Corporate governance, reputational game and volatility.

Abstract

In this article we present an incomplete information model in a reputational game where corporate governance requirements can be used as signaling, volatility is considered as reveals mechanism of the firm's type of corporate governance. To confirm the hypothesis of lower volatility of firms with a high degree of corporate governance we use daily stock market returns from 2007 to 2016. We present the results of volatility spillover and lead-lag effects in the Brazilian stock markets, measured by conditional correlations, considering in detail, the corporate governance as a mitigating factor. Using multivariate GARCH we estimate conditional correlations in 9 different models. We combine: the volatility of the Ibovespa index, IGC-NM index as higher corporate governance level, IGC-X index as a intermediate corporate governance level, with each of three types of exchange rate shocks: the dollar volatility, the representative volatility obtained via Dynamic Principal Component Analysis of 48 exchange rates, and this same volatility with 47 exchange rates excluding the dollar; also considering an international financial shock with 16 international financial market indices. The existence and direction of volatility spillovers from forward exchange and international financial shocks and the Ibovespa, IGC-NM and IGC-X indices are tested using Granger tests of second order causality, and lead-lag effects between these shocks and the indices are identified. The volatility from exchange and international financial shocks spillsover to the indices, with lead-lag effects always in the direction from the shocks to the indices. Our study of spillover and lead-lag effects of different types of currency shocks and international financial shocks provides statistical evidence showing corporate governance as mitigating factor of spillovers. At higher levels of corporate governance requirements, the volatility spillovers form foreign exchange and international financial markets are lower.

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Keywords: Reputational game; Corporate governance; Multivariate GARCH; Granger second order causality; Volatility spillover.

1. Introduction

Corporate governance is an unobservable feature of firms. Although exist quantitative requirements related to corporate governance, in a broad sense, governance is part of the firm's culture, and some firms have a strong corporate governance culture[1]. In open markets a high degree of corporate governance can attract investors, so firms try to meet requirements to signal a certain degree of corporate governance. If the hypothesis that firms with a high degree of corporate governance have lower volatility can be confirmed, volatility could be a revealing mechanism for the degree of firm's corporate governance,

One of the objectives of this article is to present, based on game theory, a finite horizon reputational game, in which firms without a strong corporate governance culture try to signal a higher degree of governance, and in which volatility serves as a mechanism to reveal the firm's true degree of corporate governance. As in the Selten (1978) chain-store paradox, the model for the corporate governance case can be built inicially, with the basic model with complete information, evoluting to more elaborate version with belief systems and signaling capable of building a reputation. The proposed reputational model's results depend on the hypothesis that firms with a

[1] Recently several companies that had a high degree of corporate governance suffered from corporate scandals involving corruption, as in the case of Brazilian companies Petrobras, Odebrecht and JBS.

higher degree of corporate governance have lower volatility. This hypothesis arise from an extensive econometric literature dealing with volatility spillover and lead-lag effect.

Early studies of stock prices and exchange rates were initially concerned with variables in terms of levels. Indeed, Phylaktis and Ravazzolo (2005) apply cointegration and multivariate test of Granger-causality to a group countries of the Pacific Basin, and show that the stock and foreign exchange markets (forex) are positively correlated. Recently researchers have studied to study the volatility spillover of stock and exchange prices in either direction. Many models have since been implemented based on these methods.

To study univariate volatility, the most commonly used models are VAR, GARCH and their various specifications. Multivariate GARCH models, on the other hand, allow for the study of volatility cross effects (conditional variances and correlations).

Most available empirical evidence on stock and forex markets has focused on the first moments, that is, on the mean values of stock prices and exchange rates. Yang and Doong (2004) observe a lack of empirical evidence focusing on the link between the second moments of the variables distributions, that is, on volatilities. However, some studies have examined the extent which the volatility of a stock market spreads over other stock markets or between different assets. While Solnik and Roulet (2000) find a significant negative relationship between the volatilities of stock and forex markets, Bodart and Reding (1999) find no relation between them. Kanas (2000) pioneering study brought new evidences the spillover effects of volatilities.

The statistical precedence of spillover effects started to be tested, now became the principal issue in research agenda on lead-lag effects. The lead-lag effects, though initially studied for prices, posteriorly began to deal with the volatility movements and to identify a market which in some sense leads price or volatility movements followed with lag by another. See, for instance, Madhavan (2000). The development of these Granger-causality tests of second order allowed for the test of lead-lag effects between markets for the case of volatility.

The conditional correlation between volatilities of external shocks (here we consider exchange rates and financial markets) and measures of quality of corporate governance (here we consider the IGC-MN and IGC-X, corporate governance indexes) have not yet been fully investigated in the financial literature. Many questions remain:

How does exchange rate volatility spillover to corporate governance indices volatilities? Does volatility in international financial markets spillover to corporate governance indices volatilities? Which of these spillover effects is most relevant for corporate governance indices volatilities? Is a higher quality of governance associated with lower spillover effects?

In this paper, we fill a gap in the literature in five different ways. First, we propose a sequence of models, from a basic model to a reputational model with signaling. Second, we apply these methods to the Brazilian case for the very first time. Third, we present a first examination of spillovers and lead-lag effects related to corporate governance. Fourth, we combine different types of exchange rate volatilities, international financial market volatilities and their spillovers in the Brazilian financial market index (Ibovespa) and in the high-quality governance financial indices (IGC-MN and IGC-X), which is also a novelty. Finally, in addition to multivariate GARCH models, we also use Granger-causality of second order to identify the direction of the spillovers, the lead-lag effects.

In Section 2 we introduce related literature. Section 3 presents the multivariate GARCH model. Section 4 includes a brief summary of Granger-causality of second order. The instrument to be used, from game theory and its application in the Chain-Store game model as well as the reputational game model is shown in Section 5. Section 6 presents the data set, the building of the exchange rate shocks and international financial markets shocks, the models, as well as the tests to be implemented. Results are shown in Section 7. Section 8 concludes the paper.

2. Literature

2.1 Impacts of Corporate Governance on the Performance of Companies

Most research on corporate governance and firm performance confirms that strong corporate governance (CG) is associated with firm valuation. Klapper and Love (2004) explore the differences between internal governance mechanisms, their relationships with normative measures of the country and the correlation between governance and performance. They find the following: (1) companies in countries with weak legal systems have, on average, a lower governance index; (2) company-level governance is correlated with information asymmetry and contractual imperfections facing the company; (3) companies whose shares are traded in the US have a higher level of CG , especially subsidiaries in countries with weak legal system; (4) good CG is positively correlated with market appreciation and operational performance; and (5) this ratio is higher in countries with a strong legal system.

Extensive internal CG measures can predict high share price value in emerging markets Black, Love and Rachinsky (2006) find an economically and statistically significant relationship between governance and market firm's value for a combined governance index, the Brunswick, Troika, Standards and Poor's disclosure, and ICLG indices. They conclude that different measures of corporate governance affect predictive power.

Brown and Caylor (2006), investigate which internal governance measures are important to predict the market value of firms, based on a sample from a new CG data provider. They document that effective corporate governance requires both internal and external measures. They also, identify five internal governance factors directly related to firm value.

Fuenzalida et al. (2013) study how the adoption of good CG practices relates to the generation of positive returns on the Lima stock exchange. They examine the performance of companies from 2004 to 2008. The results showed that the announcement of the inclusion of a firm in the CG index produces an abnormal return ranging from 0.95% to 1.11% on the day of the announcement. Garay et al. (2013) examine the relationship between the Internet-based disclosure index and firm value on the seven largest exchanges in Latin America. The study concludes that even in an environment with weak investor protection, as in Latin America, companies can improve their market value by adopting proprietary disclosure practices.

Rani, Yadav, and Jain (2013) investigate whether CG practices influence short-term performance by creating a CG index. They surveyed 155 companies which had completed an acquisition or merger announced between 2003 to 2008. They find a positive relationship with the CG index and abnormal short-term returns.

Black, Carvalho and Sampaio (2014) analyze the evolution of CG in Brazil from 2004 to 2009 and the association between governance and firm value. Three extensive surveys on governance practices conducted 2004, 2006 and 2009 provide data. Adoption of governance index elements required for listing New Market and Level 2[2] companies predict a higher market value.

Catapan and Colauto (2014) examine whether there is a relationship between corporate governance and economic-financial performance in Brazilian companies listed on Ibovespa, considering the years 2010-2012. They find a direct relation between market value of companies and level of disclosure.

2.2 Spillover between stock price and exchange rate volatility

Kanas (2000) pioneered the study of volatility spillovers of stock returns and exchange variation in the US, UK, Japan, Germany, France and Canada. He finds evidence of spillovers from stock returns to exchange rate variation for all countries, except Germany this suggests that the asset approach to the exchange rate determination is valid when formulated in terms of the second moment of the distribution of the exchange rate for these countries.

Yang and Doong (2004) explore the mean and volatility transmission mechanism between the stock and foreign exchange markets for the G-7 countries. They expand the Kanas sample to the G-7, including Italy. Volatility and an asymmetrical effect of the stock market for the foreign exchange market for France, Italy, Japan and the US, which suggests the integration between them. They show that stock price movements have an impact on future movements in the exchange rate,

[2] These concepts will be detailed in Section 5.1.

but changes in exchange rates have less direct effect on future stock returns, similar to Kanas (2000).

In a similar study applied to four Eastern European countries (Poland, Hungary, Russia and Czech Republic), Fedorova and Saleem (2009) find unidirectional side effects of currency market volatility for the stock market. Only the Czech Republic falied to show bidirectional volatility spillover effects between the markets.

Goldberg (1993) finds, in the US, that changes in exchange rate volatility have significantly negative long-term effects on investment. Darby et al. (1999), using an estimate with a single equation, find a similar negative exchange rate effect on aggregate investment based on data from five OECD countries. Carruth, Dickerson, and Henley (2000), adopting a GARCH structure, find a highly significant negative impact of uncertainty of the real exchange rate on investment.

Amihud (1994) and Bartov and Bodnar (1994) conclude that contemporary dollar changes have little power to explain abnormal returns. However, they find a lagged dollar shift negatively associated to abnormal returns. Ajayi and Mougoué (1996) find that exchange variation exerts a significant and dynamic influence on returns for eight industrialized countries.

Zapatero (1995) shows that in fully integrated financial markets there is an explicit link between stock price volatility and exchange rate volatility. In contrast, Jorion (1990) and Booth and Rotenberg (1990) find no significant link between exchange rate variation and corporate stock returns. In a similar study, Muradoglu, Taskin and Bigan (2000) try to uncover the relationship between returns and some macroeconomic variables. They conclude that there is a causal relationship from the exchange rate to stock returns in Nigeria, Mexico, Korea, Greece, Colombia and Brazil.

Chen, Naylor and Lu (2004) point out that in a large market with well-diversified firms, domestic conditions may be more important than international ones. On the other hand, they also conclude that the New Zealand market is very small compared to the US market, and businesses in New Zealand are much less diversified. Using a two-factor model, they find that returns from New Zealand firms (the first moment) are significantly explained by the exchange rate variation. However, they do not analyze the (second moment) volatility spillover between stock market returns and changes in exchange rates in the New Zealand economy.

Black (1976) and Christie (1982) similarly conclude that a fall in stock prices is followed by an increase in subsequent stock volatility. This phenomenon is called leverage, which is tested in the GJR-GARCH model developed by Glosten, Jagannathan and Runkle (1993).

Alaganar and Bhar (2007) indicate that the first and second-order effects of the exchange rate have a significant impact on diversified portfolios in the US stock market. They use the GJR-GARCH and GARCH-M models to test the impact of exchange rate volatility on portfolio returns.

They point out that the variance of the exchange rate is important for diversification in the stock market.

Morales (2008) studies volatility spillovers between stock returns and exchange rates for major Latin American countries. He finds asymmetric spillover effects, for all countries, from stock returns to exchange rates. All coefficients are positive, which he interprets as follows: good news has a greater impact on volatility than unexpected bad news.

Diamandis and Drakos (2011) examine the long-term and short-term dynamics between the stock and exchange markets of four Latin American countries (Argentina, Brazil, Chile and Mexico), as well as their interactions with US stock markets. These authors find that the two markets in these economies are positively related and the US stock market represents a transmission channel for these effects.

Chkili and Nguyen (2014) use a regime change model approach to investigate the dynamic relationships between exchange rates and stock market returns for Brazil, Russia, India, China and South Africa, the BRICS countries. The univariate analysis indicates that the stock returns of BRICS countries evolve according to two different regimes: a regime of low volatility and a regime of high volatility. On the other hand, the VAR models with Markovian regime change suggest that stock markets have more influence on exchange rates during both quiet and turbulent periods. These studies and empirical findings have important implications for portfolio investments and exchange risk hedging and also play a relevant role in the risk aversion component in investor decision making.

2.3 Spillover and lead-lag effect

In financial theory, information is of central importance. How information is incorporated into prices and how individuals use it to take effective actions are points of debate. These questions prompted a whole line of research in finance known as market microstructures, according to Madhavan (2000). Analysis of market microstructures studies the institutional structure in which transactions of financial assets are conducted. The main lines of research in this area include the adoption of fixed increments for asset prices (ticks), irregular intervals observed (or not observed) between different transactions over a period, spreads between buying and selling prices of market makers, and change in volume (number of contracts) for each operation carried out over a period. Common to all these lines of research, is how information affects the prices of assets.

A more classical line of thought, such as that of Fama (1991) and Lucas (1978), Lucas (1986), argues that equilibrium is reached using all available information. Byrne and Brooks (2008) argue for momentary errors of incorporation of information that generate small disequilibria and arbitrage opportunities. Jensen and Meckling (1976), who posit that information is only used when its marginal benefit exceeds its marginal cost processing, initially studied the speed of incorporation of information, capital cost and market value of companies. Easley and Ohara (2004), Botosan, Plumlee and Xie (2004), Bushman et al. (2004) and Plumlee (2003) find evidence that the greater the information asymmetry among economic agents, the higher the cost of capital of companies. More complex information has a longer processing time, as presented by Plumlee (2003). In addition, companies followed by a larger number of analysts incorporate information more quickly, according to Brennan and Subrahmanyam (1995).

