Change Test for CoVaR parameters (Quantiles 0.01, 0.05 and 0.10)**

| Quantile | Assets | Constant | | | Slope | | |
|---|---|---|---|---|---|---|---|
| | | Before Crisis | After Crisis | Significant change? | Before Crisis | After Crisis | Significant change? |
| **0.01** | **PETR4** | -3.036 | -3.0751 | | 0.8799 | 1.0372 | |
| | **PETR3** | -3.467 | -2.9100 | * | 0.8279 | 1.1018 | |
| | **LAME4** | -4.242 | -3.7703 | | 0.5934 | 1.3627 | ** |
| | **AMBV4** | -3.617 | -3.0802 | | 0.7055 | 0.3563 | |
| | **PCAR4** | -4.718 | -3.5650 | * | 0.839 | 0.6312 | |
| | **BBAS3** | -4.751 | -2.6040 | *** | 1.079 | 1.0288 | |
| | **BBDC4** | -3.134 | -2.2488 | ** | 0.8306 | 0.8270 | |
| | **ITSA4** | -3.021 | -2.9731 | | 0.8231 | 1.0221 | |
| | **ITUB4** | -2.923 | -2.7631 | | 0.8147 | 1.3017 | *** |
| | **VALE5** | -3.744 | -2.2030 | *** | 0.5988 | 1.2642 | ** |
| | **CSNA3** | -3.999 | -3.0358 | ** | 1.07 | 1.1104 | |
| | **GGBR4** | -3.57 | -3.2488 | | 1.054 | 1.1190 | |
| | **USIM5** | -3.956 | -4.2387 | | 1.257 | 0.4984 | * |
| | **GOAU4** | -3.459 | -3.3205 | | 0.8915 | 1.0123 | |
| | **VALE3** | -4.13 | -2.2220 | *** | 0.6601 | 1.2496 | ** |
| | **CMIG4** | -4.129 | -3.2363 | ** | 0.8784 | 0.6883 | |
| **0.05** | **PETR4** | -2.074 | -2.0463 | | 0.9384 | 0.9432 | |
| | **PETR3** | -2.288 | -2.1034 | | 0.8881 | 0.9770 | |
| | **LAME4** | -3.001 | -2.4348 | *** | 0.6553 | 1.0808 | *** |
| | **AMBV4** | -2.288 | -1.9980 | | 0.5624 | 0.4919 | |
| | **PCAR4** | -3.076 | -2.4918 | *** | 0.7069 | 0.6416 | |
| | **BBAS3** | -2.865 | -1.9752 | *** | 1.001 | 0.8982 | |
| | **BBDC4** | -2.112 | -1.4766 | *** | 0.8812 | 0.9918 | |
| | **ITSA4** | -2.154 | -1.6438 | *** | 0.836 | 1.0344 | ** |
| | **ITUB4** | -2.183 | -1.7242 | *** | 0.8094 | 1.0553 | *** |
| | **VALE5** | -2.625 | -1.4120 | *** | 0.6756 | 1.0570 | *** |
| | **CSNA3** | -2.65 | -1.8384 | *** | 0.9679 | 1.1796 | * |
| | **GGBR4** | -2.36 | -2.0041 | * | 0.9687 | 1.1185 | |
| | **USIM5** | -2.822 | -2.6007 | | 1.238 | 0.9631 | * |
| | **GOAU4** | -2.25 | -2.2640 | | 0.9584 | 1.1613 | ** |
| | **VALE3** | -2.829 | -1.6000 | *** | 0.6677 | 1.0400 | *** |
| | **CMIG4** | -2.602 | -2.0584 | ** | 0.9491 | 0.5890 | ** |
| **0.10** | **PETR4** | -1.603 | -1.3971 | * | 0.8919 | 0.9667 | |
| | **PETR3** | -1.734 | -1.5585 | | 0.8616 | 0.8954 | |
| | **LAME4** | -2.173 | -1.9418 | | 0.6296 | 0.9733 | *** |
| | **AMBV4** | -1.761 | -1.4059 | *** | 0.4932 | 0.5325 | |
| | **PCAR4** | -2.308 | -1.6500 | *** | 0.6631 | 0.6043 | |
| | **BBAS3** | -2.117 | -1.5063 | *** | 0.9711 | 1.0359 | |
| | **BBDC4** | -1.599 | -1.1277 | *** | 0.8415 | 1.0260 | *** |
| | **ITSA4** | -1.662 | -1.2872 | *** | 0.8602 | 1.0451 | ** |
| | **ITUB4** | -1.701 | -1.3081 | *** | 0.8117 | 1.0574 | *** |
| | **VALE5** | -1.926 | -1.0649 | *** | 0.725 | 1.1461 | *** |
| | **CSNA3** | -1.985 | -1.5145 | *** | 1.019 | 1.0725 | |
| | **GGBR4** | -1.868 | -1.6053 | * | 0.9814 | 1.1858 | ** |
| | **USIM5** | -2.157 | -2.0353 | | 1.274 | 1.0696 | ** |
| | **GOAU4** | -1.793 | -1.8433 | | 0.9412 | 1.0750 | |
| | **VALE3** | -2.02 | -1.1151 | *** | 0.7134 | 1.0781 | *** |
| | **CMIG4** | -2.062 | -1.6387 | *** | 0.9633 | 0.6352 | *** |
| **N** | **1,756** | 1,221 | 535 | - | 1,221 | 535 | - |

