

da Rocha Lima Filho, Roberto Ivo; Rocha, Armando Freitas

**Article**

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\*Corresponding author: Roberto Ivo da Rocha Lima Filho, Department of Industrial Engineering, Federal University of Rio de Janeiro, Av. Athos da Silveira Ramos, 149 Centro de Tecnologia - Bloco F 1 andar 21941 909 Rio de Janeiro, RJ, Brazil; Oxford University, Queen Elizabeth House, 3 Mansfield Rd, Oxford OX1 3TB, UK  
E-mails: [roberto.ivo@poli.ufrj.br](mailto:roberto.ivo@poli.ufrj.br); [roberto.darochalimafilho@brasenose.oxon.org](mailto:roberto.darochalimafilho@brasenose.oxon.org)

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## BANKING & FINANCE | RESEARCH ARTICLE

# News and markets: The 2008 crisis from a neurofinance perspective—the case of BMFbovespa

Roberto Ivo da Rocha Lima Filho<sup>1,2\*</sup> and Armando Freitas Rocha<sup>3</sup>

**Abstract:** The world is still facing a financial crisis, which started in mid 2007 and up to now is far from being solved. Stock markets around the world reacted badly and the real-time news has never played such an important role to investors as seen in previous crisis. We used this model to study the Bovespa index (IBOV) evolution from January 2003 to September 2010 and correlated the market sentiment to an index of Good/Bad news about IBOV. Indeed news is found to have a major impact on market sentiment (volatility) and it is correlated with investors' humor. In other words, the impact of the media deepened the bearish dynamics of the markets.

**Subjects:** Engineering Economics; Behavioral Sciences; Economic Psychology

**Keywords:** behavior finance; neurofinance; decision theory; financial crisis

**JEL Codes:** G01; G14; G17; D87

### 1. Introduction

The world is still facing a financial crisis, which started in mid 2007 and up to now is far from being solved. It is thus deemed to be the worst financial crisis since the Great Depression of the 30's. It was triggered by a liquidity shortfall from the US subprime lending system that provoked financial collapse of many large important financial institutions and let others in a very unstable situation; a situation which required the USA Government to bail them out from bankruptcy.

### ABOUT THE AUTHOR

Roberto Ivo da Rocha Lima Filho is currently an adjunct professor at Federal University of Rio de Janeiro in Brazil, teaching economics and principles of finance for engineering undergraduate as well as postgraduate (executive MBAs) students with a myriad of background in the job market.

The author deposited doctorate thesis for a PhD in Science at the University of São Paulo, Medical School, in early 2014. Under the Department of Pathology/Medical Informatics, the author managed to better understand the decision-making process from traders and students with no financial background with a Neuroeconomics perspective, which is a novelty in the field of finance and economics.

The author graduated in Economics in 2000 at the same University and while the author was working within the financial markets, the author got accepted to the University of Oxford, Queen Elizabeth House, to do an Msc in Economics for Development. After the author's background within the Financial Markets, the author decided to pursue career in the academia.

### PUBLIC INTEREST STATEMENT

Recently, a growing number of research in economics points to areas that encompass studies of cognitive processes such as neuroscience, psychology and computer science. The idea is not only to make the economy get closer to reality, but at the same time trying to create an ergodic theory - a stable structure - that can be based on any point of the time, despite the world always be *mutatis mutantis*. Note, in this way, a dissatisfaction with the current economic thought as it does not have satisfactory answers to anomalous movements, for example, in a time horizon decision, which still uses the assumption of rational economic behavior. However, in recent years, behavioral biases have been common in finance and economics, in which classical theories can not thoroughly explain these deviations. Alas, work with Daniel Kahnemen—Nobel Prize in 2002, a new behavioral aspect is being formalized, considering the enormous influence our emotions have on every decision we make.

Stock markets reacted badly around the world and the real-time news has never played such an important role in order to inform investors. In other words, the impact of the media deepened the bearish dynamics of the markets. Generally speaking, the “bad news” outweighed the “good” news, creating a vicious circle that is well-known in finance. Volatility tends to react more profoundly upon to negative information rather than positive one (Akerlof & Schiller, 2009).

The US subprime crisis tested important aspects of the classical finance theory such as Theory of Market Efficiency and Modern Portfolio Theory. (Block & Hirt, 2000; Melicher, Norton, & Town, 2007), and it clearly shows that investors did not behave as predicted by theoretical models such as Capital Asset Price Market (CAPM) and Markowitz’s Portfolio Selection.

In recent decades, the area of Behavioral Finance has collected a lot of evidence that investors disregard many of the assumptions of market efficiency (e.g. Rogers, Securato, & Ribeiro, 2007) such as full rationality in financial decision-making (e.g. Kuhnen & Knutson, 2005; Fellner & Maciejovsky, 2007; Huettel, Stowe, Gordon, Warner, & Platt, 2006), or maximization of the usefulness of financial investment.

The influence of emotion on decision-making has been used to explain the deviation of profit maximization and that is why market sentiment is relevant because it defines the emotional state of the financial market that can determine the movements of stock prices (Rocha, 2013). Financial market emotions are influenced by numerous factors such as market data, expert opinion, government decisions and national and international events. (Rocha & Rocha, 2011). When the size of those factors is growing significantly, it means that it can trigger investors to behave in a herd or herding (e.g. Hwang & Salmon, 2004). The herd behavior has been studied as an important movement in times of financial market crisis (e.g. Hwang & Salmon, 2004; Uchida & Nakagawa, 2007).