The lead-lag effect is observed when the movements (ir even correlation) of prices or volatilities of two distinct markets are related. One market follows the movement of the other market considered as a "leader" with some lag. For Jiang, Fung and Cheng (2001), the lead-lag effect is defined as two or more prices moving in sequence. This effect, when verified, breaks down the market efficiency hypothesis developed by Malkiel and Fama (1970), which states that stock prices behave as a random walk, immune to forecasting and arbitrage. However, even in the confirmed presence of lead-lag effects, transaction costs may render arbitrage unfeasible, making the market efficiency hypothesis again valid.

Miller (1980) identifie the lead-lag effect between the wholesale price (Leader) followed by the price of pork producers in the United States. In stock markets, the lead-lag effect is used in different ways, as in the analysis of the relationship between the cash market and futures markets by Herbst, McCormack and West (1987). For the S&P 500 index, Tse (1995) examines the same relationship for Nikkei index contracts, with evidence that futures prices lead spot prices in the short term. Further studies of the lead-lag effects include those of Brooks, Rew and Ritson (2001) for the London FTSE100 index, as well as Suárez's (2008) study of Spain's IBEX35 index. Daigler (1990) see lead-lag effects in the S&P 500, MMI and NYSE contracts, analyzing the relationship between returns and transaction volumes. Latin America is studied by Saatcioglu and Starks (1998).

For the Brazilian case, Gaio and Rolim (2007) measure the impact of changes in the main stock market indices globally on the Ibovespa they show that international stock exchanges influence prices in the Brazilian stock market. Oliveira (2008) studiessco-movements of the Dow Jones index and the Ibovespa index and identified lead-lag effects between the Brazilian market and the North American market between 2006 and 2007. Using high frequency data, he concludes that there is no room for arbitration on account of transaction costs.

On the other hand, Nakamura (2009) shows the existence of lead-lag effects between the Brazilian stock market and its American Depositary Receipt (ADRs). Pena, Guelman and Rabello (2010) analyze the relationship between the Dow Jones and Nikkei indexes with the Ibovespa Index. Using data from January 2006 to May 2008, the authors identify a contemporaneous relationship between indices and lagged effects that would come from the difference of time zones.

More recently, Maranhão and Oliveira (2017) present evidence of lead-lag effects between the volatility of different types of exchange rate shocks and the Brazilian financial market measured by the Ibovespa Index. They show a lead-lag effect always in the direction of exchange rate volatilities for the volatility of Ibovespa Index.

Neto, Medeiros and Queiroz (2012) identify lead-lag effects between the IGC-X index and the Ibovespa index, that is, a higher degree of governance is associated with a faster incorporation of information into prices, which makes the index with higher governance quality Granger-cause the Ibovespa.

3. Multivariate GARCH BEKK model

Univariate time series models were initially used in the study of volatility of returns of financial assets, especially in the case of time-varying volatility. These studies gave way to multivariate models. In this section we present some models for multivariate financial series whose conditional variance and covariances vary in time. Since many nonlinear univariate models are available, we will restrict ourselves here to some extensions within the class of auto-regressive models with conditional heteroscedasticity (ARCH), introduced by Engle (1982) and extended by Bollerslev (1990) to the multivariate case.

The first generalization of ARCH models was given by Bollerslev (1986), the so-called "*generalized*" ARCH (GARCH) model. GARCH models can be used to describe volatility with fewer parameters than the ARCH model.

In many situations, however, we need to consider more than one asset and, hence, correlations between them. Just like with time-varying variances before, the importance of temporal volatilities has increased as well, with multivariate GARCH models (MGARCH).

The MGARCH model has the following general form:

$$vech\left(\Sigma_{t|t-1}\right) = C_0 + \sum_{j=1}^{q} A_j vech(u_{t-j}u'_{t-j}) + \sum_{j=1}^{m} B_j vech\left(\Sigma_{t-j|t-j-1}\right) \qquad (1)$$

$$u_t = \Sigma_t^{1/2} z_t, \qquad z_t \sim i.i.d(0, I_k) \qquad (2)$$

$$\Sigma_t = \Sigma_t^{1/2}(\Sigma_t^{1/2}), \qquad (Cholesky) \qquad (3)$$

The parameters space of a GARCH model has high dimension. It generally needs to be restricted in order to get unicity of representation and to obtain adequate properties of conditional covariances. To reduce the space of parameters, Bollerslev, Engle and Wooldridge (1988) discuss diagonal MGARCH models, where $A_j's$ and $B_j's$ below are diagonal matrices. Alternatively, there are the multivariate GARCH BEKK models are usually given in the following form:

$$\Sigma_{t|t-1} = C_0^{*\prime} C_0^* + \sum_{n=1}^{N} \sum_{j=1}^{q} A_{jn}^{*\prime} u_{t-j} u_{t-j}' A_{jn}^* + \sum_{n=1}^{N} \sum_{j=1}^{m} B_{jn}^{*\prime} \Sigma_{t-j|t-j-1} B_{jn}^* \quad (4)$$

where C_0^* is a $K \times K$ triangular matrix and the coefficients $A_{jn}^{*\prime}$ and $B_{jn}^{*\prime}$ are also $K \times K$ matrices.

Though the low-order BEKK model is a relatively parsimonious representation of the structure of conditional covariances, the number of parameters still grows faster than the dimension of the underlying system. Therefore, in practice, only systems with a low number of variables are viable.

In financial markets positive and negative shocks and news have quite different effects [Black (1976)]. Leverage effects can be introduced into MGARCH models[3] in different ways. For example, Hafner and Herwartz (1998) and Herwartz and Lutkepohl (2000) generalize the univariate proposal of Glosten, Jagannathan and Runkle (1993)'s and substituted $A_{jn}^{*\prime} u_{t-j} u_{t-j}' A_{jn}^*$ by

$$A_{11}^{*\prime} u_{t-1} u_{t-1}' A_{11}^* + A_{ss\_I}^{*\prime} u_{t-1} u_{t-1}' A_{ss\_I}^* (\sum_{k=1}^{K} u_{kt} < 0) \quad (5)$$

in a BEKK model. Here I(.) denotes an indicator function with value 1 if the argument is valid, and 0 otherwise. $A_{\_}^*$ is an additional coefficient of the $K \times K$ matrix.

4. Granger-causality test of second order

The definition of Granger-causality is based on prediction. Under appropriate conditions, optimal predictions are obtained as conditional expectations. Therefore, Granger-causality can be defined in optimal terms as conditional expectations, according to Granger (1988). In other words, we can define a time series variable X_t as causal with respect to Z_t if

$$E(z_{t+1}|z_t, z_{t-1}, \dots) \neq E(z_{t+1}|z_t, z_{t-1}, \dots, x_t, x_{t-1}, \dots) \quad (6)$$

This definition suggests a straightforward extension for higher-order conditional moments. We define X_t to be causal for Z_t in the r-th moment if

$$E(z_{t+1}^r|z_t, z_{t-1}, \dots) \neq E(z_{t+1}^r|z_t, z_{t-1}, \dots, x_t, x_{t-1}, \dots) \quad (7)$$

[33] An important issue in the GARCH literature is the existence of heavy tails in the distributions of returns. This aspect has also been treated in multivariate models. However, in this study, given the building of Granger causality of second order, we will deal only with the BEKK model of multivariate normality.

Hence, the first inequality defines causality on average and, considering the second moments, the second inequality defines variance-causality, which is analogous to the previous definition of Granger-causality on average. In other words, if X_t is causal in variance for Z_t, the conditional volatility of Z_t can be predicted in a more precise way, given current and past information on X_t, than without such information.

According to Granger-causality of second order, a vector of variables does not cause another vector of variables, if past information about the variability of the former variables cannot improve the prediction of the later variables' conditional variances. The definition of non-causality of second order assumes that the Granger causal relations can exist in the conditional mean process, but that they should, nevertheless, be modeled in terms of filters. Otherwise these relations could impact the parameters responsible for the causal relations in conditional variances.

4.1 Tests of non-causality in variance

Based on the squared residuals $\hat{\xi}_{i,t}^2 = u_{i,t}^2 / \hat{\sigma}_{i,t}^2$, where $\hat{\sigma}_{i,t}^2$ is the estimated conditional variance of $u_{i,t}^2$ using univariate GARCH, Cheung and Ng (1996) introduce a statistic to test the null hypothesis of non-causality in variance. In practice, the choice of m should cover the biggest potential lag of causality in variance. Cheung and Ng (1996) prove that, under consistent estimation of the univariate GARCH parameters, P_m asymptotically follows the distribuição χ_m^2 under the null hypothesis[4]. Analogous statistics can be defined to test the hypothesis of bidirectional causality. A multivariate version was proposed by Hafner and Herwartz (2006, 2008), as we are about to present.

Non-causality in variance is associated to a certain set of constraints which nullify some values of the matrices A_j and B_j in (1). To find these constraints, we define an index:

$$k_{ij}^K = i + (j-1)\left(K - \frac{j}{2}\right) \quad (8)$$

for $i, j \in \tau \cup \upsilon$ and $i \geq j$, which are the position of the $(i,j)-th$ element of the $(K \times K)$ symmetric matrix M in the vector $vech(M)$. Remember that $vech(M)$ has $K^* = \frac{K(K+1)}{2}$ distinct elements. In addition, define the following sets of indices:

$$\tau^* = \left\{ k_{ij}^K \middle| i.j \in \tau \right\} \quad (9)$$

[4] P_m represents the order P in GARCH(p; q) models.

$$\upsilon^* = \{1, \dots, K^*\} | \tau^* \tag{10}$$

We can now define the conditions for non-causality in variance. Consider the following conditions:

$$[\phi_n]_{ij} = 0, \quad \forall n \geq 1, \;\; \forall i \in \tau^*, \forall j \in \upsilon^* \tag{11}$$

that is:

$$[A_a]_{ij} = 0, a = 1, \dots, q, [B_b]_{ij} = 0, b = 1, \dots, p, \forall i \in \tau^*, \forall j \in \upsilon^* \tag{12}$$

Assume that $\tilde{Q}$ is a matrix of dimension $k(K-k) \times (K)^2$ and rank $k(K-k)$. The $(r, \overline{w})$ elements of $\tilde{Q}$ are given by

$$\tilde{Q}_{r,\overline{w}} = \begin{cases} 1, \overline{w} = s_{mn} \\ 0, \overline{w} \neq s_{mn} \end{cases} \tag{13}$$

where

$$r = m + (n-1),\; s_{mn} = i_m + (j_n - 1)K, i_m \in \tau, j_n \in \upsilon, and\; m = 1, \dots, k, n = 1, \dots, K-k$$

The null hypothesis of absence of causality in the BEKK model can now be written:

$$H_0: Q\upsilon = 0 \tag{14}$$

with $\upsilon = [vech(A_0^*)', vech(A^*)', vech(B^*)']'$ and $Q = [0_{k(K-k)\times K}, \tilde{Q}, \tilde{Q}]$.

Suppose we have T observations $u_1, \dots, u_T$. Assume that the true process is known and belongs to the BEKK class, as seen by Comte and Lieberman (2003). A consistent estimator of the true vector of parameters ϑ_0 is denoted by $\hat{\vartheta}$ and its asymptotic distribution is given:

$$\sqrt{T}\left(\hat{\vartheta} - \vartheta_0\right) \xrightarrow{asy} N(0, \Omega_\vartheta) \tag{15}$$

with some symmetric positively definite matrix Ω_ϑ. Assume as well that a consistent estimator of Ω_ϑ is given by $\widehat{\Omega}_\vartheta$. Then $\sqrt{T}(\hat{\vartheta}-\vartheta_0) \xrightarrow{l} N(0,\Omega_\upsilon)$ satisfies the regularity conditions of Comte and Lieberman (2003), and Ω_ϑ is given by

$$\Omega_\vartheta = S^{-1}DS^{-1} \qquad (16)$$

where

$$D = E\left[\frac{\partial l_t(\vartheta)}{\partial\vartheta}\frac{\partial l_t(\vartheta)}{\partial\vartheta'}|_{\vartheta_0}\right],\quad S = -E\left[\frac{\partial^2 l_t(\vartheta)}{\partial\vartheta\partial\vartheta'}|_{\vartheta_0}\right] \qquad (17)$$

with

$$l_t(\vartheta) = -\frac{K}{2}\ln(2\pi) - \frac{1}{2}\ln\left|\Sigma_{t|t-1}(\vartheta)\right| - \frac{1}{2}\upsilon_t'\Sigma_{t|t-1}^{-1}(\vartheta)\upsilon_t \qquad (18)$$

Hafner and Herwartz (2006) give expressions for D and S and their estimates. For the significance tests, Hafner and Herwartz (2008) show that analytical techniques for Ω_ϑ are far superior to numerical derivation, in terms of the test's power.

The authors propose the following standard Wald statistic to test the hypothesis $H_0\colon Q\upsilon = 0$:

$$W_T = T\left(Q\hat{\vartheta}\right)'\left(Q\hat{\Sigma}_\vartheta Q'\right)^{-1}\left(Q\hat{\vartheta}\right) \qquad (19)$$

Using $\sqrt{T}(\hat{\vartheta}-\vartheta_0) \xrightarrow{asy} N(0,\Omega_\vartheta)$ and Lutkepohl (1993) proposition, the asymptotic distribution of the Wald statistics is given by

$$W_T \xrightarrow{asy} \chi^2_{k(K-k)}. \qquad (20)$$

An analogous statistic can be defined for the Diagonal VEC model (the same is true for Diagonal BEKK) on the basis of the null hypothesis $H_0\colon Q\upsilon = 0$, provided that the conditions of asymptotic normality of the estimators are satisfied. The degrees of freedom of the Wald statistic for the Diagonal VEC model are $k^*(K^*-k^*)$.