Legend: * p<.1; ** p<.05; *** p<.01

Source: Authors Elaboration.

*Note: the significant columnrepresents the indications about structural change test, based in Qu (2008) and Oka and Qu (2011).*

In general, we find that the parameters (intercept and slope) of CoVaR model had statistically significant changes, regardless of the quantile evaluated. For example, for the quantile 0.05 and assuming a significance level of 10%, we observed that 69% of companies' stockshad alterations in at least one of the parameters. In the specific case of the reaction coefficient (slope), decisive parameter for the calculation of the marginal contribution of a distress in the market index on the stock companies' returns, we found that most companies (56%) had changes in this parameter. The slope parameter, according to Adrian and Brunnermeier (2011), measures the response of the VaR returns of stock company*i* given the VaRof market returns.

Analyzing the coefficients of reaction between the two periods were statistically significant changes, we point out that in general calculate the value at risk of the stock companies' returnswere more elastic to the value at risk of the Ibovespa returns.This result is observed in the three quantiles.The stocks with the highest variation were LAME4, VALE5 and VALE3, indicating that a distress on the market return is correlated with a greater effect on the value at risk of the company.In the case of Americana stores (LAME4), we have some recent events that may have contributed to the sensitivity of their stocks to market fluctuations; an example was the bankruptcy filing made by AthenabancoFomentoMercantil in the period after crisis. We also note that some companies had a negative change in response parameter, like USIM5 and CMIG4 that showed consistently for the three quantile definitions less sensitive to the value at risk IBOV after economic crisis.

Another interesting result is that most of the companies' stocks post-crisis had a response parameter of superiorto one unit, indicating that a financial distress on the market index are more than proportionally correlated withthe value at risk of each company. This reflects a clear sign of financial instability environment created during the economic crisis 2007-2009.

Table 3 shows the stress test estimated for each financial paper negotiated in the domestic capital market of the sample, compared to a distress indicator in the domestic market, IBOV. More specifically, to assess the marginal contribution of a financial distress in the domestic market index on the vulnerability of the return of company*i*.

**Table 3: Stress test for Stock Companies' Returns before and After Economic Crisis 2007-2009**

| Sector | | BeforeCrisis (B) | | | AfterCrisis (A) | | |
|---|---|---|---|---|---|---|---|
| | **Assets** | Quantile 0.01 | Quantile 0.05 | Quantile 0.10 | Quantile 0.01 | Quantile 0.05 | Quantile 0.10 |
| Oil, GasandBiofuel | **PETR4#** | -3.722 | -2.751 | -1.903 | -3.226 | -2.119 | -1.601 |
| | **PETR3** | -3.502 | -2.604 | -1.838 | -3.035 | -2.006 | -1.547 |
| Cyclicalconsumption | **LAME4#** | -2.510 | -1.921 | -1.343 | -4.996 | -2.441 | -1.747 |
| Non-cyclicalconsumption | **AMBV4#** | -2.984 | -1.649 | -1.052 | -2.587 | -1.270 | -0.885 |
| | **PCAR4#** | -3.549 | -2.072 | -1.415 | -3.076 | -1.596 | -1.190 |
| Financial | **BBAS3** | -4.565 | -2.935 | -2.072 | -3.957 | -2.260 | -1.743 |
| | **BBDC4#** | -3.513 | -2.583 | -1.795 | -3.045 | -1.990 | -1.842 |
| | **ITSA4#** | -3.482 | -2.451 | -1.835 | -3.018 | -2.336 | -1.876 |
| | **ITUB4#** | -3.446 | -2.373 | -1.732 | -4.773 | -2.383 | -1.898 |
| Basic Material | **VALE5#** | -2.533 | -1.981 | -1.547 | -4.635 | -2.387 | -2.057 |
| | **CSNA3** | -4.528 | -2.838 | -2.174 | -3.925 | -2.664 | -1.829 |
| | **GGBR4#** | -4.458 | -2.840 | -2.094 | -3.864 | -2.188 | -2.129 |
| | **USIM5#** | -5.319 | -3.629 | -2.719 | -1.829 | -2.175 | -1.920 |
| | **GOAU4#** | -3.771 | -2.810 | -2.008 | -3.269 | -2.623 | -1.689 |
| | **VALE3** | -2.792 | -1.958 | -1.522 | -4.581 | -2.348 | -1.935 |
| PublicUtility | **CMIG4#** | -3.716 | -2.783 | -2.055 | -3.221 | -1.330 | -1.140 |