Neurofinance emerged as a combined effort of Neurosciences and Finance in order to better understand the dynamics of decision-making in normal times as well as in crisis, seeking a type of knowledge that could understand the neural mechanisms involved in the analysis of benefit and risk (Rocha & Rocha, 2011; Rocha, 2013). It is a rapidly advancing field and has generated important contributions to the understanding of financial reasoning (e.g. Gehring & Willoughby, 2002; Huettel et al., 2006; King-Casas, Tomlin, Anen, Camerer, & Quartz, 2005; Knutson, Fong, Bennett, Adams, & Hommer, 2003; Kuhnen & Knutson, 2005; O’Doherty, Kringelbach, Rolls, Hornak, & Andewus, 2001; Preuschoff, Bossaerts, & Quartz, 2006; Rocha, Burattini, Rocha, & Massad, 2009; Sanfey et al., 2006; Tobler, Fletcher, Bullmore, & Schultz, 2007; Vorhold et al., 2007).

Indeed news is found to have a major impact on market sentiment (volatility) through euphoria (in the positive side) or hysteria (in the negative side) and it is correlated with investors’ humor. In other words, the impact of the media deepened the bearish or bullish dynamics of the markets.

In Section 2, we will lay out the basis for our model by showing how emotions play an important role in decision-making process. In Section 1, A price anchoring model will be derived and then arguments will be laid out in order to ground our hypothesis in how markets evaluate risks and benefits and what are the implications of such factors in the decision-making process. In Section 3, a simulation will be done with the Brazilian Stock Exchange (given our assumptions) and finally the role of news will be incorporated in Section 5.

## 2. Making decisions

### 2.1. The model

In a recent review of the economic decision-making, Seymour and McClure (2008) show that people are extremely susceptible to manipulation in their expectations and evaluations of prices. People

judge values and prices in relative rather than absolute terms, and they use them as an anchored product or price.

Departing from these observations, Rocha and Rocha (2011)<sup>1</sup> proposed that, in the trading day  $t$ , the seller ( $s$ ) expects to get a price  $p_{s_i}^s(t)$  for selling  $i$ th stock  $s_i$ , while the buyer ( $b$ ) hopes to buy the same stock ( $i$ th) at a price  $p_{s_i}^b(t)$ , and they use these prices as an anchor to converge or not to a common closing ( $c$ ) price  $p_{s_i}^c(t)$  for stock trading. In turn, both  $p_{s_i}^s(t)$  and  $p_{s_i}^b(t)$  are anchored in the closing price  $p_{s_i}^c(t - 1)$  from the previous session. Then, the possible price variations are:

$$\begin{aligned} \Delta_{s_i}^v(t) &= p_{s_i}^s(t) - p_{s_i}^b(t - 1) \\ \Delta_{s_i}^c(t) &= p_{s_i}^c(t) - p_{s_i}^c(t - 1) \end{aligned} \tag{1}$$

Considering that positive variations is related to the bull market and negative for bear market, trading prices become dependent on market volatility and therefore humor.

Rocha and Rocha (2011) developed model for financial decision-making, where intention to buy— $\mu_{s_i}^b(t)$ —a stock  $S_i$  in a certain time ( $t$ ) is dependent on the perception towards the expected benefit— $\lambda_{s_i}(t)$ — and intention to sell  $\mu_{s_i}^s(t)$  the same stock is dependent on the perception of the risk— $\chi_{s_i}(t)$ . Both benefit perception  $\lambda_{s_i}(t)$  and risk estimation  $\mu_{s_i}^s(t)$  are influenced by the transaction cost  $c_{s_i}(t)$  of this stock  $s_i$ .

In addition, the conflict  $\varsigma_{s_i}(t)$  embedded in deciding (if buy or sell is worthwhile) is a function of  $\lambda_{s_i}(t)$  and  $\chi_{s_i}(t)$ .<sup>2</sup>

In this context, it is possible assume that the humor— $h_{s_i}(t)$ —within a certain decision-making process is proportional to  $\varsigma_{s_i}(t)$ , that is

$$h_{s_i}(t) = \tilde{h}_{s_i}(t) - \varsigma_{s_i}(t) \tag{2}$$

where  $\tilde{h}_{s_i}(t)$  is the a market emotional threshold at time  $t$ . The intuition here is to explain that a market is not euphoric or hysteric ad infinitum. It will reach a superior/inferior threshold and reverse to the other direction.

In such conditions,  $h_{s_i}(t) > 0$  quantifies the optimism associated with a bull market;  $h_{s_i}(t) < 0$  quantifies the pessimism associated with a bear market.

Finally,  $\tilde{h}_{s_i}(t)$  is assumed to be influenced by market media news besides other factors such as government decisions and national and international events as previously stated.

The current work makes use of the formalization of Rocha and Rocha (2011) to model the decision-making process within the financial market, assuming that  $p_{s_i}^c(t)$  is anchored in  $p_{s_i}^c(t - 1)$  and therefore the change in trading floor is a function  $\Delta_{s_i}^c(t) = p_{s_i}^c(t) - p_{s_i}^c(t - 1)$  of  $h_{s_i}(t)$ .

In Section 2.2, it is presented how investors analyze benefits and risks given different emotions played out by the market.

## 2.2. Evaluating benefits and risks

Finance theory assumed expected benefits as a projection of complex future earnings (Block & Hirt, 2000). From Neuroscience point of view, benefits assessment is a prior estimate of the possible reward to be obtained by implementing a given action and it is a function of dopaminergic circuits (e.g. Rocha & Rocha, 2011; Schultz, 2004). Benefit is an analytical variable from Finances point of view, while a subjective evaluation from Neurosciences perspective.

Risk assessment has been generally considered a function of the probability of occurrence of events. Recent studies, however, have shown that risk perception has quantitative and qualitative components (e.g. Vorhold et al., 2007). The neural mechanisms estimate risks usually in circumstances where information about the probability of occurrence of the events is scarce and the opportunity for analytical complexity is virtually nonexistent. The neural circuits for risk assessment involve primarily serotonergic circuits.