5. Corporate governance and reputational game

Environments of conflicting strategies were first studied by John von Neumann (1928). The evolution of this study resulted in Theory of Games and Economic Behavior, written by John von Neumann himself and Oskar Morgenstern. One of the Nobel Prize winners in this area was the German Reinhart Selten. One of his studies, known as The Chain Store Paradox (1978), contributed fundamentally to the pratical applications of the principles of games. This study deals with the situation of a chain of stores. Each store has a market. Each store are in monopoly context, obtaining a high profit from mark-ups. For each market, an incoming player which analyzes the possibility of contesting the market.

In the event that the market is challenged by the entrant, the monopolist reacts by means of price war or by accommodating the entrant and thereby obtaining duopolistic profits. The price war results in losses for both players, and the duopolist profit, although smaller than the monopoly profit, is considerable.

The determining feature of this game is complete information, because the entrant knows exactly what the monopolist's decision will be. Thus, the solution occurs through retroactive induction where the former analyzes the result of the last market. In these conditions, if the entrant responds to the market, it will always be better for the monopolist to accommodate it, because it will be preferable to obtain smaller duopolistic profits, although still positive, than to suffer losses due to the price war.

Knowing the decision of the monopolist to accommodate it, the entrant decides to contest the market, since it can obtain part of the profits of the monopolist. This sequence occurs until the last market where it is an optimal strategy for the entrant to contest the market, and a dominant strategy for the monopolist to accommodate it.

The result of this game, as it is referenced in the title of the article, is paradoxical, because it is concluded that price wars will never occurr and a monopolist will always accommodate an entrant that challenges his market.

This mismatch between reality and theory was solved by Kreps and Wilson (1982) and Milgron and Roberts (1982), who identify the existence of imperfect information in the interaction between agents. Imperfect information made the agents not know the characteristics of other players.

Applying this axiom to the problem of the chain store paradox, the incoming agent is unsure if the monopolist would be willing to defend its achievement of profit or maintain its position of exclusivity. Choosing to defende exclusivity, the monopolist would enter into a price war, even if it implied a loss in that market.

The entrant then needs to re-evaluate its analysis to decide whether or not to contest the market, based on its expectations about the monopolist. If the entrant believes that there is a high probability that the monopolist only cares about his or her profit, the entrant will contest the market. If the entrant believes that there is a high probability that the monopolist cares more about its exclusive position in that market, the entrant will not contest this market to avoid the damages of a price war. The monopolist, through attitudes in a market, may signal to the subsequent markets that his type is not to accept the entry of competitors.

Thus, more recently Contract Theory has emerged, which uses game theory to describe conflicting strategic behavior using Principal-Agent models, analyzing the characteristics of incentives generated by institutions, with which agents are confronted. From this line developed important concepts of modern economic theory, such as adverse selection, moral hazard and signaling.

Jensen and Meckling (1976) focus on the study of the agency relationship between shareholders and executives. The problem appears even if the administrator is the owner, but does not hold the total capital of the company. The administrator can act according to parameters that are not best from the owner's point of view. This agent is in a position to obtain pecuniary gains (comfort in activity) that may not revert to shareholders.

The agency costs are then the sum of the incentive or monitoring expenses by the principal, of guarantees given by the agents, and the residual loss. The principal may limit divergences in their interests by establishing appropriate incentives for the agent and incurring monitoring costs designed to limit aberrant agent activities. Moreover, in some situations, the agent will spend resources (bonding costs) to ensure that he not take certain actions that would harm the interests of the principal, or compensate the principal if he does. However, it is generally impossible for the principal or agent, at zero cost, to ensure that the agent will make optimal decisions from the point of view of the principal (residual loss).

Given agency costs, why does the modern economy organize itself with this separation? This is the question addressed by Fama (1980), who explains how the separation of property and control, typical in large organizations, can be an efficient form of organizing economic development. The role of corporate governance (CG) is, among other things, to monitor the relationships between management and shareholders (majority and minority shareholders) and to try to minimize the discrepancies between them. For Shleifer and Vishny (1997) corporate governance presents a set of mechanisms by which investors guarantee that they will obtain the return of their investments. In a more comprehensive way, Costa (2008) clarifies that governance can be understood as the set of incentive and control mechanisms, both internal and external costs, to deal with the managerial problem.

5.1 Signing game: Creating reputation

In this section we present the reputation model considering the corporate governance problem. We define the utilities functions for building a strategic game between investors and firms. Once these functions are defined, we present the game with complete information followed by the complete information set with two investors and one firm, and we finalize the incomplete information model, in which the firm's reputation for corporate governance will be defined.

5.1.1 Behavior of Investors

Consider investors $I_j, j = 1, \dots, n$ with the decisions $\{i, ni\}$ to invest or not in a firm E_k $k = 1, \dots, m$, and the return associated with its strictly increasing utility function:

$$R_{I_j} = D_E + P_E B_e(i) - \lambda\sigma_E \quad (21)$$

$$U_I = U(R_{I_j})$$

where

R_{I_j}: Total Return on Investor Investment I_j;

D_E: Dividend paid by the firm E;

P_E: Firm share price E;

$B_e(i)$: Stock of firm E which is a function of the invested amount i;

λ : share of loss caused by the volatility;

σ_E: a volatility measure of firm E and

U_I: utility function increasing and concave.

Considering the hypotheses:

$\frac{\partial B_e(i)}{\partial P_E} < 0$ and $\frac{\partial^2 B_e(i)}{\partial P_E^2} < 0$

5.1.2 Behavior of Firms

Firms E_k $k = 1, \dots, m$ with decisions $\{c, nc\}$, comply with legal requirements to obtain a certain level of corporate governance, or otherwise. Company E_k, has an increasing and concave utility function, will be given by:

$$R_{E_k} = P_E B_E + R_{tE} - f(C)T - \lambda\sigma_E - D_E \quad (22)$$

$$U_E = U(R_{E_k})$$

where

R_{E_k}: Total firm E_k results;

P_E: Firm share price E;

B_E: Stock share of firm E;

R_{tE}: Firm revenue E_k in the current period;

$f(C)$: Cost function related to the cost value spent in the current period;

T: Units of products/services produced in the current period;

λ: share of loss caused by the stock price volatility;

σ_E: a stock price volatility measure of firm E;

D_E: Dividend paid by the firm E and

U_E: Increasing and concave utility function of firm E.

If firm E_k decides " c " will have to pay a higher cost $C_{cg} > C$, and we assume, in a first moment, $\sigma_E^{cg} < \sigma_E$. The result will now be given by

$$R_{E_k}^{cg} = P_E B_E + R_{tE} - f(C_{cg})T - \lambda\left[\frac{\sigma_E[(\sigma_E - \sigma_E^{cg}) - 1]}{\sigma_E - \sigma_E^{cg}}\right] - D_E \qquad (23)$$

$$U_E = U(R_{E_k}^{cg})$$

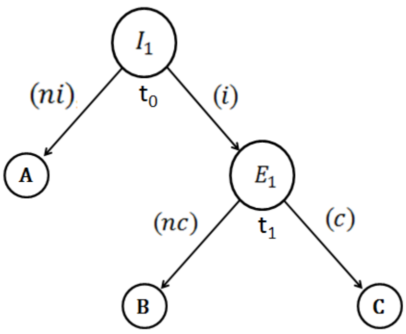
If the firm does not receive an investment, it will not have the $P_E B_E$, $\lambda\sigma_E$, $\lambda\left[\frac{\sigma_E[(\sigma_E - \sigma_E^{cg}) - 1]}{\sigma_E - \sigma_E^{cg}}\right]$ and D_E components. In order for the game to make sense, we assume the hypothesis: $U(R_{E_k}^{cg}) > U(R_{E_k})$ and therefore firm E_k will always have incentives to receive investments from the opening of its capital. If it does not receive investments, the return will be only

$$R_{E_k} = R_{tE} - f(C)T \qquad (24)$$

5.1.3 *Basic model: Complete information game with an investor and a firm*

First we will show a game where there is only one investor I_1 deciding whether to invest or not to invest in firm E_1. Thus, the Investor (I_1) decides first if he invests in firm E (i) or does not invest (ni); after this, the Firm (E_1) decides whether it meets the requirements to obtain a certain degree of corporate governance (c) or does not comply (nc). This strategic relationship between an investor I_1 and the firm E_1 is shown in Figure 1.

Figure 1. Game in extensive form - complete information, one investor and one firm.



Payoffs:

$$\mathbf{A}: \begin{cases} I_1: U(R_{I_1}) = 0 \\ E_1: U(R_{E_1}) + R_{tE} - f(C)T \end{cases}$$

$$\mathbf{B}: \begin{cases} I_1: U(R_{I_1}) + D_E + P_E B_e(i) - \lambda\sigma_E \\ E_1: U(R_{E_1}) + P_E B_E + R_{tE} - f(C)T - \lambda\sigma_E - D_E \end{cases}$$

$$\mathbf{C}: \begin{cases} \mathrm{I_1: U(R_{I_1}) + D_E + P_E B_e(i) - \lambda \sigma_E^{cg}} \\ \mathrm{E_1: U(R_{E_1}^{cg}) + P_E B_E + R_{tE} - f(C_{cg})T - \lambda \left[\frac{\sigma_E[(\sigma_E - \sigma_E^{cg}) - 1]}{\sigma_E - \sigma_E^{cg}} \right] - D_E} \end{cases}$$

Firm E_1 [5]is concerned with several factors: the utility generated by the result; the positive impacts generated by the publicly traded stock and its price; and the result of the current period, which are offset by the negative impacts generated by volatility, costs and values paid as dividends. On the other hand, the investor I_1 will have the utility generated by the result of the invested value plus the positive impacts of the dividends, from their stock of shares deducted from the negative impact of the share volatility.

The complete information game will be solved by retroactive induction. Therefore, three cases will be considered, according to the game's parameters:

Case 1: $\lambda\sigma_E > \lambda\sigma_E^{cg} > \boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{I_1}}) + D_E + P_E B_e(i)$: In this case, the investor decide $I_1 \rightarrow (ni) \Rightarrow E_1 : \boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{E_1}}) + \boldsymbol{R}_{\boldsymbol{tE}} - \boldsymbol{f}(\boldsymbol{C})\boldsymbol{T}$**,** and the game is over;

Case 2: $\boldsymbol{U}(R_{E_1}^{cg} - \boldsymbol{R}_{\boldsymbol{E_1}}) > [f(C) - f(C_{cg})]\mathrm{T} + \lambda \left[\frac{\sigma_E}{\sigma_E - \sigma_E^{cg}}\right]) \Rightarrow E_1 \rightarrow (c)$: In this case, the firm finds that it, meets the requirements to obtain a certain degree of corporate governance and decides to face the additional costs of these requirements. The investor, knowing that firm E_1 will have complied with the requirements of corporate governance, and considering the hypothesis that $\sigma_E^{cg} < \sigma_E$, decides to invest, if only if $\lambda\sigma_E^{cg} < \boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{I_1}}) + D_E + P_E B_e(i)$;

Case 3: $\boldsymbol{U}(R_{E_1}^{cg} - \boldsymbol{R}_{\boldsymbol{E_1}}) < [f(C) - f(C_{cg})]\mathrm{T} + \lambda \left[\frac{\sigma_E}{\sigma_E - \sigma_E^{cg}}\right]) \Rightarrow E_1 \rightarrow (\mathrm{n}c)$: In this case, the firm does not meet the requirements to obtain a certain degree of corporate governance or decides not to face the additional costs of these requirements. The investor knows that firm E_1 will not have complied with the requirements of corporate governance, and decides to invest, if only if $\lambda\sigma_E < \boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{I_1}}) + D_E + P_E B_e(i)$.

We must consider to what extent the equilibrium of play with a first investor can affect the later equilibrium. A second investor decides whether it will meet its own goal or not by observing the outcome of the firm's interaction with the first investor. This approach is introduced in the next section.

5.1.4 Sequential model: Complete information game with two investors and a firm

To analyze the existence of more than one state in the equilibrium of the game, consider a model with two investors deciding sequentially whether or not to invest in firm E.

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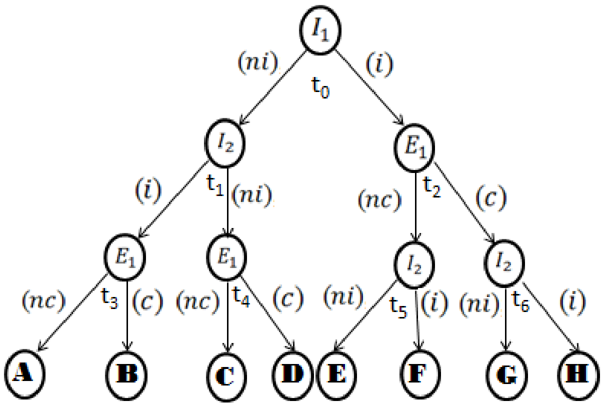
[5] To simplify notation, since we have only one firm, E will be used subsequent formulas rather than E_1.

Investor 1 (I_1) first decides whether to invest (i_1) or not (ni_1): then, Firm (E_1) decides whether it satisfies the requirements for the degree of corporate governance (c1) or not (nc1), if I_1 chooses (i_1). Investor 2 (I_2) observes the result of the strategic interaction between I_1 and firm E_1 and decides (i_2), or not (ni_2) to invest in the firm E_1. Then firm E_1 decides whether it meets the requirements for corporate governance degree (c_1) or not (nc_1), considering the possibilities of I_2 to choose (ni_2), or not. The game is represented in its extensive-form[6] in Figure 2 below, in which, for simplicity, it is considered that the firm does not discount the future, (intertemporal discount factor equals 1).

Figure 2. Game in extensive-form - complete information, two investors and one firm.



To emphasize the trade-off between the cost of implementing the requirements of a degree of corporate governance and the volatility of firms with corporate governance, it is assumed that corporate governance fragility's condition is valid.

