GESTÃO, FINANÇAS E CONTABILIDADE

TESTING THE EFFICIENCY-CAPM JOINT HYPOTHESIS IN THE BOVESPA

ANÁLISE DA HIPÓTESE CONJUNTA DA EFICIÊNCIA DO CAPM NA BOVESPA

ANÁLISIS DE LA HIPÓTESIS CONJUNTA EFICIENCIA-CAPM EM EL BOVESPA

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ABSTRACT
Market efficiency implies stock prices fully reflect all publicly available information instantaneously and, thus, no investment strategies can systematically earn abnormal returns. However, market efficiency per se is not testable. In order to analyze whether a stock market is efficient we have to test the joint hypothesis which refers fact that testing for market efficiency necessary involves asset pricing models. Then, we can compare real returns with expected returns predicted by a specific pricing model. In this context, the purpose of this study is to analyze whether the BOVESPA is an efficient market or, by contrast, it is possible to obtain abnormal returns employing the Capital Asset Pricing Model. To that end, we employ an intuitive trading rule based on purchasing exclusively those shares that are considered undervalued by the CAPM and compare it with the passive strategy of purchasing all shares that are members of the selective market index. Finally, our results are consistent with market efficiency as well as with the CAPM.
Keywords: Efficiency. Asset Pricing Models. CAPM. Investment Strategies.

RESUMO
A eficiência dos mercados implica que os preços refletem completamente e instantaneamente toda a informação disponível ao publico e, portanto, nenhuma estratégia de investimento consegue gerar lucros anormais de forma consistente. No entanto, a eficiência do mercado por

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si só não é testável. Para analisar se um mercado é eficiente, é necessário testar a denominada "hipótese conjunta" que envolve a utilização dum modelo de precificação de ativos. Dessa forma, é possível comparar os rendimentos reais obtidos no mercado com os retornos esperados calculados no modelo de avaliação utilizado. Neste contexto, o objetivo deste estudo é analisar se a BOVESPA é um mercado eficiente ou se, pelo contrário, é possível obter retornos anormais utilizando o Capital Asset Pricing Model. Para tal, aplicamos uma estratégia de investimento intuitiva baseada na compra exclusiva das ações, consideradas subavaliadas pelo CAPM, e comparar com a estratégia passiva de todas as ações que compõem o índice seletivo. Finalmente, observamos que os resultados são consistentes com a eficiência do mercado, bem como com o CAPM.
Palavras-chave: Eficiência. Modelos de valorização. CAPM. Estratégias de Investimento.

RESUMEN
La eficiencia de los mercados de valores implica que los precios de las acciones reflejan instantáneamente toda la información disponible al público y, por lo tanto, ninguna estrategia de inversión puede generar ganancias anormales sistemáticamente. Sin embargo, la eficiencia del mercado per se no es comprobable. Con el fin de analizar si un mercado de valores es eficiente tenemos que testar la denominada "hipótesis conjunta" que implica la utilización de un modelo de valoración de activos. De esa manera, podremos comparar los rendimientos reales obtenidos en el mercado con los rendimientos esperados en función del modelo de valoración empleado. En este contexto, el propósito de este estudio es analizar si el mercado BOVESPA es eficiente o, por el contrario, es posible obtener rendimientos anormales empleando el Modelo de Valoración de Activos de Capital. Para ello, empleamos una intuitiva estrategia de inversión basada en la compra exclusiva de aquellas acciones que se consideran infravaloradas por el CAPM y las comparamos con la estrategia pasiva de comprar todas las acciones que componen el índice de mercado selectivo. Finalmente, observamos que nuestros resultados son consistentes con la eficiencia del mercado, así como con el CAPM.
Palabras clave: Eficiencia. Modelos de Valoración. CAPM. Estrategias de inversión.

1. INTRODUCTION

The Capital Asset Pricing Model (CAPM) is the most explained and used valuation model in modern finance. The usage of this model or of any alternative model is essential to the current financial reasonability that constantly questions what value this decision adds to a specific company or asset to decide consistently.