In the Neurfinance context, therefore, what matters is not the expected return  $r_{s_i}(t)$ —at time  $t$  of a given share (stock)  $s_i$ , but the subjective reward evaluation (or feeling)— $\lambda_{s_i}(t)$ —of  $r_{s_i}(t)$ .

Conversely, what matters is not the loss or its financial cost  $c_{s_i}(t)$ , but the risk perception  $\chi_{s_i}(t)$  associated with  $c_{s_i}(t)$  (Rocha & Rocha, 2011).

Psychophysics uses the paradigm of assessment ratios (ratio magnitude estimation paradigm) to study perception (namely here  $S$ ) triggered in individuals by varying stimuli intensity  $i$ . This paradigm suggests that  $\frac{f(S)}{f(i)} \rightarrow k$  usually converges to a constant outcome (e.g. Bernasconi, Choirat, & Seri, 2008).

Many different models have been proposed to define  $f$  and  $f'$ . But logarithmic functions have been most frequently used. So here, it is proposed that:

$$\lambda_{s_i}(t) = \beta_{s_i}^{\frac{1}{\kappa_1 r_{s_i}(t)}} \tag{3}$$

$$\chi_{s_i}(t) = \frac{c_{s_i}(t)^{\kappa_2}}{c_{s_i}(t)^{\kappa_2} + (\theta_{s_i} - c_{s_i}(t))^{\kappa_2}} \tag{4}$$

where  $\kappa_1$ ,  $\beta_{s_i}$  are, respectively, measures of dopamine uptake given a certain stock return  $r_{s_i}(t)$ . In the case of risk assessment,  $\theta_{s_i}$  and  $\kappa_2$  show the proportional level of serotonin uptake. The values of the constants ( $\beta$ ,  $\theta$ , and  $\{\kappa_i\}_{i=1,2}$ ) are adjusted to maintain  $\lambda_{s_i}(t) > \chi_{s_i}(t)$ , as necessary hypothesis to define a financial market closing price convergence.

Any financial index (e.g. Block & Hirt, 2000) can be used to calculate  $r_{s_i}(t)$  and  $c_{s_i}(t)$ , because in the context on what matters is how the return and cost are evaluated psychologically.

Moreover, it is thought that human diversity implies that different types of investors uses various indexes for their own calculations so as to ensure that there is always someone wanting to sell (as well as to buy) that given same stock  $s_i$ .

What is important for the model presented here is the use of perceived benefit  $\lambda_{s_i}(t)$  and perceived risk  $\chi_{s_i}(t)$  instead of the actual values of  $r_{s_i}(t)$  and  $c_{s_i}(t)$  in the process of decision-making.

### 2.3. Attractiveness (suitability) of a stock $s_i$

Surveys in the behavioral finance and neuroeconomics (e.g. Fellner & Maciejovsky, 2007; Huettel et al., 2006; Kuhnen & Knutson, 2005; Peterson, 2007; Rocha & Rocha, 2011) have shown that the attractiveness (suitability) of an investment, named  $\psi_{s_i}(t)$ , depends not only on the relationship  $\lambda_{s_i}(t)/\chi_{s_i}(t)$  between perceptions of benefit  $\lambda_{s_i}(t)$  and risk  $\chi_{s_i}(t)$ , but also on the reliability, called as  $\rho_{s_i}(t)$ , towards to the market movement (behavior that can be again addressed as bearish or bullish) with respect to a certain stock  $s_i$ . Therefore, it is proposed that:

$$\Psi_{s_i}(t) = \frac{\rho_{s_i}(t)\lambda_{s_i}(t)}{\lambda_{s_i}(t) + \chi_{s_i}(t)} \tag{5}$$

so that if:

1. the perceived benefit  $\lambda_{s_i}(t)$  is much greater than the risk  $\chi_{s_i}(t)$  then  $\psi_{s_i}(t) \rightarrow \rho_{s_i}(t)$ , otherwise
2. the perception of risk  $\chi_{s_i}(t)$  is much greater than the benefit  $\lambda_{s_i}(t)$  then  $\psi_{s_i}(t) \rightarrow 0$ , and
3. the reliability  $\rho_{s_i}(t) \rightarrow 0$  then  $\Psi_{s_i}(t) \rightarrow 0$ , otherwise
4. the reliability  $\rho_{s_i}(t) \rightarrow 1$  then  $\psi_{s_i}(t) \rightarrow \frac{\rho_{s_i}(t)\lambda_{s_i}(t)}{\lambda_{s_i}(t) + \chi_{s_i}(t)}$ .

The current value of  $\rho_{s_i}(t)$  depends on the success of previous investment in  $s_i$  and investor confidence in the economy, which is, in general, and is set in the closed normalized interval [0, 1].

But how this mechanism works in the trading floor with different market participants will be shown in Section 2.4.

#### 2.4. Trading conflict and cognitive effort

Neurosciences have shown that decision-making depends on a large network of neurons distributed in several areas of the brain (Botvinick, Cohen, & Carter, 2004; Glimcher & Rustichini, 2004; Ledoux, 1996; Paulus & Frank, 2006; Paulus, Hozack, Frank, & Brown, 2002; Rocha, Massad, & Pereira, 2004; Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003; Walton, Devlin, & Rushworth, 2004). Some of these areas are in charge of performing specific about benefits and risks while some others calculate the conflict generated by divergent perceptions of benefit and risk, as well as estimate the cognitive effort for making a decision. All these pieces of information are used by some other sets of neurons to determine intention of trading.