We initially assumed the conditions: $\sigma_E^{cg} < \sigma_E$ and $C_{cg} > C$, however if we consider the fragility condition of corporate governance of $\sigma_E^{cg} \to \sigma_E$, then $\boldsymbol{U}(R_{E_1}^{cg} - \boldsymbol{R}_{\boldsymbol{E_1}})$, $\lambda \to \infty \Rightarrow E_1 \to (nc_1)\ \forall t_k$.

Solving the game by retroactive induction we have the following: at decision node t_6 the investor will only invest in the company if the fragile condition of corporate governance is not met or $\lambda_2\sigma_E < \boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{I_2}}) + D_{E_2} + P_E B_e(i)$. The same will happen $\forall t_k$ possible nodes. Thus, if the condition of corporate governance fragility occurs, investors will assess whether the losses caused by the volatility are more than offset by the dividend benefits, the stock of shares and by the utility generated by this result, however if this condition is reached the firm will not implement the requirements to obtain a certain degree of corporate governance, regardless of the cost of implementation.

[6] The payoffs details are described in Appendix B.

With this result, if corporate governance fragility condition is reached, would never be a credible threat (the degree of corporate governance), and the firms would never bear the cost of implementing requirements to improve corporate governance. This result is similar to those obtained in the chain store paradox, Selten (1978).

5.1.5 The Incomplete Information Model: Building Reputation

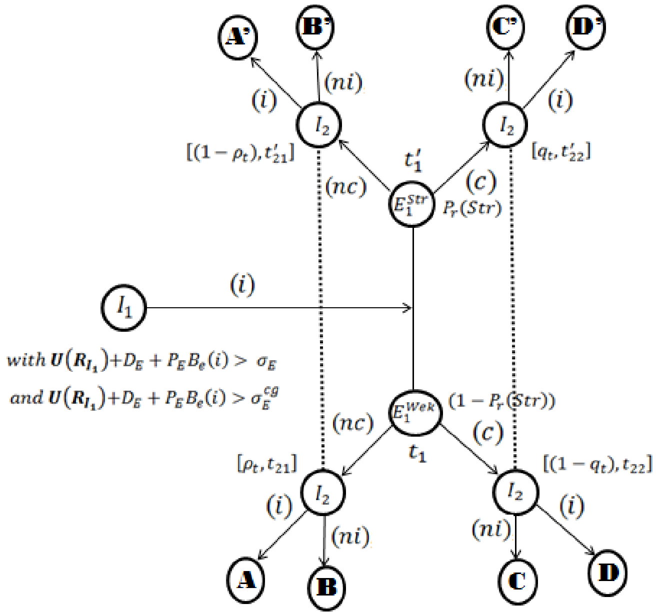
How firms face the fragility condition of corporate governance is directly linked to the impacts of costs of improving their corporate governance. Uncertainty about this relation will be modeled as follows: the investor estimates that the firm is one of two types: strong (Str) with probability $P_r(Str)$ or weak with probability $(1 - P_r(Str))$. A strong firm does not care about the cost of implementing the requirements of a particular degree of corporate governance and therefore: $C_{cg} \to C$ with

$\boldsymbol{U}\left(R_{E_1}^{cg} - \boldsymbol{R}_{\boldsymbol{E}_1}\right) > \lambda\left[\frac{\sigma_E}{\sigma_E - \sigma_E^{cg}}\right]) \Rightarrow E_1 \to (c)$. On the other hand, a weak (Wek) firm is subject to a fragile condition of corporate governance. The cost of implementing corporate governance requirements, together with the negative impacts of volatility, influence the firm and therefore: $C_{cg} > C$. The decision will be taken, if only if:

$$\begin{cases} \boldsymbol{U}\left(R_{E_1}^{cg} - \boldsymbol{R}_{\boldsymbol{E}_1}\right) < \left[f(C) - f\left(C_{cg}\right)\right]\mathrm{T} + \lambda\left[\dfrac{\sigma_E}{\sigma_E - \sigma_E^{cg}}\right]) \Rightarrow E_1 \to (\mathrm{n}c) \\ \boldsymbol{U}\left(R_{E_1}^{cg} - \boldsymbol{R}_{\boldsymbol{E}_1}\right) > \left[f(C) - f\left(C_{cg}\right)\right]\mathrm{T} + \lambda\left[\dfrac{\sigma_E}{\sigma_E - \sigma_E^{cg}}\right]) \Rightarrow E_1 \to (c) \end{cases}$$

The extensive form[7] of this game is shown in Figure 3.

Figure 3. Game in extensive form - Incomplete information, two investors and one firm.



[7] The payoff details are described in Appendix B.

The investor belief system will be formed in: $\theta_1 \in [\widehat{P_r}, (t'_{21}, t_{21})]$ and $\theta_2 \in [\widehat{P_r}, (t'_{22}, t_{22})]$. The beliefs $\widehat{P_r}$ (investor's probability estimation of $P_r(Str)$) are formed from the actions of the firm:

$$\begin{cases} If\ E_1 \rightarrow (c) \Rightarrow q_{t+1} \geq q_t\ with\ q_t > (1 - q_t)\ in\ (t'_{22}, t_{22}) \\ If\ E_1 \rightarrow (nc) \Rightarrow \rho_{t+1} \geq \rho_t\ with\ \rho_t > (1 - \rho_t)\ in\ (t'_{21}, t_{21}) \end{cases} \quad (25)$$

For the resolution of this game consider the following additional hypotheses:

$$(i) \qquad P_r(Str) > \frac{[f(C) - f(C_{cg})]\mathrm{T}}{\boldsymbol{U}\left(R^{cg}_{E_1} - \boldsymbol{R}_{\boldsymbol{E_1}}\right)} \quad (26)$$

$$(ii) \qquad (1 - P_r(Str)) > \frac{f(C)\mathrm{T}}{\boldsymbol{U}\left(\boldsymbol{R}_{\boldsymbol{E_1}} - \mathrm{R_{tE}}\right)} \quad (27)$$

$$(iii) \qquad \rho_{t+1} > \frac{\boldsymbol{U}\left(\mathbf{R}^{\mathbf{CG}}_{\mathbf{I_2}}\right) - \boldsymbol{U}\left(\boldsymbol{R}_{\boldsymbol{I_2}}\right)}{\lambda_2 \sigma_E \boldsymbol{U}\left(\mathbf{R}^{\mathbf{CG}}_{\mathbf{I_2}} - \boldsymbol{R}_{\boldsymbol{I_2}}\right)} \quad (28)$$

Hypothesis (i) expresses that, ex-ante, the probability of the firm being of the strong-type is sufficiently high compared to the quotient of the implementation costs to improve corporate governance and the utility generated by this improvement. This hypothesis also reflects the idea that the expected utility of improved of corporate governance is greater than its implementation costs. Hypothesis (ii) guarantees that even for the weak-type firm, the expected result with the investor's investment I_2 is greater than its cost, ie receiving investments is preferred. Hypothesis (iii) guarantees that investor I_2 is risk-averse to the firm's results without corporate governance. This hypothes is also ensures that if the firm does not comply with the requirements for a given level of corporate governance, so is more likely to be weak-type , it will not receive the investment of I_2.

We start the resolution of the game by sequential rationality. Because of incomplete information, the concept of adequate equilibrum for the resolution of this game is the Perfect Bayesian Equilibrium (PBE).

Consider the firm's decision at node t'_1. Since it is a strong-type, and given hypothesis (i), this guarantees that the dominant strategy will be (c) to meet the requirements to obtain a certain degree of corporate governance, regardless of subsequent choices of investor I_2, in the information sets θ_1, θ_2. Thus, the pursuit of equilibrium reduces to two cases depending on the firm's choice of weak-type in t_1:

Case 1: The weak-type firm chooses in t_1, not to implement the requirements to obtain a certain degree of corporate governance (nc), separating equilibrium: in which the firm of different types chooses different strategies. In this case the Bayesian Consistency (BC) implies the updating the beliefs θ_1 and θ_2:

$$\theta_1 \colon \left[\widehat{P_r} = \rho_{t+1}; \rho_{t+1} \geq \rho_t\ and\ \rho_t > (1 - \rho_t), t_{21}\right) | \rho_{t+1} \overset{P_r}{\rightarrow} 1]$$

and

$\theta_2: [\widehat{P_r} = q_t; q_{t+1} \leq q_t \text{ and } q_t < (1 - q_t), t_{21})|q_t \overset{P_r}{\rightarrow} 0].$

The investor will decide to invest, if only if $\lambda_2 \sigma_E < \widehat{P_r}[\boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{I_2}}) + D_{E_2} + P_E B_e(i)]$ at node (t'_{21}, t_{21}), however we will consider sequential rationality and hypotheses (ii), (iii). Once the firm plays (nc), it increases the probability of being weak-type. Considering hypothesis (iii) the investor reviews its belief, and chooses (ni). Knowing that the investor will have this choice, the firm considering hypothesis (ii), and will choose (c), therefore it is not a Perfect Bayesian Equilibrium, thus there is no separating equilibrium in this game.

Case 2: The weak-type firm chooses in t'_1 to implement the requirements to obtain a certain degree of corporate governance (c), aggregator equilibrium: in which the firm of different types chooses same strategies. In this case the Bayesian Consistency (BC) implies updating the beliefs θ_1 and θ_2:

$\theta_1: [\widehat{P_r} = q_{t+1}; q_{t+1} \geq q_t \text{ and } q_t > (1 - q_t), t_{21})|q_{t+1} \overset{P_r}{\rightarrow} 1]$

and

$\theta_2: [\widehat{P_r} = \rho_t; \rho_{t+1} \leq \rho_t \text{ and } \rho_t < (1 - \rho_t), t_{21})|\rho_t \overset{P_r}{\rightarrow} 0].$

The investor will decide not to invest, if and only if: $\lambda_2 \sigma_E^{cg} > \widehat{P_r}[\boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{I_2}}) + D_{E_2} + P_E B_e(i)]$ at node (t'_{22}, t_{22}). On the other hand, we have $\widehat{P_r} = q_{t+1}$ and considering Bayesian Consistency (BC) we have

$$\frac{\lambda_2 \sigma_E^{cg}}{\boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{I_2}}) + D_{E_2} + P_E B_e(i)} > q_{t+1}. \qquad (29)$$

For the above choices to constitute a (PBE), it is necessary that I_2 chooses (ni) in (t'_{21}, t_{21}), otherwise the weak-type firm would prefer to choose (nc). In turn I_2 will choose (ni) in (t'_{21}, t_{21}), whenever equation (29) occurs. This condition reveals that even strong-type firms (with a strong governance culture) can be viewed by the investor as weak-type if σ_E^{cg} volatility increases. There is an inverse relationship between firm volatility and the probability of the firm being of the strong-type. Thus we build the unique Perfect Bayesian Equilibrium of this game, which is described below:

$E_1^{Str}: (c); E_1^{Wek}: (c); I_2: (ni) \text{ in } (t'_{21}, t_{21}), (i) \text{ in } (t'_{22}, t_{22})$ with

$q_{t+1} \in \left[0, \frac{\lambda_2 \sigma_E^{cg}}{\boldsymbol{U}(\boldsymbol{R}_{\boldsymbol{I_2}}) + D_{E_2} + P_E B_e(i)}\right].$

The equilibrium of reputational game occurs because weak-type firms (firms without a strong corporate governance culture) can send the signal of being strong-type by meeting the requirements for a certain degree of corporate governance. This signaling builds the reputation of the weak-type firm as having strong corporate governance culture, thereby attracting investments. This aggregate equilibrium may occur in the reverse direction, where an increase in volatility may reduce the firm's probability of appearing strong-type to the investor, causing the investor to give up investments in the firm, so the volatility can be used as reveal mechanism of corporate governance level.

Even in the model with complete information, volatility plays an important role in the decision to invest, according to the fragility condition of corporate governance. When the firm's volatility with a certain degree of corporate governance approaches the volatility of a firm without corporate governance, the firm does not have incentives to bear the cost of these requirements. Thus it is crucial to test the hypothesis that the volatility of firms with higher governance is less than the volatility of a firm without this level of corporate governance. This test will be implemented using the econometric approach presented above.

6. Description of the models, dynamic principal componente analysis and tests

The definition of volatility of exchange rates and international financial markets is a relevant question. Though many definitions could be adapted to capture such volatilities, this study uses the time series[8] of 48 exchange rates to produce a proxy of exchange rate shocks and 16 international financial markets indexes[9] to produce a proxy of international financial market shocks, in addition to Ibovespa and the high-quality corporate governance financial indices (IGC-MN and IGC-X), in the period from 01/02/2007 to 03/31/2016, daily[10].

6.1 Financial measures of corporate governance

Ibovespa (Ibov) indicates the average performance of the assets of greater negotiability and representativeness of the Brazilian stock market. Ibovespa is a total return index (an indicator that reflects not only the changes in the prices of the index's assets over time, but also the impact that the distribution of earnings by the companies issuing these assets have on the index return). No requirement for a high standard of corporate governance is required to trade shares on the Ibov. However, different types of requirements have been developed to distinguish different levels of corporate governance. The three main levels of classification of companies with shares traded on Ibov exist:

High level of CG: Launched in 2000, the “New Market” (NM) has established a highly-differentiated corporate governance standard since its inception. As of the first listing in 2002, it has become the standard of transparency and governance required by investors for new capital openings and is recommended for companies wishing to make large offers targeted at any type of investor.

[8] The table with the 48 exchange rates utilized is given in the appendix.
[9] The table with the 16 international stock market indices utilized is given in the appendix.
[10] All data is available and was obtained from the Bloomberg platform.

Intermediate level of CG: The “Level 2” (L2) listing segment is similar to the “New Market”, but with a few exceptions. The listed companies have the right to hold preferred shares (PN). In the event of sale of control of the company, holders of common and preferred shares are granted the same treatment as the controlling shareholder, thus providing for the tag-along right of 100% of the price paid for the common shares of the controlling shareholder.