Source: Authors Elaboration.

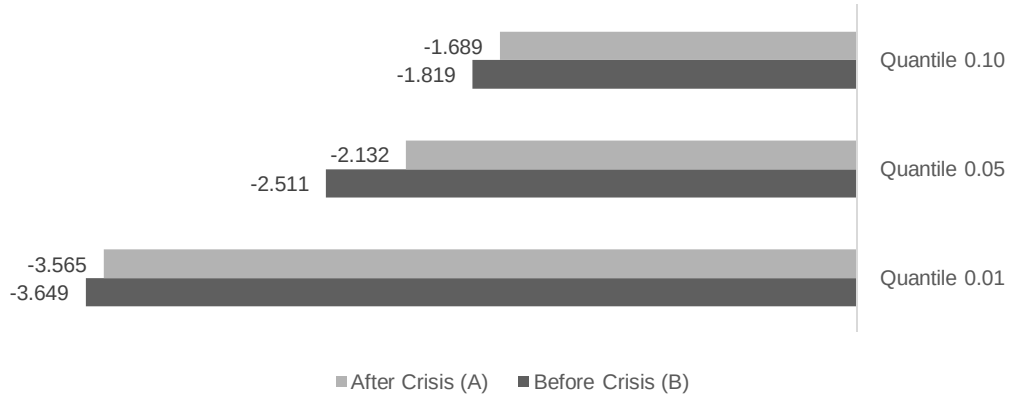
*Note: the asset with symbol # means preferred stocks; the asset without symbol represents common stocks.*

We can check in Table 3, initially, some consistency in the ordering of the stress test measure to each asset of the data, mainly before the crisis, independent of the quantile evaluated. The stocks with higher stress effect correlated with the market are: USIM5, BBAS3, CSNA3, GGBR4. This information indicate, in particular, that companies stocks related to the basic materials sector were more susceptible to financial distress in the market index.

In general, the ranking of the stress test after crisis indicate that the stocks more elastic to a market distress are: VALE5, ITUB4 and CSNA3. We can see the CSNA3 asset remained one of the most that value at risk of IBOV (in adverse context) correlatedwith the value at risk of the stock returns of this company.When we verify the measures of stress tests post-crisis, we found that the ordering of stocks becomes more unstable to the definition of quantile risk. For example, the stock returns of LAME4 werethe ones with a greater stress for the first quantile, the third to the quantile 0.05 and ninth for the last quantile.This fact occurred due to the response coefficient that showed more sensibility to lower quantiles, where in the quantile 0.01 the response parameter was 1.36, while in the other quantiles this parameter decreased strongly, respectively, 1.08 for the quantile 0.05 and 0.97 for the quantile 0.10. A variation of 30% in the response parameter between quantiles 0.10 and 0.01,reflectsstraight in the ranking of the stress test.

The Figure 3 exhibits the average of stress test for stock companies' returns in Brazilian Financial Market before and after crisis for different quantiles.