The perception of benefit and risk creating a conflict  $\zeta_{s_i}(t)$  become similar, reaching a maximum when  $\lambda_{s_i}(t) = \chi_{s_i}(t)$  and goes down if  $\lambda_{s_i}(t)$  or  $\chi_{s_i}(t)$  approach zero. Therefore, Rocha et al. (2009) proposed the following functional form (“Shannon Entropy”) to fit this dynamics:

$$\zeta_{s_i}(t) = -\bar{\lambda}_{s_i}(t) \log_2 \bar{\lambda}_{s_i}(t) - \bar{\chi}_{s_i}(t) \log_2 \bar{\chi}_{s_i}(t) \tag{6}$$

where,

$$\bar{\lambda}_{a_i} = \frac{\lambda_{a_i}}{\lambda_{a_i} + \chi_{a_i}}, \bar{\chi}_{a_i} = \frac{\chi_{a_i}}{\lambda_{a_i} + \chi_{a_i}}, \tag{7}$$

The assessment of cognitive effort for decision-making involves the same areas and neural circuits that estimate the conflict generated by perceptions of benefit and risk (Botvinick et al., 2004; Mantini, Corbetta, Perruci, Romani, & Del Gratta, 2009; Mulert et al., 2008; Zysset et al., 2006). Therefore, Rocha et al. (2009) proposed that the facility image (“Easiness”) for decision-making can be calculated as

$$e_{s_i}(t) = 1 - \zeta_{s_i}(t) \tag{8}$$

#### 2.5. Intention of trading

Intention to act is a complex psychological construct that begins with the estimation of the expected benefit and risk of acting that are the determining variables for calculating action suitability (e.g. Glimcher, 2004).

The attractiveness of buying a given stock  $s_i$  is determined by how much benefit (earning) is expected within a period of time, while the attractiveness of selling a given stock  $s_i$  is determined by how much risk (loss) is expected within a defined future. Both estimations are very dependent on how reliable is the market to support benefit and risk estimations. The cognitive effort required to makes reliable calculations of the intention to buy or to sell a given stock  $s_i$  is determined, as discussed above, by the risk/benefit ratio, and it is very influent on our capacity of decision-making.

Low conflict makes decision easy and clear cut, whereas the contrary—high conflict—makes decision hard and it favors procrastination (Rocha & Rocha, 2011).

In this context, the desire or intention  $\mu_{s_i}^b(t)$  to buy and the desire or intention to sell  $\mu_{s_i}^s(t)$  can be thought of as follows:

$$\begin{aligned} \mu_{s_i}^b(t) &= \lambda_{s_i}(t)e_{s_i}(t)\psi_{s_i}(t), \\ \mu_{s_i}^s(t) &= \xi_{s_i}(t)e_{s_i}(t)/(1 + \psi_{s_i}(t)) \end{aligned} \tag{9}$$

As the desire to purchase  $\mu_{s_i}^b(t)$  increases with the benefit  $\lambda_{s_i}(t)$  and adequacy  $\psi_{s_i}(t)$  of a given stock  $s_i$ ,

While the desire to sell  $\mu_{s_i}^s(t)$  increases with the cost  $\chi_{s_i}(t)$  and inadequate  $1/\psi_{s_i}(t)$  of  $s_i$ . Both  $\mu_{s_i}^b(t)$  and  $\mu_{s_i}^s(t)$  reaches their maximum when with the easiness of decision-making approaches 1.

## 2.6. Pricing assets

Humor  $h_{s_i}(t)$  of investors, according to Equation (2), is dependent on the conflict  $\zeta_{s_i}(t)$  generated by the assessments of benefit  $\lambda_{s_i}(t)$  and risk  $\chi_{s_i}(t)$  from the trading shares  $s_i$ . If  $h_{s_i}(t) > 0$ , the sensation experienced by the investor will be joy or euphoria and  $h_{s_i}(t) \gg 0$ .

While if  $h_{s_i}(t) < 0$ , the sensation experienced by investors will be anxious or even panic and  $h_{s_i}(t) \ll 0$ .

Moreover, it is here where the price movement  $p_{s_i}(t)$  of shares  $s_i$  should be dependent on the intentions of buying and selling  $\mu_{s_i}^b(t)$ ,  $\mu_{s_i}^s(t)$ .

Within this context, a buying market is defined if the intention to buy is greater than the intention to sell, i.e.  $\mu_{s_i}^b(t) > \mu_{s_i}^s(t)$ .

On the contrary, a selling market is defined if the intention to sell greater than the desire to buy, i.e.  $\mu_{s_i}^s(t) > \mu_{s_i}^b(t)$ .

The price  $p_{s_i}(t)$  of  $s_i$  increases in a buying market and it decreases in a selling market.

It is then hypothesized that market sentiment  $m_{s_i}(t)$  will be modulated by the humor  $h_{s_i}(t)$  of investors and therefore will depend on his intentions of buying and selling. Recalling that  $h_{s_i}(t) = \tilde{h}_{s_i}(t) - \zeta_{s_i}(t)$ , then

$$\begin{aligned} \text{if } \zeta_{s_i}(t) > \tilde{h}_{s_i}(t) \text{ then } m_{s_i}(t) &= \frac{\mu_{s_i}^b(t)}{\mu_{s_i}^s(t)} h_{s_i}(t) \\ \text{otherwise } m_{s_i}(t) &= \frac{\mu_{s_i}^s(t)}{\mu_{s_i}^b(t)} h_{s_i}(t) \end{aligned} \tag{10}$$

In the above context, the price  $p_{s_i}(t)$  of shares  $s_i$  financial market can be calculated as a linear time-lagged function:

$$p_{s_i}(t) = p_{s_i}(t - 1)(1 + m_{s_i}(t)) \tag{11}$$

i.e. the price  $p_{s_i}(t)$  in the instant  $t$  is a function of price at time  $t - 1$  and the market sentiment  $m_{s_i}(t)$ .