Basic level of CG: Companies listed in the “Level 1” (L1) segment must adopt practices that promote transparency and access to information by investors. To do this, they disclose information above those required by law, such as an annual calendar of corporate events. The minimum free float of 25% must be maintained in this segment. That is, the company keeps at least 25% of the outstanding shares in the market.

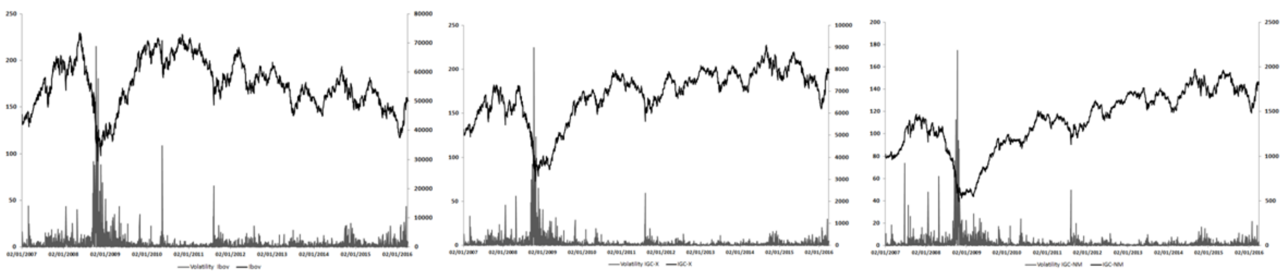
Based on this classification of different degrees of corporate governance, two other indices follow the Ibov model. These new indices reflect changes in the prices of shares of companies with different levels of corporate governance:

IGC-NM: indicator of the average performance of the quotations of the assets of issuance of companies that present the highest levels of corporate governance, listed in NM.

IGC-X: indicator of the average performance of the quotations of the assets of issuance of companies that present the basic and intermediate levels of corporate governance, listed in L2 or L1.

Figure 4 presents the three financial indices and their respective volatilities in the sample study period

Figure 4. Financial indices and volatilities.



6.2 Constructing representative volatilities

We aim to construct a representative return from several types of volatility:

1. VOL_ER - volatilities of 48 exchange rates: we use 48 exchange rates to capture a general effect of exchange rates shocks.

2. VOL_ER_DOLLAR - volatilities of 47 exchange rates (except dollar/real): in this data set, with the exclusion of the US dollar, we estimate a counterfactual effect of all the remaining exchange rates.
3. DOLLAR - volatility of dollar. We capture the unique effects of the dollar, given its importance for Brazilian international reserves.
4. VOL_FIN - volatility of 16 international stock exchanges.

Returns were calculated for each data series (including Ibov, IGC-NM and IGC-X) of each of the information sets. Once returns were calculated, we applied dynamic principal component analysis (DPCA), initially proposed by Box and Tiao (1977), and adapted by Ahn and Reinsel (1990), Reinsel and Velu (1998), Stock and Watson (2011), to each set (VOL_ER, VOL_ER_DOLLAR and VOL_FIN). We thereby obtain a representative return for the variability of the information set. Clearly the dollar data set was excluded from this treatment with DPCA, and only the dollar/real return was calculated. The use of DPCA in finance has been positive, as shown, for instance, by Meric et al. (2008), who studied comovements and causality in financial markets such as those of the USA, UK, Australia, China, Russia, India, Japan and South Korea.

The following models were estimated:

Table 1. MGARCH-BEKK Models

Model	Variables	Level of CG
1	Ibov, VOL_ER, VOL_FIN	No requeriments
2	Ibov, VOL_ER_DOLLAR, VOL_FIN	
3	Ibov, VOL_DOLLAR, VOL_FIN	
4	IGC-NM, VOL_ER, VOL_FIN	High Level
5	IGC-NM, VOL_ER_DOLLAR, VOL_FIN	
6	IGC-NM, VOL_DOLLAR, VOL_FIN	
7	IGC-X, VOL_ER, VOL_FIN	Intermediate and Basic level
8	IGC-X, VOL_ER_DOLLAR, VOL_FIN	
9	IGC-X, VOL_DOLLAR, VOL_FIN	

For each model we estimated the conditional correlations with the MGARCH BEKK model, since the Granger-causality tests are implemented for the results of these models. We use auto-correlation tests for the residuals obtained from these models to verify their adequacy. We applied the tests to standard residuals and their squares. The Granger-causality of second order tests were run to identify the direction of causality, in the sense of Granger, of the estimated conditional correlations.

7. Empirical Results

Initially we checked whether the data set could be treated with DPCA. In exploratory terms, we observed, by means of the KMO statitistic with values above 0.9, that the use of PCS is appropriate. In inferential terms, Bartlet test indicated that DPCA was appropriate, rejecting the null hypothesis.

Table 2. Results from the Bartlet test and KMO statistic

Índices	Description	BARTS P-value	KMO	Variance explained by the 1st dynamic principal component
VOL_ER	EXCHANGE RATES - RETURNS	0,00	0,95	0,864
VOL_ER_DOLLAR	EXCHANGE RATES – RETURNS (WITHOUT DOLLAR)	0,00	0,98	0,895
VOL_FIN	STOCK EXCHANGE MARKETS – RETURNS	0,00	0,90	0,886

H_0: Use of DPCA or Factor Analysis is not appropriate.
Values of KMO between 0.5 and 1.0 indicate that Factor Analysis or DPCA is appropriate.

Since in all cases, the first component is highly representative of the total variance of the returns, we used the first component to build the representative return. Table 3 presents the results of the exploratory statistics.

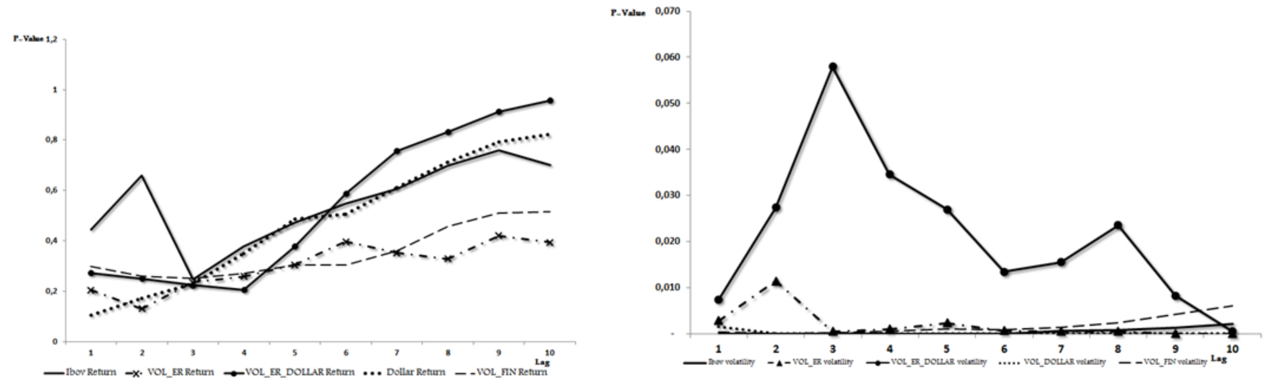
Table 3. Exploratory statistics and tests on returns

TESTS/ESTATIÍSTICS	IBOVESPA	ICG-NM	ICG-X	VOL_ER	VOL_ER_DOLLAR	DOLLAR	VOL_FIN
n	2284	2284	2284	2284	2284	2284	2284
Mean	0,02	0,04	0,03	-0,01	0,01	0,02	0,02
Median	0,02	0,05	0,04	-0,01	0,01	0,008	0,07
Max	14,35	13,65	14,51	3,25	8,22	6,10	8,71
Min	-11,42	-10,11	-9,97	-9,71	-4,47	-7,30	-13,76
Variance	3,41	2,27	2,69	0,34	0,47	1,24	2,18
Standard deviation	1,84	1,50	1,64	0,58	0,69	1,11	1,48
Asymetry	0,20	0,11	0,25	-2,46	1,56	0,30	-0,76
Curtosis	9,12	10,92	11,00	42,99	24,37	7,47	11,59
Coeff.of Variation	85,13	40,13	53,89	40,51	24,90	37,42	60,26
Jarque Bera (P-Valor)	0,00	0,00	0,00	0,00	0,00	0,00	0,00
ADF (P-Valor)	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Jarque Bera - H_0: the data are normally distributed.
ADF - H_0: Presence of unit root.
The results with constant term and/or term with temporal trend do not change.
The selection of lag in the tests used the AIC information criterion.

Table 3 shows the presence of stylized facts about returns listed by Caldeira, Souza and Machado (2010), such as almost zero mean, curtosis, asymmetry, absence of normality and stationarity of the series. These results indicate that the representative returns obtained through DPCA are indeed a summary measure of exchange rates returns. However, the corroboration comes from the LM test for standard returns and their squares. That is, autocorrelation for returns are absent, but autocorrelation structure for the squared returns[11] is present, as shown in the following graphs.

Figure 5. LM test for autocorrelation of returns and volatilities



[11] For simplicity we will call it volatility.

The selection of orders in GARCH models is more developed in the univariate case. As highlighted by Lutkepohl (2005), the literature on the multivariate case is limited. However, in this study, we use the identification approach for the univariate case as an indication for the multivariate case, since for the structural MGARCH (BEKK) the saturation of parameters can quickly ruin its estimation. Therefore, we used the sequence suggested by Franses and Dijk (2000) and obtained, the following, for the univariate case.

Table 4. Identification of possible orders in the models

Varibles	ACF/PACF analysis	Suggested order	Order Assumed for Univariate GARCH
Ibov	PACF2	GARCH(1,1) or GARCH(1,2)	GARCH(1,1)
IGC-NM	PACF2	GARCH(1,1) or GARCH(1,2)	GARCH(1,1)
IGC-X	PACF2	GARCH(1,1) or GARCH(1,2)	GARCH(1,1)
VOL_ER	PACF2	GARCH(1,1) or GARCH(1,2)	GARCH(1,1)
VOL_ER_DOLLAR	ACF1 and PACF1 and exponential decay	GARCH(2,1) or GARCH(1,2)	GARCH(1,2)
DOLLAR	PACF2	GARCH(1,1) or GARCH(1,2) or GARCH(2,1)	GARCH(1,1)
VOL_FIN	ACF1 and PACF1	GARCH(1,2)	GARCH(1,2)

PACF1: Partial autocorrelation function is statistically significant in the first lag.
PACF2: Partial autocorrelation function is statistically significant in the first and second lag.
ACF1: Partial autocorrelation function is statistically significant in the first lag, with PACF with exponential decay.

Table 4 shows that the suggested univariate order was at most 2, both for the autocorrelation componente and for the moving average component. Thus, the order of the models to be estimated in the multivariate case should also be of low order. However, the validation of the suggested orders will be given by the elimination of autocrrelation of the standard residuals and their squares. For parsimony, the lowest-order univariate GARCH models were chosen. These univariate models present adequate adjustment for each of the series respectively, and were used to construct the Cheung and Ng (1996) test.

7.1 Estimated MGACH-BEKK models

In this section we present the results of the estimated models that properly reproduced the generating process of the series. According to Table 4, the multivariate GARCH models presented low order. For each model presented in Table 1, BEKK-FULL and Diagonal BEKK models were estimated in different orders. The results are summarized in Table 5. They indicate that the best adjustments are concentrated on the estimated Diagonal BEKK models. Again using the principle of parsimony, models of lower order were chosen. However models 5 and 8 were unable to eliminate the autocorrelation of all the estimated residues series and their squares, which emphasizes the importance of including the dollar to configure exchange rate shocks.

Table 5. MGARCH-BEKK estimated

MGARCH	Order			
	(1,1)	(1,2)	(2,1)	(2,2)
BEKK-FULL Model 1	ANE	ANE	APE	APE
BEKK-FULL Model 2	ANE	APE	APE	APE
BEKK-FULL Model 3	ANE	ANE	ANE	ANE
BEKK-FULL Model 4	ANE	APE	APE	ANE
BEKK-FULL Model 5	ANE	ANE	ANE	ANE
BEKK-FULL Model 6	ANE	ANE	ANE	APE
BEKK-FULL Model 7	ANE	ANE	ANE	APE
BEKK-FULL Model 8	ANE	ANE	ANE	ANE
BEKK-FULL Model 9	ANE	ANE	APE	APE
D-BEKK Model 1	ATE	ATE	APE	APE
D-BEKK Model 2	APE	APE	APE	ANE
D-BEKK Model 3	ATE	ATE	APE	APE
D-BEKK Model 4	ATE	APE	APE	ANE
D-BEKK Model 5	ANE	ANE	ANE	ANE
D-BEKK Model 6	ATE	APE	APE	ANE
D-BEKK Model 7	APE	APE	ANE	ANE
D-BEKK Model 8	ANE	ANE	ANE	ANE
D-BEKK Model 9	ATE	APE	ANE	ANE

Autocorrelation not eliminated: ANE;
Autocorrelation partially eliminated: APE (at least two residuals and its squares component without autocorrelation);
Autocorrelation totally eliminated: ATE.

Table 6 shows that: parameter C_{32} related to the cross-correlation of the financial and exchange rate shocks was not statistically significant in any of the estimated D-BEKK models. Similary, parameter α_{ss22}, related to the asymmetry of the exchange rate shocks. The value of C_{22} that is associated with the constant component of exchange rate shock was not statistically significant in models 3, 5 and 7, in the same manner in which the constant component of financial shock was not statistically significant in models 4, 5 and 8. The MA component of the exchange rate shocks was not statistically significant in models 4, 7 and 8. Model 5 presented the largest number of statistically insignificant parameters, besides having too few adjustment to eliminate the autocorrelation of the residues and their squares. On the other hand, model 6 presented the lowest number of statistically significant parameters. The models with VOL_ER and VOL_FIN and their respective financial indices present the best results in terms of log-likelihood.