**Figure 3: Average of Stress test for Stock Companies' Returns in Brazilian Financial Market**

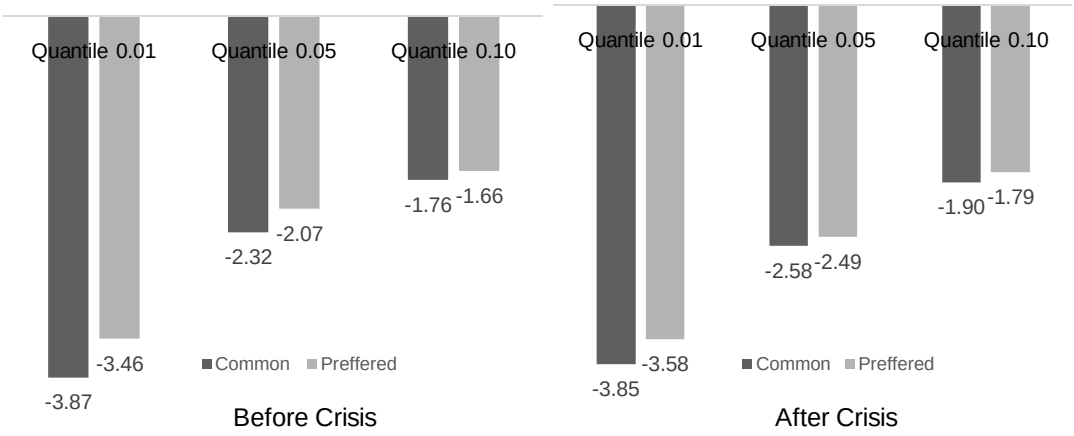



Source: Authors Elaboration.

The results of Figure 3 reinforce the idea that after the period of the American crisis the risk measure investigated in this study for Brazilian firms were impacted by adverse macroeconomic scenario. However, we note that, on average, the stock companies' returns were less correlatedwith changes in the value at risk of the domestic market, regardless of the definition of quantile risk. For the quantile 0.05, we observed a statistically significant difference over 15% in this indicator between before and after crisis, meaning a reduction of the marginal contribution of the value at risk of IBOV to the firms operating in the domestic market.

These results of reduction of the stress test after crisis remains also when considering the various types of assets (see Figure 4).

**Figure 4: Average of Stress Test for Stock Companies' Returns in Brazilian Financial Market by Kind of Stocks (Common and Preferred)**




Source: Authors Elaboration.

In Figure 4, we can see that for both common and preferred stocks had reduced stress indicator after crisis. Thus, we highlight that firms operating in the Brazilian financial market had, in general, a reduction in the stress test, independently of the quantile of risk and the type of stock (common or preferred), signaling the importance of calculating this indicator with structural changes.

## 6. Conclusions

The main innovation of this work was to discuss through the construction of stress test with structural changes, the losses responses of each stock before and after economic crisis 2007-2009 in response to the returns of domestic market (IBOV), assumed by a financial distress in the IBOV returns. The central results show that some of the reaction coefficient of the stock companies' returns operating in the Brazilian financial market had structural changes, as well as the value at risk of the market index decreased between the two periods. In general, the marginal contribution of financial distress in the market index, independently of the quantile evaluated, generated a lower stress on the stock companies' returnsafter the international crisis than before of this adverse macroeconomic context.

Therefore, the results of this study reinforce the importance of using risk indicators sensitive to potential changes, for example, in the economic or political context. As noted, the U.S. economic crisis of 2007-2009, cataloged by NBER, reduced indicators of stress in Brazil investigated period (until 2011), indicating a relative consolidation of the domestic financial market. When we do not consider structural changes in the parameters of risk measures, such as the works of Almeida, Frascaroli and Cunha (2012) and Araújo and Leão (2012) applying the methodology CoVaR to Brazil, we can underor overestimate the indicators.

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# Appendix

## Table A1: Descriptive Statistics of Stock Companies' Returns Selected and Market Index from January 2003 to August 2011