With this model setup, it will be possible extend the results for a given stock exchange and therefore simulate if the above variables fit the market’s dynamics given a determined timeframe.

Having kept that in mind, a simulation of the Brazilian Stock Exchange was applied in Section 3, calibrating the previous variables in order to see how well is the “goodness of fit” of them with respect to real situation.

### 3. Trading at BMFBovespa (São Paulo Stock Exchange)

The evolution of the Ibovespa index, namely Ibov ( $p_{Ibov}(t)$ ), was considered within the timeframe as of January 2003 to September 2010 in a monthly basis obtained at BMFBovespa’S website (see  $p_{Ibov}(t)$  in Figure 2(A)).

It was modeled taking into consideration the financial decision process model described in Section 2.

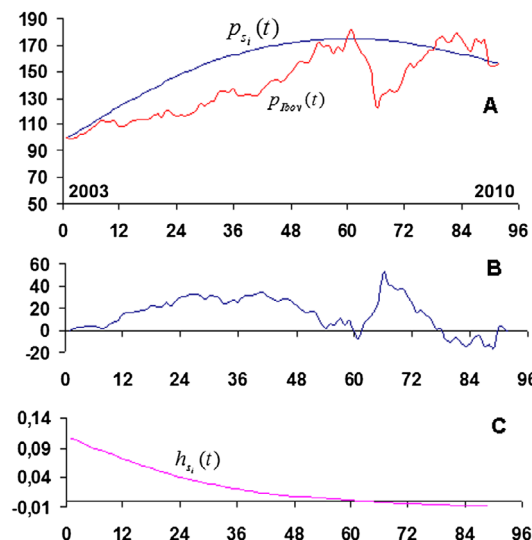
Figure 1 shows the simulated values  $p_{s_i}(t)$  for the Ibov trading according to the model described above. Ibov was anchored in its first closing value on 3 January 2003 and market sentiment was assumed constant and having a value of  $\tilde{h}_{s_i}(t) = 0.48$  for the entire period. The difference between  $p_{s_i}(t)$  and  $p_{Ibov}(t)$  is shown in Figure 1(B). The simulated investor’s humor  $h_{s_i}(t)$  varied in a nonlinear fashion as shown in Figure 1(C).

Market sentiment  $h_{s_i}(t)$  imposed a nonlinear variation over  $p_{s_i}(t)$ . Simulation shows that  $p_{s_i}(t)$  accompanies  $p_{Ibov}(t)$  during 2003, but from 2004 onwards the growth of the Ibov is lower than that estimated by the model.

This difference remained stable during the years of 2004 and 2005 and started closing up this wedge from October 2007 on, reaching a negative value in May 2008. This suggested a mean-revertent dynamics of the prices as stipulated by the theory of financial.

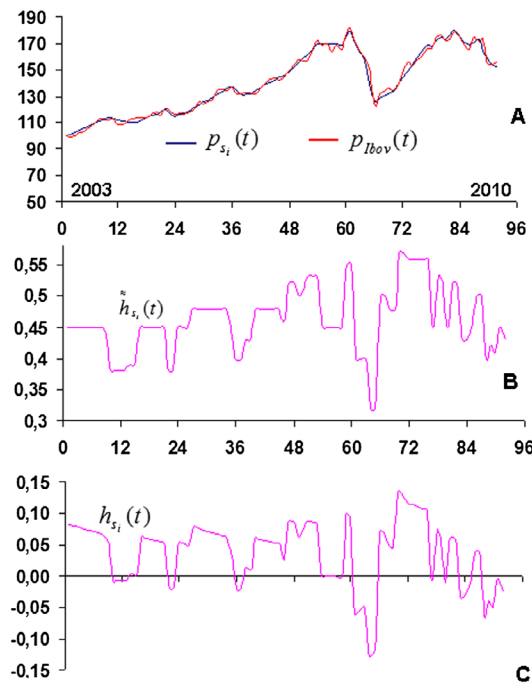
However, from May 2008 onwards, the value of  $h_{s_i}(t)$  becomes a reflex of the change of market sentiment due to the sub-prime crisis. This shift in market sentiment marks the start of the 2008

**Figure 1. Ibov evolution ( $p_{Ibov}(t)$ ) from January 2003 to September 2010 and the simulated index  $\tilde{h}_{s_i}(t)$  calculated assuming that the investor emotional threshold  $p_{s_i}(t)$  remained constant at 0.48 during the entire period. The difference between  $p_{Ibov}(t)$  and  $h_{s_i}(t)$  is shown in (B) and the evolution of  $p_{Ibov}(t)$  is shown in (C).**





**Figure 2. Ibov evolution** ( $p_{Ibov}(t)$ ) from January 2003 to September 2010 and the simulated index  $p_{s_i}(t)$  calculated adjusting the emotional threshold of the investor  $\tilde{h}_{s_i}(t)$  as shown in (B). Humor  $h_{s_i}(t)$  has varied as shown in (C).



crisis, when then the difference between  $p_{s_i}(t)$  and  $p_{Ibov}(t)$  increases again, reaching its peak in October 2008 and beginning to decline again to reach its minimum in September 2010.

The above figure shows the Ibov simulation when the values of  $\tilde{h}_{s_i}(t)$  were *ad hoc* adjusted as shown in Figure 2(B) in order to reduce the difference between  $p_{s_i}(t)$  and  $p_{Ibov}(t)$  (given the market sentiment at the time). Observe that this procedure allows purposely a near perfect fit  $p_{s_i}(t)$  to  $p_{Ibov}(t)$  because it modified the behavior of  $h_{s_i}(t)$ .