Table 7, shows models 5 and 8 in none of the models tested, can eliminate the autocorrelation of residues and their squares. The conditional correlations of these models were maintained only to provide basis for comparison. These results indicate the great relevance of the dollar for studies of volatility spillover.

If we consider a level of significance of 1% only model 2 partially eliminates the autocorrelation of the residuals and its square. All other models have good adjustment results this criterion.

Table 6. Estimated MGARCH models

Ibov	Model 1 – D- BEKK(1,1)				Model 2 – D-BEKK(1,1)				Model 3 – D-BEKK(2,1)			
Parameters	Estimate	Std. Dev.	Statistic	P-value	Estimate	Std. Dev.	Statistic	P-value	Estimate	Std. Dev.	Statistic	P-value
C_{11}	0,216	0,032	6,746	0,000	0,203	0,033	6,181	0,000	0,231	0,028	8,149	0,000
C_{21}	-0,022	0,013	-1,626	0,048	-0,045	0,068	-0,657	0,044	-0,080	0,014	-5,532	0,000
C_{22}	0,096	0,026	3,684	0,000	0,106	0,030	3,523	0,000	0,114	0,027	4,179	0,159
C_{31}	0,054	0,034	1,565	0,059	0,151	0,117	1,291	0,098	0,091	0,016	5,698	0,000
C_{32}	0,015	0,054	0,273	0,392	-0,031	0,014	-2,283	0,989	-0,038	0,018	-2,103	0,982
C_{33}	0,165	0,024	6,929	0,000	0,163	0,026	6,368	0,000	0,170	0,030	5,747	0,000
α_{11}	0,189	0,023	8,297	0,000	0,190	0,031	6,150	0,000	0,212	0,017	12,488	0,000
α_{22}	0,285	0,100	2,835	0,002	0,342	0,239	1,428	0,077	0,295	0,019	15,228	0,000
α_{33}	0,158	0,030	5,207	0,000	0,142	0,037	3,873	0,000	0,182	0,024	7,536	0,000
α_{ss11}	0,247	0,040	6,186	0,000	0,251	0,047	5,368	0,000	0,194	0,036	5,372	0,000
α_{ss22}	-0,029	0,023	-1,260	0,896	-0,081	0,109	-0,737	0,769	-0,062	0,020	-3,046	0,999
α_{ss33}	0,295	0,036	8,240	0,000	0,304	0,036	8,550	0,000	0,275	0,039	7,036	0,000
β_{11}	0,960	0,006	149,624	0,000	0,960	0,006	149,418	0,000	0,959	0,005	175,313	0,000
β_{22}	0,958	0,030	32,450	0,000	0,921	0,116	7,972	0,000	0,948	0,006	152,890	0,000
β_{33}	0,956	0,009	106,090	0,000	0,957	0,010	94,579	0,000	0,952	0,011	84,302	0,000
AIC	18710,78				19756,94				20814,97			
BIC	18796,78				19842,94				20900,97			
LOG	-9340,39				-9863,47				-10392,5			

IGC-NM	Model 4 –D-BEKK(1,1)				Model 5 – D-BEKK(1,1)				Model 6 – D-BEKK(2,1)			
Parameters	Estimate	Std. Dev.	Statistic	P-value	Estimate	Std. Dev.	Statistic	P-value	Estimate	Std. Dev.	Statistic	P-value
C_{11}	0,150	0,031	4,822	0,000	0,147	0,031	4,753	0,000	0,169	0,024	6,891	0,000
C_{21}	-0,019	0,025	-0,763	0,078	-0,042	0,052	-0,806	0,790	-0,069	0,015	-4,675	0,001
C_{22}	0,076	0,052	1,478	0,070	0,085	0,040	2,101	0,118	0,093	0,027	3,470	0,000
C_{31}	0,045	0,096	0,466	0,321	0,157	0,129	1,217	0,112	0,091	0,015	6,037	0,000
C_{32}	0,024	0,051	0,471	0,319	-0,026	0,025	-1,058	0,855	-0,049	0,023	-2,116	0,983
C_{33}	0,175	0,038	4,660	0,000	0,167	0,035	4,829	0,000	0,179	0,035	5,173	0,000
α_{11}	0,179	0,029	6,184	0,000	0,126	0,033	3,875	0,000	0,213	0,025	8,550	0,000
α_{22}	0,244	0,243	1,006	0,157	0,340	0,252	1,351	0,088	0,285	0,019	15,165	0,000
α_{33}	0,208	0,087	2,383	0,009	0,208	0,051	4,054	0,000	0,194	0,032	6,018	0,000
α_{ss11}	0,269	0,039	6,857	0,000	0,301	0,040	7,558	0,000	0,205	0,034	6,012	0,000
α_{ss22}	-0,042	0,062	-0,678	0,751	-0,086	0,130	-0,664	0,747	-0,070	0,021	-3,329	1,000
α_{ss33}	0,261	0,062	4,239	0,000	0,256	0,047	5,474	0,000	0,260	0,045	5,770	0,000
β_{11}	0,962	0,007	135,343	0,000	0,966	0,008	124,466	0,000	0,960	0,006	153,238	0,000
β_{22}	0,969	0,071	13,568	0,000	0,919	0,124	7,413	0,000	0,951	0,006	169,127	0,000
β_{33}	0,952	0,019	49,779	0,000	0,954	0,014	70,246	0,000	0,953	0,012	77,983	0,000
AIC	17871,24				18933,47				20042,53			
BIC	17957,25				19019,48				20128,54			
LOG	-8920,62				-9451,74				-10006,3			

IGC-X	Model 7 – D-BEKK(1,1)				Model 8 – D-BEKK(2,2)				Model 9 – D-BEKK(1,1)			
Parameters	Estimate	Std. Dev.	Statistic	P-value	Estimate	Std. Dev.	Statistic	P-value	Estimate	Std. Dev.	Statistic	P-value
C_{11}	0,144	0,042	3,455	0,000	0,140	0,020	7,050	0,000	0,159	0,018	8,754	0,000
C_{21}	-0,023	0,030	-0,757	0,008	-0,054	0,080	-0,672	0,749	-0,073	0,015	-4,971	0,060
C_{22}	0,102	0,116	0,882	0,189	0,122	0,035	3,455	0,000	0,122	0,039	3,110	0,010
C_{31}	0,040	0,088	0,455	0,032	0,139	0,119	1,162	0,123	0,089	0,017	5,306	0,000
C_{32}	0,038	0,097	0,387	0,350	-0,002	0,002	-0,942	0,827	-0,036	0,034	-1,049	0,853
C_{33}	0,170	0,059	2,855	0,002	0,158	0,029	5,520	0,000	0,182	0,032	5,677	0,000
α_{11}	0,162	0,025	6,606	0,000	0,110	0,029	3,798	0,000	0,209	0,019	10,958	0,000
α_{22}	0,239	0,233	1,025	0,153	0,319	0,282	1,134	0,129	0,289	0,019	15,156	0,000
α_{33}	0,219	0,125	1,745	0,041	0,220	0,045	4,937	0,000	0,193	0,033	5,865	0,000
α_{ss11}	0,261	0,050	5,267	0,000	0,293	0,027	10,739	0,000	0,183	0,034	5,350	0,000
α_{ss22}	-0,028	0,164	-0,174	0,569	-0,066	0,082	-0,807	0,790	-0,062	0,023	-2,719	0,997
α_{ss33}	0,246	0,102	2,409	0,008	0,243	0,049	4,969	0,000	0,272	0,043	6,314	0,000
β_{11}	0,966	0,007	137,867	0,000	0,969	0,004	236,494	0,000	0,964	0,004	234,099	0,000
β_{22}	0,971	0,066	14,657	0,000	0,930	0,122	7,651	0,000	0,950	0,006	159,022	0,000
β_{33}	0,951	0,034	27,699	0,000	0,951	0,013	75,840	0,000	0,949	0,013	71,868	0,000
AIC	17953,61				19024,25				20103,95			
BIC	18039,61				19110,26				20189,96			
LOG	-8961,8				-9497,13				-10037			

Table 7. LM test of residuals and their squares

Ibov	Model 1 – D-BEKK(1,1)						Model 2 – D-BEKK(1,1)						Model 3 – D-BEKK(1,1)					
Lag	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$
1	0,48	0,30	0,04	0,71	0,60	0,06	0,49	0,34	0,00	0,73	0,80	0,06	0,48	0,56	0,29	0,73	0,27	0,31
2	0,77	0,53	0,03	0,26	0,80	0,05	0,78	0,41	0,00	0,28	0,18	0,04	0,78	0,20	0,80	0,25	0,27	0,30
3	0,58	0,63	0,03	0,41	0,21	0,05	0,60	0,59	0,00	0,42	0,35	0,04	0,57	0,26	0,12	0,42	0,18	0,27
4	0,73	0,50	0,04	0,58	0,24	0,04	0,74	0,60	0,00	0,59	0,07	0,03	0,72	0,40	0,41	0,58	0,09	0,19
5	0,85	0,60	0,03	0,69	0,24	0,05	0,86	0,73	0,00	0,71	0,12	0,04	0,85	0,48	0,11	0,67	0,09	0,18
6	0,92	0,71	0,03	0,80	0,30	0,04	0,92	0,73	0,00	0,81	0,19	0,04	0,92	0,46	0,20	0,78	0,09	0,16
7	0,89	0,32	0,03	0,85	0,26	0,04	0,90	0,69	0,00	0,87	0,24	0,04	0,90	0,57	0,38	0,84	0,10	0,13
8	0,91	0,35	0,03	0,91	0,36	0,04	0,92	0,74	0,00	0,92	0,29	0,05	0,91	0,58	0,37	0,90	0,10	0,15
9	0,94	0,30	0,05	0,95	0,35	0,07	0,94	0,78	0,00	0,95	0,06	0,08	0,94	0,60	0,66	0,94	0,11	0,25
10	0,89	0,38	0,04	0,66	0,44	0,06	0,90	0,81	0,00	0,67	0,09	0,08	0,89	0,64	0,11	0,63	0,15	0,11

IGC-NM	Model 4 – D-BEKK(1,1)						Model 5–D-BEKK(1,1)						Model 6 –D-BEKK(1,1)					
Lag	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$
1	0,80	0,21	0,04	0,18	0,97	0,06	0,86	0,00	0,00	0,23	0,45	0,05	0,83	0,08	0,10	0,33	0,13	0,54
2	0,85	0,43	0,05	0,36	0,54	0,08	0,83	0,00	0,00	0,38	0,09	0,07	0,90	0,22	0,27	0,47	0,03	0,57
3	0,48	0,53	0,04	0,53	0,20	0,08	0,45	0,00	0,00	0,47	0,04	0,07	0,47	0,28	0,36	0,61	0,06	0,53
4	0,64	0,38	0,04	0,70	0,26	0,06	0,62	0,00	0,00	0,63	0,03	0,05	0,61	0,42	0,13	0,77	0,10	0,42
5	0,37	0,48	0,04	0,84	0,28	0,06	0,36	0,00	0,00	0,73	0,03	0,05	0,37	0,48	0,38	0,88	0,14	0,39
6	0,40	0,60	0,04	0,91	0,37	0,04	0,38	0,01	0,00	0,81	0,03	0,03	0,42	0,45	0,64	0,93	0,07	0,31
7	0,51	0,24	0,02	0,95	0,36	0,02	0,48	0,01	0,00	0,87	0,03	0,02	0,53	0,55	0,12	0,96	0,10	0,24
8	0,61	0,26	0,02	0,88	0,47	0,03	0,59	0,02	0,00	0,89	0,03	0,02	0,62	0,56	0,12	0,88	0,15	0,30
9	0,47	0,23	0,03	0,86	0,51	0,04	0,47	0,01	0,00	0,77	0,04	0,04	0,45	0,59	0,23	0,85	0,22	0,48
10	0,54	0,30	0,02	0,81	0,60	0,02	0,55	0,01	0,00	0,66	0,06	0,02	0,51	0,63	0,41	0,78	0,11	0,29

ICG-X	Model 7 – D-BEKK(1,1)						Model 8 – D-BEKK(1,1)						Model 9 – D-BEKK(1,1)					
Lag	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$	$u_{1,t-p}$	$u_{2,t-p}$	$u_{3,t-p}$	$u^2_{1,t-p}$	$u^2_{2,t-p}$	$u^2_{3,t-p}$
1	0,36	0,20	0,04	0,35	0,97	0,06	0,39	0,00	0,00	0,04	0,41	0,05	0,39	0,19	0,05	0,13	0,16	0,07
2	0,66	0,42	0,05	0,41	0,49	0,08	0,69	0,00	0,00	0,04	0,11	0,08	0,69	0,23	0,05	0,10	0,14	0,07
3	0,30	0,51	0,05	0,09	0,18	0,08	0,31	0,00	0,00	0,09	0,05	0,08	0,30	0,28	0,05	0,19	0,17	0,07
4	0,46	0,36	0,04	0,18	0,25	0,06	0,47	0,00	0,00	0,17	0,03	0,06	0,46	0,43	0,03	0,31	0,12	0,05
5	0,48	0,47	0,04	0,26	0,28	0,05	0,47	0,00	0,00	0,25	0,04	0,05	0,51	0,48	0,04	0,40	0,16	0,05
6	0,60	0,58	0,01	0,32	0,37	0,03	0,59	0,01	0,00	0,27	0,03	0,03	0,62	0,45	0,04	0,46	0,19	0,06
7	0,66	0,23	0,03	0,38	0,37	0,05	0,65	0,02	0,00	0,30	0,03	0,02	0,68	0,55	0,04	0,48	0,12	0,05
8	0,75	0,26	0,03	0,39	0,47	0,05	0,73	0,02	0,00	0,35	0,04	0,02	0,76	0,56	0,04	0,46	0,18	0,06
9	0,69	0,22	0,02	0,43	0,52	0,04	0,69	0,01	0,00	0,38	0,05	0,04	0,68	0,58	0,05	0,47	0,25	0,06

10	0,69	0,29	0,04	0,34	0,61	0,06	0,69	0,01	0,00	0,29	0,07	0,01	0,67	0,63	0,03	0,37	0,13	0,05

P-value of LM test.