| Description | Variable | Total | | | | | BeforeCrisis | | | | | AfterCrisis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Obs | Mean | Std. Dev. | Min | Max | Obs | Mean | Std. Dev. | Min | Max | Obs | Mean | Std. Dev. | Min | Max |
| Return of Ibovespa (market index) | **IBOV** | 1756 | 0.1001 | 1.5626 | -8.4307 | 5.7458 | 1221 | 0.1410 | 1.6320 | -6.8565 | 5.1589 | 535 | 0.0067 | 1.3881 | -8.4307 | 5.7458 |
| Return of preferred shares from Petrobrás | **PETR4** | 1756 | 0.0957 | 1.8783 | -7.8846 | 13.2463 | 1221 | 0.1708 | 1.9441 | -6.8858 | 13.2463 | 535 | -0.0758 | 1.7079 | -7.8846 | 5.1790 |
| Return of common shares from Petrobrás | **PETR3** | 1756 | 0.0887 | 1.9357 | -8.2302 | 13.4972 | 1221 | 0.1715 | 2.0024 | -7.4662 | 13.4972 | 535 | -0.1001 | 1.7612 | -8.2302 | 5.4583 |
| Return of preferred shares from LojasAmericanas | **LAME4** | 1756 | 0.2043 | 2.2865 | -8.6178 | 9.2288 | 1221 | 0.2563 | 2.3306 | -8.6178 | 9.0151 | 535 | 0.0858 | 2.1801 | -6.6569 | 9.2288 |
| Return of preferred shares from AMBEV* | **AMBV4** | 1756 | 0.1171 | 1.6848 | -16.2071 | 6.0027 | 1221 | 0.1019 | 1.7608 | -16.2071 | 6.0027 | 535 | 0.1519 | 1.4982 | -4.7602 | 5.7433 |
| Return of preferred shares from Pão de Açúcar | **PCAR4** | 1756 | 0.0340 | 2.0419 | -8.0592 | 11.9030 | 1221 | 0.0115 | 2.1335 | -7.8605 | 8.7112 | 535 | 0.0853 | 1.8167 | -8.0592 | 11.9030 |
| Return of common shares from Banco do Brasil | **BBAS3** | 1756 | 0.1633 | 2.2990 | -9.0560 | 14.3303 | 1221 | 0.2092 | 2.4815 | -9.0560 | 14.3303 | 535 | 0.0586 | 1.8130 | -7.1204 | 7.2921 |
| Return of preferred shares from Bradesco | **BBDC4** | 1756 | 0.1290 | 1.9372 | -9.2210 | 8.4342 | 1221 | 0.1716 | 2.0374 | -7.0388 | 8.4342 | 535 | 0.0319 | 1.6841 | -9.2210 | 5.6333 |
| Return of preferred shares from Itaú (S.A.) | **ITSA4** | 1756 | 0.1352 | 1.9402 | -11.5907 | 7.6283 | 1221 | 0.1863 | 1.9832 | -5.5994 | 7.6283 | 535 | 0.0188 | 1.8346 | -11.5907 | 6.4162 |
| Return of preferred shares from Itaú-Unibanco | **ITUB4** | 1756 | 0.1107 | 1.9593 | -10.2225 | 7.9385 | 1221 | 0.1572 | 2.0127 | -5.9983 | 7.9385 | 535 | 0.0046 | 1.8292 | -10.2225 | 6.6249 |
| Return of preferred shares from Vale do Rio Doce | **VALE5** | 1756 | 0.1352 | 2.0065 | -9.6205 | 8.2377 | 1221 | 0.1663 | 2.0781 | -8.2618 | 7.4435 | 535 | 0.0641 | 1.8325 | -9.6205 | 8.2377 |
| Return of common shares from Cia. Sid.Nacional | **CSNA3** | 1756 | 0.1492 | 2.3446 | -12.4014 | 8.6328 | 1221 | 0.2398 | 2.4875 | -9.1044 | 8.6328 | 535 | -0.0576 | 1.9668 | -12.4014 | 8.1068 |
| Return of preferred shares from Gerdau (S.A.) | **GGBR4** | 1756 | 0.1166 | 2.3157 | -11.6154 | 9.8495 | 1221 | 0.2010 | 2.3350 | -11.6154 | 8.3844 | 535 | -0.0759 | 2.2612 | -11.4337 | 9.8495 |
| Return of preferred shares from Usiminas | **USIM5** | 1756 | 0.1641 | 2.7014 | -13.6324 | 12.3593 | 1221 | 0.2754 | 2.8349 | -13.6324 | 9.6228 | 535 | -0.0898 | 2.3518 | -6.6656 | 12.3593 |
| Return of preferred shares from Gerdau | **GOAU4** | 1756 | 0.1361 | 2.2294 | -9.5714 | 9.4811 | 1221 | 0.2286 | 2.2084 | -9.5714 | 8.9612 | 535 | -0.0750 | 2.2647 | -8.6146 | 9.4811 |
| Return of common shares from Vale do Rio Doce | **VALE3** | 1756 | 0.1381 | 2.0869 | -10.0072 | 8.5019 | 1221 | 0.1755 | 2.1666 | -8.6561 | 7.3489 | 535 | 0.0529 | 1.8916 | -10.0072 | 8.5019 |
| Return of preferred shares from CEMIG** | **CMIG4** | 1756 | 0.1202 | 2.1834 | -7.9631 | 10.0889 | 1221 | 0.1467 | 2.4149 | -7.9631 | 10.0889 | 535 | 0.0597 | 1.5293 | -7.0242 | 4.7667 |

Source: Authors elaboration from database of Economatica.
*AMBEV= Beverages Company of the Americas; **CEMIG= Energy Company of Minas Gerais