Despite showing a logarithmic decrease over the years ( $h_{s_i}(t) = -0.0349 \ln(t) + 0.1469$ ,  $R^2 = 0.9591$ ), the dynamics remains positive for most of the period and shows two time intervals, in which is predominantly negative. The first is the period between May and September 2008, and the second from August 2010 until the present.

It is interesting to note here that the calculated average for  $\tilde{h}_{s_i}(t)$  imposed here to fit the curves of  $p_{s_i}(t)$  and  $p_{Ibov}(t)$  is equal to 0.46, a value used to set the course  $p_{s_i}(t)$  Figure 1.

This new simulation confirms the change in market sentiment that characterized the crisis from May to October 2008 and shows a new trend for a bear market more recent but less intensive, as of August 2010. But the role of news has an important impact in this dynamics and this will be shown in Section 4.

#### 4. The impact of news upon $\tilde{h}_{s_i}(t)$

The previous simulation shed some light about the dynamics of investor's humor and its influence on share prices. Here, it is proposed that the *ad hoc*  $\tilde{h}_{s_i}(t)$  adjustments (Figure 2(B)) required to a better fit of  $p_{Ibov}(t)$  by  $p_{s_i}(t)$  may be correlated with the influence of stock market media news on the investor's humor.

For such a purpose, media news about BMFBovespa was collected from Brazilian newspapers since 2007, when the sub-prime crisis started hitting the US economy and spread out to the world.

The news were classified into bad (B), normal (N), and good news (R). This classification was made by the discretion of the authors.

As an example, news of positive GDP's result—Gross Domestic Product—was classified as good news (R), while a negative one, which might signal a recession, is a bad (B).

It is widely used the Jarque Bera test for testing out whether a variable has a normal distribution or not, based on the sample kurtosis and skewness. This statistic is asymptotically a  $\chi^2$  distribution with two degrees of freedom with the null hypothesis being a normal distribution, that is, a skewness must be equal to zero and kurtosis equal to 3. As expected, bad news (B) have a near chi-squared distribution (Figure 3) because of a right-handed skewness and high value of kurtosis (mesokurtic shape), suggesting a stronger impact on asset prices if it is compared to good news (G), which can be deemed to be normal distributed (with mean near zero skewness—they are symmetrical—and kurtosis equals to absolute three).

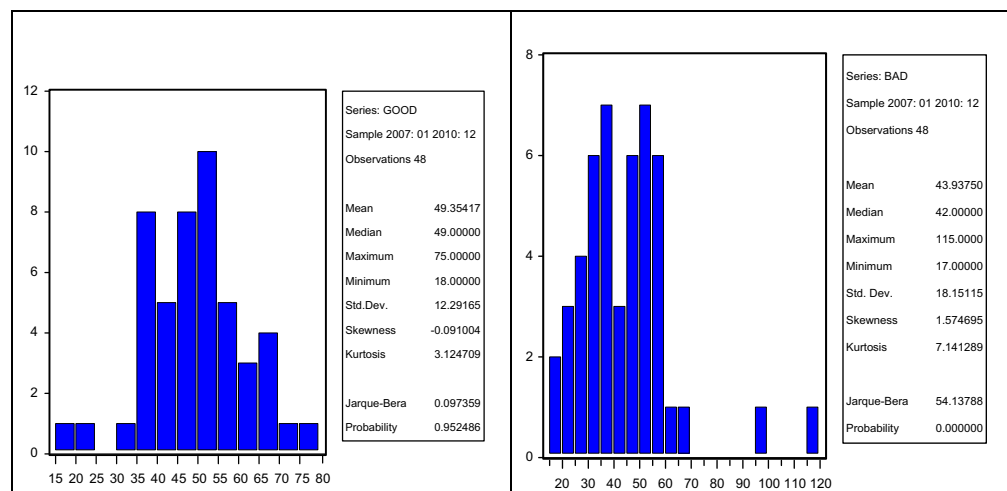
The ratio between B and G news was calculated and compared it to the humor of investors as calculated by Equation (2).

Figure 4(A) displays the evolution of this index and the investor's humor from January 2007 to September 2010.

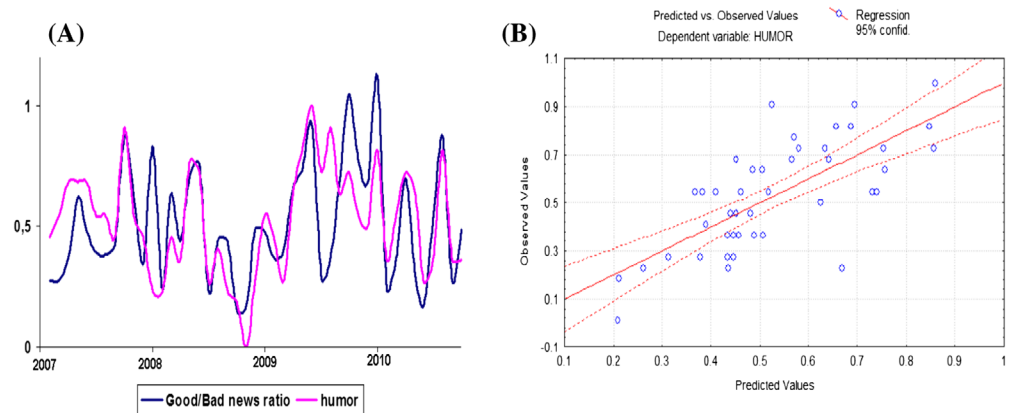
The variables humor, lag1(humor) and Good/Bad index were regressed as shown in Table 1 and Figure 4. The results turned out to be statistically robust—good  $R^2$  as of 52%, no sign of autocorrelation—given the significance of all variables within the regression (see also Predict vs. Observed graph in Figure 4(B)). Moreover, the magnitude of the impact of news as of 0.587 corroborates its importance within the market's feeling, since it contemplates good and bad results from companies, economic indicators and other relevant factors. The variable lag1(humor) contributes 0.37 to the investor's humor and shows that the effect of news does not dissipate instantaneously. It remains hovering within the financial transactions.