With the exception of models 5 and 8 that did not present an adequate adjustment, the other models allow us to adequately estimate the conditional correlations that represent volatility spillover between the exchange and financial shocks and the market indices.

Once the univariate and multivariate models were properly estimated, we obtained the estimated conditional correlations and the parameters to be used in the tests of Granger-causality of second order and in the comparative analyses to follow.

7.2 Granger second-order causality tests

Table 8 shows that all of the Granger's second order causality tests considered (the statistical precedence, the direction of causality in the Granger’s sense), always occurs from shocks, exchange rate and financial, for market indices.

As for the relationship between exchange and financial shocks, the Cheung and Ng (1996) and Hafner and Herwartz (2006) tests indicate no causality in the second order Granger's sense for models 4, 3 and 6. However Granger's causality in the second order of the exchange shock to the financial shock is seen in model 2, and a second-order Granger bi-causality in model 1. Models 7 and 9 that in the Cheung and Ng (1996) test indicate an absence of second-order Granger causality between exchange and financial shocks, by the Hafner and Herwartz (2006) test indicate causality in the second-order Granger's sense of exchange rate shock for the financial shock. The Granger bi-causality pointed out in models 5 and 8 considering the Hafner and Herwartz (2006) test. However, according to the Cheung and Ng (1996) test, Granger's causality was verified to exchange shock for the financial shock.

In general, the non-causality tests point to the absence of a statistical precedence relationship between exchange and international financial market shocks. The non-causality tests indicate the existence of a lead-lag effect of exchange rate and international financial markets shocks for market indices. These results confirm that the exchange rate, and international financial markets spillovers, has a statistical precedence regarding the volatility of Ibov, ICG-NM, and ICG-X.

The spillovers in MGARCH models were estimated, and the presence of lead-lag effects was verified: between exchange rate shocks and international financial markets for the market indices and financial indices of corporate governance. We next evaluate the magnitude of these spillovers to identify whether corporate governance can mitigating them.

Table 8. Granger causality tests of second-order

Model 1 – GARCH's Order: (1,1)(1,1)(1,2)

	Ibov	VOL_ER	VOL_FIN	Joint Test
Ibov	-	0,205	0,415	0,391
VOL_ER	0,003	-	0,013	0,030
VOL_FIN	0,009	0,073	-	0,009

Model 2 – GARCH's Order: (1,1)(1,2)(1,2)

	Ibov	VOL_ER_DOLLAR	VOL_FIN	Joint Test
Ibov	-	0,958	0,549	0,837
VOL_ER_DOLLAR	0,000	-	0,003	0,000
VOL_FIN	0,014	0,126	-	0,013

Model 3 – GARCH's Order: (1,1)(1,1)(1,2)

	Ibov	DOLLAR	VOL_FIN	Joint Test
Ibov	-	0,198	0,450	0,344
DOLLAR	0,057	-	0,117	0,028
VOL_FIN	0,043	0,096	-	0,013

Model 4 – GARCH's Order: (1,1)(1,1)(1,2)

	ICG-NM	VOL_ER	VOL_FIN	Joint Test
ICG-NM	-	0,647	0,749	0,826
VOL_ER	0,007	-	0,265	0,040
VOL_FIN	0,033	0,266	-	0,106

Model 5 – GARCH's Order: (1,1)(1,2)(1,2)

	ICG-NM	VOL_ER_DOLLAR	VOL_FIN	Joint Test
ICG-NM	-	0,234	0,652	0,826
VOL_ER_DOLLAR	0,137	-	0,015	0,040
VOL_FIN	0,053	0,631	-	0,106

Model 6 – GARCH's Order: (1,1)(1,1)(1,2)

	ICG-NM	DOLLAR	VOL_FIN	Joint Test
ICG-NM	-	0,783	0,707	0,902
DOLLAR	0,023	-	0,209	0,032
VOL_FIN	0,015	0,156	-	0,084

Model 7 – GARCH's Order: (1,1)(1,1)(1,2)

	ICG-X	VOL_ER	VOL_FIN	Joint Test
ICG-X	-	0,121	0,986	0,826
VOL_ER	0,004	-	0,164	0,040
VOL_FIN	0,019	0,298	-	0,106

Model 8 – GARCH's Order: (1,1)(1,2)(1,2)

	ICG-X	VOL_ER_DOLLAR	VOL_FIN	Joint Test
ICG-X	-	0,205	0,960	0,447
VOL_ER_DOLLAR	0,097	-	0,006	0,079
VOL_FIN	0,024	0,650	-	0,067

Model 9 – GARCH's Order: (1,1)(1,1)(1,2)

	ICG-X	DOLLAR	VOL_FIN	Joint Test
ICG-X	-	0,867	0,969	0,984
DOLLAR	0,012	-	0,143	0,019
VOL_FIN	0,010	0,237	-	0,036

H_0: $Y_{(i)}$ does not Granger-causes $Y_{(j)}$, com $i \neq j$.

Joint test H_0: $Y_{(i)}$ does not Granger-causes any $Y_{(j)}$, with $i \neq j$.

P-value of Cheung and Ng (1996) test of Granger causality of 2nd order.

Model 1 – D-BEKK(1,1)

	Ibov	VOL_ER	VOL_FIN
Ibov	-	0,151	0,213
VOL_ER	0,05	-	0,095
VOL_FIN	0,08	0,066	-

Model 2 – D-BEKK(1,1)

	Ibov	VOL_ER_DOLLAR	VOL_FIN
Ibov	-	0,781	0,456
VOL_ER_DOLLAR	0,012	-	0,011
VOL_FIN	0,005	0,114	-

Model 3 – D-BEKK(1,1)

	Ibov	DOLLAR	VOL_FIN
Ibov	-	0,112	0,150
DOLLAR	0,021	-	0,117
VOL_FIN	0,023	0,155	-

Model 4 – D-BEKK(1,1)

	ICG-NM	VOL_ER	VOL_FIN
ICG-NM	-	0,447	0,421
VOL_ER	0,011	-	0,151
VOL_FIN	0,019	0,312	-

Model 5 – D-BEKK(1,1)

	ICG-NM	VOL_ER_DOLLAR	VOL_FIN
ICG-NM	-	0,121	0,257
VOL_ER_DOLLAR	0,042	-	0,001
VOL_FIN	0,053	0,021	-

Model 6 – D-BEKK(1,1)

	ICG-NM	DOLLAR	VOL_FIN
ICG-NM	-	0,110	0,271
DOLLAR	0,001	-	0,338
VOL_FIN	0,005	0,267	-

Model 7 – D-BEKK(1,1)

	ICG-X	VOL_ER	VOL_FIN
ICG-X	-	0,325	0,763
VOL_ER	0,001	-	0,067
VOL_FIN	0,022	0,388	-

Model 8 – D-BEKK(1,1)

	ICG-X	VOL_ER_DOLLAR	VOL_FIN
ICG-X	-	0,120	0,351
VOL_ER_DOLLAR	0,007	-	0,015
VOL_FIN	0,001	0,006	-

Model 9 – D-BEKK(1,1)

	ICG-X	DOLLAR	VOL_FIN
ICG-X	-	0,166	0,798
DOLLAR	0,002	-	0,057
VOL_FIN	0,018	0,138	-

H_0: $Y_{(i)}$ does not Granger-causes $Y_{(j)}$, com $i \neq j$.

P-value of Hafner and Herwartz (2006) test of Granger causality of 2nd order.

7.3 Comparative analyses

Given the evidence of volatility spillovers and lead-lag effects, a series of statistical comparisons are now made to identify which type of overflow is larger, i.e, which estimated conditional correlation is more representative. We applied average tests[12] inference to draw.

According to Figure 6, conditional correlations are predominantly negative in relation to exchange rate shocks, and predominantly positive in relation to financial shocks. The estimated conditional correlation of greater magnitude is associated with financial shocks. Considering the effects of lead-lag, this means that increase volatility of international financial markets is followed by higher volatility in the market indices. Dollar exchange shocks alone in models 3, 6 and 9 seem to be larger than when considering other proxies of exchange rate shocks.

The negative results of the conditional correlation of the exchange rate shocks, considering the lead-lag effects, mean that greater volatilities of currency shocks are followed by lower volatilities in the market indices. These results align with those found by Goldberg (1993), Darby et al. (1999), Carruth, Dickerson and Henley (2000), Amihud (1994) and Bartov e Bodnar (1994).

Dollar exchange shocks isolated in models 3, 6 and 9 seem to be larger than when considering other proxies of exchange rate shocks. All other exchange rates combined, excluding the dollar fail to have good adjustments in models 5 and 8. In model 2, the conditional correlation values present a smaller magnitude than the shock that contains the dollar and the dollar itself. The conditional correlations of shocks that contain all exchange rates (models 1, 4 and 7) are more volatile and smaller than those of the dollar in some moments, even with positive values. This stylized fact should be studied in the way of Boehmer, Masumeci and Poulsen (1991). These results highlight the great importance of dollar volatility for studies of spillovers in financial markets.

With the exception of models 5 and 8, in all other models the conditional correlations of exchange shocks increase at the moment of peak market index volatility (at the height of the 2008-09 crisis). This increase is more evident in the models that consider the dollar separately: models 3, 6 and 9.

[12] Unitailed T tests with unequal variances.

Figure 6. MGARCH D-BEKK Conditional correlations

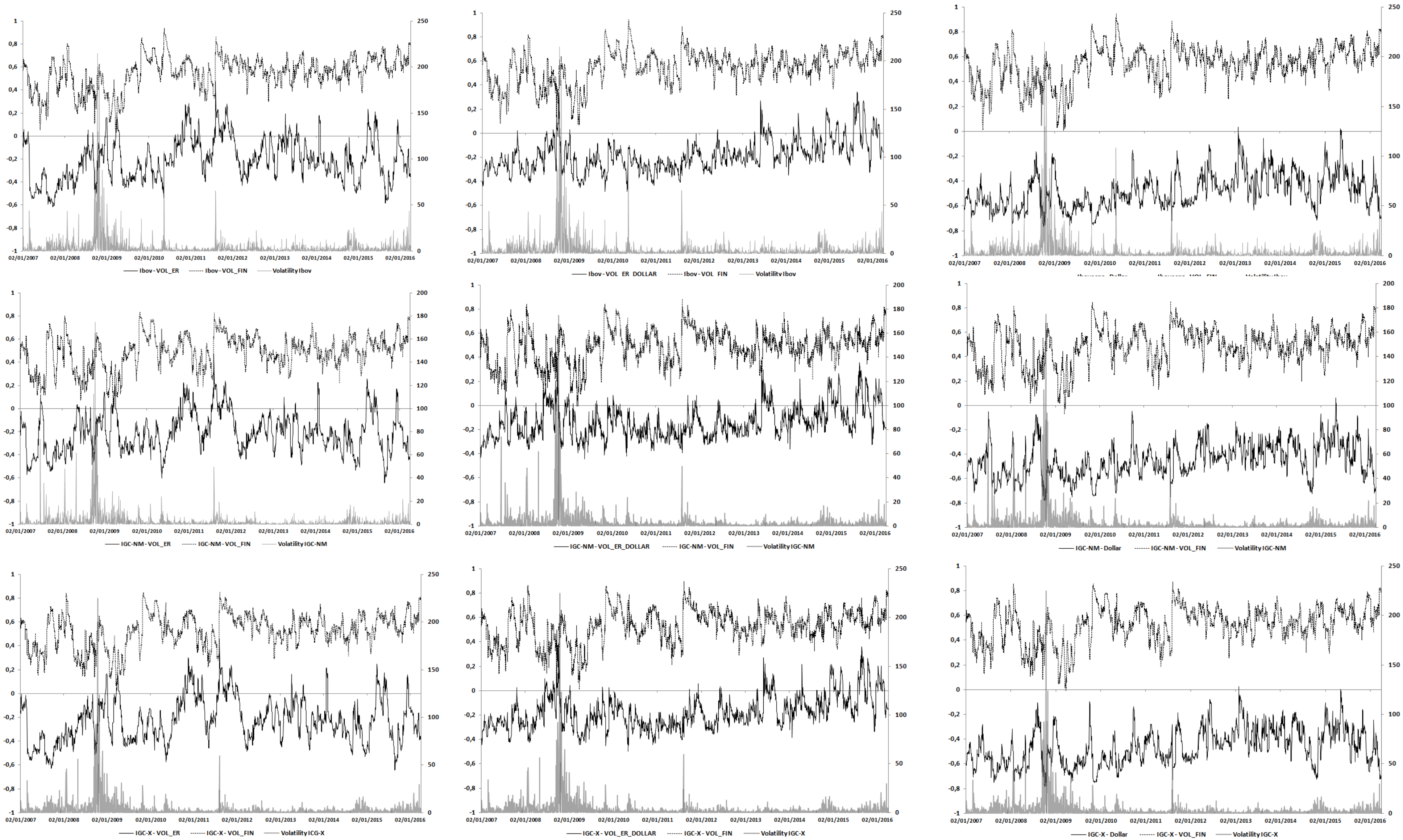


Table 9 not only confirms our impressions based on the graphs, but also reveals the main results of the study: the effects of corporate governance on volatility spillovers and lead-lag effects.

The first result we highlight is that the magnitude of the spillovers associated with shocks of the international financial markets are, in all models, larger than the exchange rate shocks. Although it is not surprising for the more general case of models 1, 2 and 3, it is certainly an unprecedented result when we consider the issue of corporate governance in models 4 to 9. Looking only at the spillovers of international financial market shocks, the conditional correlation of the models that use Ibov are statistically larger than the models that use the IGC-NM and IGC-X. Here is the first evidence of a mitigating effect of corporate governance for this type of spillover. When we compare only the conditional correlation of the corporate governance indices, we see that the IGC-NM financial shock spillover, associated with a higher level of governance, is statistically lower than that of IGC-X models, which has lower level of governance requirement. This provides additional evidence of the mitigating effects of corporate governance.