The above results indicate that the *ad hoc* simulation of humor threshold in Figure 2 may be replaced by calculating  $\tilde{h}_s(t)$  according to the equation shown in Table 1 and the Good/Bad index. This hypothesis was tested by simulating the Ibov with  $\tilde{h}_s(t)$  calculated according to this procedure. The results of this simulation shown in Figure 5(A) and the adjustment of  $p_s(t)$  to  $p_{Ibov}(t)$  seems to confirmed the proposal.

**Figure 3. Good and Bad news distribution: the first chart has a clear normal distribution, where  $K = 3$  and  $S = 0$ , while in the second one Bad news tends to show a  $\chi^2$  distribution with  $K = 7$  and  $S = 1.5$ .**



**Figure 4. Correlation between the Good/Bad news ration and humor  $h_{s_i}(t)$  during the period January 2007 to September 2007.**



**Table 1. Regression analysis 1**

**Regression summary for dependent variable: HUMOR**

**$R = 0.72$   $R^2 = 0.52$  Adjusted  $R^2 = 0.50$**

**$F(2,41) = 22.23$   $p < 0.00000$  Std. Error of estimate: 0.16**

	Std. Error		Std. Error		$t(41)$	$p$ -level
	$\beta$	of $\beta$	$B$	of $B$		
Intercept			0.04	0.08	0.57	0.57
Good/Bad	0.59	0.11	0.54	0.10	5.41	0.00
Lag <sub>1</sub> (Humor)	0.38	0.11	0.38	0.11	3.49	0.00

However, there is a  $p_{s_i}(t)$  deviation from  $p_{Ibov}(t)$  at the beginning of the 2008 crisis. So, it was also hypothesized that there exist a time lag of the media to recognize the beginning of crisis, generating higher (or smaller) good (bad) news in April to September of 2008.

In the same line of reasoning, it may be assumed that there was other news time lag during the beginning of the economic crisis recovering from November 2008 on. Based on these assumptions, the dummy variable shown in Figure 5(C) was introduced in the simulation. This resulted in a better adjustment of  $p_{s_i}(t)$  to  $p_{Ibov}(t)$  as shown in Figure 5(B). These results confirmed our hypotheses that market sentiment  $\tilde{h}_{s_i}(t)$  in Equation (2) may be at least partially derived from the ratio between good and bad media news about the stock market.

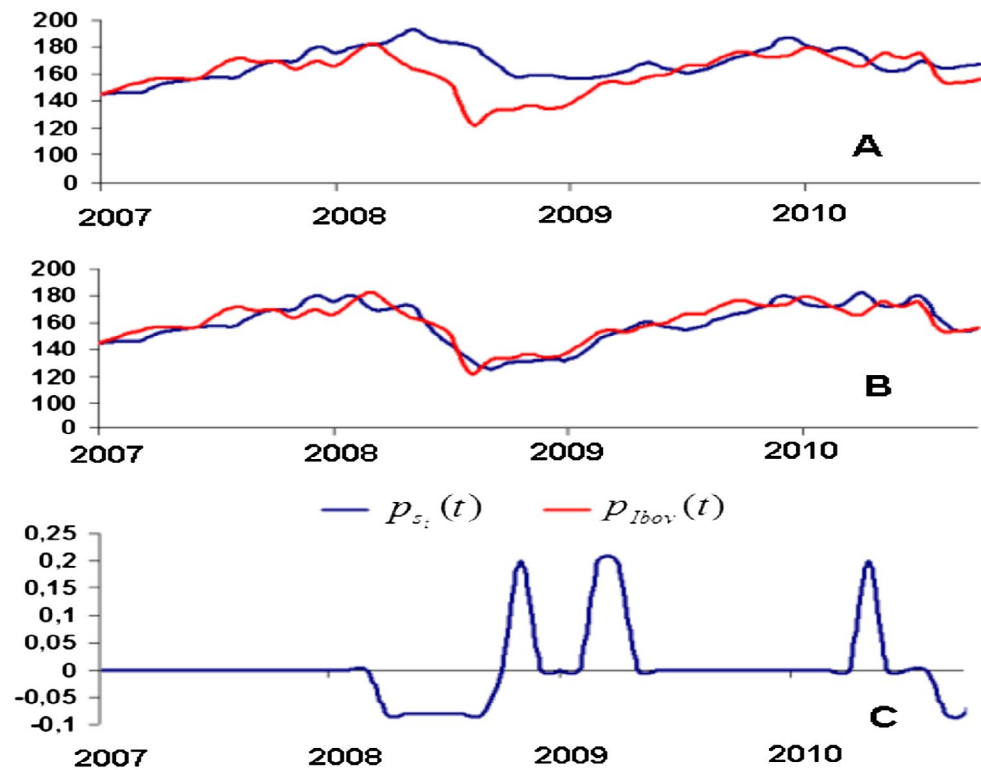
### 5. Discussion

The predominant economic thinking assumes that a rational economic agent has the emotion as the enemy. In this line of approach, the Theory of Market Efficiency (Block & Hirt, 2000; Melicher et al., 2007) proposes that the price of shares and its range contains all the information that investors need in a rational decision-making, because it performs a random path that always leads to its market value.

However, this theory has been criticized and several studies (e.g. Kim & Shamsuddin, 2008; Lim, Brooks, & Kim, 2008; Pasquariello, 2008) have shown that it is not applicable in times of bubbles and financial crises. The anchored price theory (see e.g. Seymour & McClure, 2008) is one of the strongest evidence that the classical theory does not adequately describe the behavior of the investor.

Here, a neuro-model for decision-making was been successfully used to study the evolution of the Ibov between January 2003 and September 2010, which was characterized by a financial bubble that has evolved to the crisis triggered by the fall in market confidence associated the US housing crisis.

**Figure 5. Ibov evolution** ( $p_{Ibov}(t)$ ) from January 2003 to September 2010 and the simulated index  $p_{s_i}(t)$  calculated assuming that the emotional threshold of the investor  $\tilde{h}_{s_i}(t)$  is computed from equation obtained with regression analysis shown in Table 1 (A) and adjusted (B) by the dummy variable shown in (C).



In this model, the investor uses both their perceptions of benefit  $\lambda_{s_i}(t)$  and of risk  $\chi_{s_i}(t)$  to predict  $p_{s_i}(t)$  the index evolution  $p_{Ibov}(t)$ . Important to the model are the concepts of investor's humor  $h_{s_i}(t)$  and market's sentiment  $m_{s_i}(t)$ . The investor's humor  $h_{s_i}(t)$  is calculated from the resulting conflict  $c_{s_i}(t)$  associated with assessments of  $\lambda_{s_i}(t)$  and  $\chi_{s_i}(t)$ , while the market sentiment  $m_{s_i}(t)$  depends upon the intentions of buying and selling  $\mu_{s_i}^c(t)$ ,  $\mu_{s_i}^v(t)$  and is modulated by  $h_{s_i}(t)$ .

Perceived benefit  $\lambda_{s_i}(t)$  is estimated from an economic index for evaluation of expected return  $r_{s_i}(t)$  and is dependent on the values set for the constant  $\beta$  and  $\kappa_1$  in Equation (3). Risk perception  $\chi_{s_i}(t)$  is estimated based on the evaluation of expected cost  $c_{s_i}(t)$  and is dependent on the values set for the constant  $\theta$  and  $\kappa_2$  in Equation (4). Here, the values of these constants were adjusted *ad hoc* to maintain  $\lambda_{s_i}(t) > \chi_{s_i}(t)$ , a condition considered necessary for the existence of the stock market.

The change in investor humor  $h_{s_i}(t)$  is the main factor for the success of the model to describe the evolution of Ibov during a period of seven years, in which the market experienced a major crisis in 2008 characterized by a period of nervousness created by the economic instability of many countries within the euro area. It is the dependence on the conflict generated by perceptions of risk and benefit that sets the general pattern of market evolution as shown in Figures 1.

However, it is the dependence of  $\tilde{h}_{s_i}(t)$  on local and global macroeconomic conditions that fine-tune the market sentiment and dictates its behavior ( $p_{s_i}(t)$ ).

Local and global macroeconomics influence is exerted over  $\tilde{h}_{s_i}(t)$  and it is mostly exercised by means of media news, as the present results clearly demonstrated (Figures 4 and 5).

In addition, these news effects over  $\tilde{h}_{s_i}(t)$  are complex, because market news are also dependent on stock price evolution. Besides, the effects of the collective humor over the market are long lasting as disclosed by its dependence on lagged humor variable.

The stock price dependence on global ( $\tilde{h}_s(t)$ ) and local ( $h_s(t)$ ) humor as seen here, is not, however, shaped by the classical theory in finance. Most importantly, however, it is not disputed that the present model provides a better alternative or not to the understanding of the behavior of the stock market, but rather the fact that it can be tested empirically as discussed above. This kind of approach provides new interpretations about systematic and unsystematic global systemic risks (Rocha, 2013).

## 6. Conclusion

Our initial hypothesis was that news might have a major impact on market sentiment (volatility) and it is correlated with investors' humor. In other words, the impact of the media can deepen the bearish dynamics of the markets.

The variables humor, lag1(humor) and Good/Bad index were regressed together and the results turned out to be statistically robust, given the significance of all variables within the regression. We can recall the magnitude of the impact of news as of 0.587 and therefore it corroborates its importance within the market's feeling, since it contemplates good and bad results from companies, economic indicators and other relevant factors. The humor also has a carry-over effect, which is given by lag variable, showing a hard movement to dissipate within the financial market.

With those significant results, we suggest that the market is heavily influenced by the different types of news (good or bad ones).

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### Author details

Roberto Ivo da Rocha Lima Filho<sup>1,2</sup>

E-mails: [roberto.ivo@poli.ufrj.br](mailto:roberto.ivo@poli.ufrj.br), [roberto.darochalimafilho@brasenose.oxon.org](mailto:roberto.darochalimafilho@brasenose.oxon.org)

ORCID ID: <http://orcid.org/0000-0001-9588-8951>

Armando Freitas Rocha<sup>3</sup>

E-mail: [armando@enscer.com.br](mailto:armando@enscer.com.br)

<sup>1</sup> Department of Industrial Engineering, Federal University of Rio de Janeiro, Av. Athos da Silveira Ramos, 149 Centro de Tecnologia - Bloco F 1 andar 21941 909 Rio de Janeiro, RJ, Brazil.

<sup>2</sup> Oxford University, Queen Elizabeth House 3 Mansfield Rd, Oxford OX1 3TB, UK.

<sup>3</sup> ENSCER Faculdade de Medicina Department of Medical Informatics, University of São Paulo, São Paulo, SP, Brazil.

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### Notes

1. The model is in log-terms.

2. As property, investor will reach a maximized “decision” when  $\frac{x_s(t)}{\lambda_s(t)} \rightarrow 1$  and minimum when  $\lambda_{s_1}(t)$  and/or  $x_{s_1}(t)$  tend to zero.

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