Turning out attention to exchange shocks, the first important result is that, in most cases, the conditional correlations in models with only the dollar are statistically larger than the models that consider the set of 48 exchange rates in turn, these are larger than the models that consider all other exchange rates excluding the dollar. This result underscores the importance of the dollar for the study of spillovers.

The shocks using the dollar in the Ibov model are statistically higher than in the models with IGC-NM and ICG-X this corroborates the mitigation of spillovers by better corporate governance. This result is reinforced when we compare the conditional correlations of the IGC-NM and IGC-X exchange shocks. The conditional correlations of exchange rate shocks, either exclusively from the dollar or from the combination of the 48 exchange rates, are statistically higher in models containing IGC-X this indicates that a higher level of corporate governance is associated with lower values of exchange spillovers.

Some results were atypical. For example, an isolated result occurs when the model with IGC-X with all 48 exchange rates presents a conditional correlation statistically higher than the Ibov model that uses the same exchange proxy. Other atypical results are related to the proxy of exchange shock in models 5 and 8. The conditional correlations of exchange shocks with IGC-NM presented higher statistical results than the respective IGC-X models. However, models 5 and 8 did not present a good adjustment, as already mentioned in Section 7.1.

Table 9. T test for comparisons - conditional correlations

Model	1		2		3		4		5		6		7		8		9	
	r_{12}	r_{13}	r_{12}	r_{13}	r_{12}	r_{13}	r_{12}	r_{13}	r_{12}	r_{13}	r_{12}	r_{13}	r_{12}	r_{13}	r_{12}	r_{13}	r_{12}	r_{13}
1	r_{12}	0	1	0	0	0	1	0	1	0	1	0	0	0	1	0	1	0
		r_{13}	1	0	1	0	1	1	1	1	1	1	1	1	1	1	1	1
2			r_{12}	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
				r_{13}	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3					r_{12}	0	1	0	1	0	1	0	1	0	1	0	1	0
						r_{13}	1	1	1	1	1	1	1	1	1	1	1	1
4							r_{12}	0	1	0	0	0	0	0	1	0	0	0
								r_{13}	1	0	1	0	1	0	1	0	1	0
5									r_{12}	0	0	0	0	0	0	0	0	0
										r_{13}	1	0	1	0	1	0	1	0
6											r_{12}	0	0	0	1	0	0	0
												r_{13}	1	0	1	0	1	0
7													r_{12}	0	1	0	0	0
														r_{13}	1	0	1	0
8															r_{12}	0	0	0
																r_{13}	1	0
9																	r_{12}	0
																		r_{13}

r_{12}: Correlation of the exchange rate shock of the respective model.
r_{13}: Correlation of the international financial shock of the respective model.
H_0: $|Y_{(i)}| \leq |Y_{(j)}|$, with $i \neq j$.
1: H_0 rejected at the 5% significance level.

8 Conclusions

In this article we address issues of credibility and reputation of corporate governance between firms and investors. In a model with complete information we arrive at a paradoxical result similar to that presented by Selten (1978). That is, the condition of fragility of corporate governance, which guarantees that if the volatility of firms with a high degree of corporate governance tends to the volatility of the other ordinary firms, the corporate governance requirements would never be met. With incomplete information, investors will not know if a firm really has a strong corporate governance culture and must infer about this characteristic.

The results indicate that a weak-type firm (without a strong corporate governance culture) can create a reputation for being strong-type, meeting the requirements and bearing the costs of implementing a certain degree of corporate governance. This behavior attracts investment, however, volatility plays relevant role volatility acts as a reveal mechanism of firm type. Increases in volatility reduce probability of the firm's being strong-type, as inferred by investors. The central hypothesis to be tested is whether the volatility of firms with a high degree of governance is lower than the volatility of other firms.

This hypothesis was tested considering the volatility spillover and lead-lag effect literature. Analysis of volatility spillover investigates conditional correlation in asset volatility, whereas studies of lead-lag effect seek to identify the statistical precedence of these spillovers. In this paper we propose to estimate the spillovers using multivariate GARCH models and to test the lead-lag effects with second-order Granger causality tests.

We first developed a theoretical overview of the literature on spillover and lead-lag effects and aspects of corporate governance that impact firm performance. We propose to evaluate the impacts of corporate governance, in term of market indices, on the spillover processes and their lead-lag effects. We thereby identify some mitigating capacity of corporate governance. We verified the possibility of building proxies for currency shocks and international financial shocks with the help of DPCA. Representative returns presented temporal dynamics that were consistent with stylized facts about returns. This allowed us to use them to estimate the spillover effects of different currency shocks: exclusively from the dollar, from a combination of 48 currencies, and from 47 currencies excluding the dollar, in addition to the international financial shock of 17 financial markets.

The estimation of MGARCH BEKK models that eliminated autocorrelation of standard residuals and their squares, in most cases, indicate that such models were able to produce a good representation of the series generating processes. They produced conditional correlations with temporal dynamics, which allowed us to study in detail the spillovers and the lead-lag effects. The Granger tests of second-order causality not only validated the existence of spillovers, they also validated the presence of lead-lag effects of volatility between currency and international financial shocks and stock markets in Brazil. We find that the Granger causality always happens from currency and international financial shocks to market indices: Ibovespa, IGC-MN and IGC-X. That is, precedence of spillovers between currency, international financial markets and Brazilian's indices volatilities is statistically significant.

The estimated conditional correlations present negative values for the proxies of currency shocks. In other words, increased currency volatility is associated with reduced volatility of the Ibovespa index, which agrees with most of the empirical literaure for other countries.

Tests to compare estimated conditional correlations highlighted the importance of the dollar volatility in spillover. In particular it contrasts with the other proxies of currency shocks with different combinations of currencies. The presence of the dollar is associated with a larger estimated conditional correlation this occurs whether considering the dollar return exclusively, or together with the other 47 exchange rates.

The results clearly indicate the mitigating effect of corporate governance in terms of lower foreign exchange spillovers. The higher degree of corporate requirement, as verified by the IGC-NM indice, the lower levels of exchange spillovers were observed. Shocks arising from the international financial markets behave the same as the exchange rate shocks, however, always showing a greater magnitude and positively correlated. The mitigating effect of corporate governance was also verified for this case. At higher levels of corporate governance, lower spillovers were observed. In spite of these issues, we conclude by highlighting the pioneering nature of the study of spillover and lead-lag effects of different types of currency shocks and international financial shocks whithin the same model and in particular to the corporate governance case.

These econometric results confirm the hypotheses of the theoretical models of strategic behavior. Considering the incomplete information model and the fragility condition of corporate governance, the volatility became a revealing mechanism in reputational models. The effects of spillover were lower in indices of companies with a high degree of corporate governance, and the direction always proceeds from the shocks to indices. This confirms the relevance of volatility in the context of corporate governance.

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Appendix A

Table 10. Exchange rates used

1	Germany	Marco	25	Ireland	Irish Pound (Punts)
2	Argentina	Argentinian peso	26	Israel	Shekel
3	Australia	Australian Dollar	27	Italy	Lira
4	Austria	Schilling	28	Japan	Yen
5	Bolivia	Boliviano	29	South Corea	Won
6	Brazil	Real	30	Malaysia	Ringgit
7	Bulgaria	Lev	31	Mexico	Mexican peso
8	Canada	Canadian dollar	32	Norway	Norwegian Krone
9	Chile	Chilean Peso	33	New Zealand	New Zealand Dollar
10	China	Yuan	34	Paraguay	Guarani
11	Cingapura	Singapore Dollars	35	Peru	New Peru Sun
12	Colombia	Colombian peso	36	Poland	Polish Zloty
13	Ecuador	Sucre	37	Romania	Leu
14	Slovakia	Slovak Crown	38	Russian	Rublo
15	Slovenia	Slovenia Dollar	39	Sweden	Swedish krona
16	Spain	Peseta	40	Switzerland	Swiss Franc
17	Europe	Euro	41	Thailand	Bath
18	Philippines	Philippine Peso	42	Taiwan	Taiwan Dollar
19	France	Franc	43	Czech	Czech koruna
20	Hong Kong	Hong Kong dollar	44	Turkey	New Turkish Lira
21	Hungary	Forint	45	Ukraine	Hyvnia from Ukraine
22	India	Indian Rupee	46	Uruguay	Uruguayan Peso
23	Indonesia	Indonesian Rupee	47	Vietnam	Dong
24	England	British Pound	48	South Africa	ZAR

Table 11. International Financial Indices used

1	Germany	DAX	9	Nasdaq	Nasdaq

2	Argentina	Merval	10	New York	Dow Jones
3	Chile	Chile Stock Mkt	11	Peru	Lima General Index
4	Colombia	IGBC General	12	S&P 500	S&P 500
5	France	CAC 40	13	Japan	Nikkei 225
6	Hong Kong	Hang Seng	14	Venezuela	Venezuela Stock mk
7	London	FTSE 100	15	Shanghai	Shanghai SE
8	Mexico	Bolsa do México	16	Europe	EU Stoxx

Appendix B

Payoff – Model with complete information, two investors and one firm

$$\textbf{A}: \begin{cases} I_1: U(R_{I_1}) = 0 \\ I_2: \boldsymbol{U}(\boldsymbol{R_{I_2}}) + D_{E_2} + P_E B_e(i) - \lambda_2 \sigma_E \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C)T - \lambda\sigma_E - D_{E_2} \end{cases}$$

$$\textbf{B}: \begin{cases} I_1: U(R_{I_1}) = 0 \\ I_2: \boldsymbol{U}(\boldsymbol{R_{I_2}}) + D_{E_2} + P_E B_e(i) - \lambda_2 \sigma_E^{cg} \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C_{cg})T - \lambda\sigma_E^{cg} - D_{E_2} \end{cases}$$

$$\textbf{C}: \begin{cases} I_1: U(R_{I_1}) = 0 \\ I_2: U(R_{I_2}) = 0 \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + R_{tE} - f(C)T \end{cases}$$

$$\textbf{D}: \begin{cases} I_1: U(R_{I_1}) = 0 \\ I_2: U(R_{I_2}) = 0 \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + R_{tE} - f(C_{cg})T \end{cases}$$

$$\textbf{E}: \begin{cases} I_1: \boldsymbol{U}(\boldsymbol{R_{I_1}}) + D_{E_1} + P_E B_e(i) - \lambda_1 \sigma_E \\ I_2: U(R_{I_2}) = 0 \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C)T - \lambda\sigma_E - D_{E_1} \end{cases}$$

$$\textbf{F}: \begin{cases} I_1: \boldsymbol{U}(\boldsymbol{R_{I_1}}) + D_{E_1} + P_E B_e(i) - \lambda_1 \sigma_E \\ I_2: \boldsymbol{U}(\boldsymbol{R_{I_2}}) + D_{E_2} + P_E B_e(i) - \lambda_2 \sigma_E \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C)T - \lambda\sigma_E - D_{E_1} - D_{E_2} \end{cases}$$

$$\textbf{G}: \begin{cases} I_1: \boldsymbol{U}(\boldsymbol{R_{I_1}}) + D_{E_1} + P_E B_e(i) - \lambda_1 \sigma_E^{cg} \\ I_2: U(R_{I_2}) = 0 \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C_{cg})T - \lambda\sigma_E^{cg} - D_{E_1} \end{cases}$$

$$\textbf{H}: \begin{cases} I_1: \boldsymbol{U}(\boldsymbol{R_{I_1}}) + D_{E_1} + P_E B_e(i) - \lambda_1 \sigma_E^{cg} \\ I_2: \boldsymbol{U}(\boldsymbol{R_{I_2}}) + D_{E_2} + P_E B_e(i) - \lambda_2 \sigma_E^{cg} \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C_{cg})T - \lambda\sigma_E^{cg} - D_{E_1} - D_{E_2} \end{cases}$$

Payoff – Model with incomplete information – reputational game

With $P_r((1-\rho_t)|Str)$ **or** $P_r(\rho_t|(1-Str))$:

$$\textbf{A'or A}: \begin{cases} I_1: \boldsymbol{U}(\boldsymbol{R_{I_1}}) + D_{E_1} + P_E B_e(i) - \lambda_1 \sigma_E \\ I_2: \boldsymbol{U}(\boldsymbol{R_{I_2}}) + D_{E_2} + P_E B_e(i) - \lambda_2 \sigma_E \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C)T - \lambda\sigma_E - D_{E_1} - D_{E_2} \end{cases}$$

$$\textbf{B'or B}: \begin{cases} I_1: \boldsymbol{U}(\boldsymbol{R_{I_1}}) + D_{E_1} + P_E B_e(i) - \lambda_1 \sigma_E \\ I_2: U(R_{I_2}) = 0 \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C)T - \lambda\sigma_E - D_{E_1} \end{cases}$$

With $P_r(q_t|Str)$ **or** $P_r((1-q_t)|(1-Str))$**:**

$$\textbf{C'or C}: \begin{cases} I_1: \boldsymbol{U}(\boldsymbol{R_{I_1}}) + D_{E_1} + P_E B_e(i) - \lambda_1 \sigma_E^{cg} \\ I_2: U(R_{I_2}) = 0 \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C_{cg})T - \lambda\sigma_E^{cg} - D_{E_1} \end{cases}$$

$$\textbf{D'or D}: \begin{cases} I_1: \boldsymbol{U}(\boldsymbol{R_{I_1}}) + D_{E_1} + P_E B_e(i) - \lambda_1 \sigma_E^{cg} \\ I_2: \boldsymbol{U}(\boldsymbol{R_{I_2}}) + D_{E_2} + P_E B_e(i) - \lambda_2 \sigma_E^{cg} \\ E_1: \boldsymbol{U}(\boldsymbol{R_{E_1}}) + P_E B_E + R_{tE} - f(C_{cg})T - \lambda\sigma_E^{cg} - D_{E_1} - D_{E_2} \end{cases}$$