That model proposed by Sharpe (1963 and 1964), based on the premises of Markowitz (1959), with the contributions of Tobin (1958), Treynor (1962), Lintner (1965), Mossin (1966) and Black (1972), has revolutionized the premises of finance by conveying, by means of a fairly simple equation, the relationship between risk and returns.

When a company makes correct decisions, it expects that the markets recognize them by exerting upward pressure on the securities value. There is confidence that the markets reflect accurately all the information that should affect prices and, therefore, is considered efficient. Although efficiency is essential to modern finance and, like the CAPM, has been called into question, it remains valid, despite being subject to analysis for many years.

As stated on several occasions by Fama (1970, 1991 and 1998), efficiency is tested together with a model of expected returns, known as "joint hypothesis", one at a time. If the result is that the market valuates correctly according to the CAPM, we accept both efficiency and the CAPM; if the result is the opposite, we will have to reject either the CAPM, efficiency or both, thereby considering either that the CAPM is a bad model, that the market valuation is incorrect or both.

The aim of this study is to present a test of the CAPM, which is simultaneously a test of the markets' efficiency for the Brazilian stock market. Specifically, it allows knowing if it is possible to beat the market using the CAPM and to assess the market efficiency based on the model.

The analysed data were the shares of companies that were part of the IBOVESPA between January 2000 and December 2016. The choice of this period is due to the stability of the Brazilian economy after the Real Plan, and the choice of this market is due to the importance it has in the global context, in the context of the American continent, namely in the context of South America, as the thirteenth largest stock exchange in the world.

Our work is divided into 6 clearly defined sections: in Section 2 we make a review of existing literature related to the CAPM and efficiency, in Section 3 we describe the methodology, in Section 4 we describe the data and the selection of the analysis period, in Section 5 we describe the results and finally in Section 6 we present the main findings.

2. LITERATURE REVIEW

Since Sharpe (1963) proposed the CAPM, adopting concepts such as risk aversion on the part of investors from the Modern Portfolio Theory of Markowitz (1952), the model has been studied, analysed, criticised, used and developed by researchers, scholars and professionals from all over the world.

The CAPM model, as indicated by Levy and Roll (2012), has deep practical implications not only for individual investors, as well as for professional investors. While accepting that there are many academic studies that reject the model, the authors show that the CAPM is able to reflect reality and consider that it cannot be empirically rejected, as some other studies try to do.

On the other hand, there have been many studies on market efficiency, and several authors such as Fama (1970, 1998), Malkiel (2003), Ferruz *et al.* (2006) and Gómez-Bezares (2010), among others, apply different methodologies in different markets and in different periods of time. Thereby, Duarte and Mascareñas (2013) and Ávila *et al*. (2016) debate the evolution of the research made on efficiency in the major markets and, among other things, find diversity among them, depending on factors such as the market development level, the period chosen for the analysis, etc., and most studies deny market efficiency. Given that the debate is still ongoing, it is interesting to bring new empirical evidence that can lead to more consistent conclusions.

Both the CAPM model and questions regarding market efficiency were analysed for the Brazilian market: a good example of those studies are those conducted by several authors that we present briefly in Table 1. In those studies we can find several analyses of the subject, but not along the lines indicated by Levy and Roll (2012).

TABLE 1 – Studies on CAPM and Portfolios in the Brazilian Market

Author	Analysis Period	Methods and Tests Used
Found evidence on the validity of the CAPM		
Rochman and Eid (2006)	2001 to 2006	Jensen's model (1968)
Silva and Munhoz (2006)	1995 to 2005	Standard deviation from profit (σ). Pearson's correlation
Tambosi, Costa and Rossetto (2006)	1994 to 2002	Regressions according to Fama and MacBeth (1973)'s methodology
Lins, Silva and Marques (2009)	1998 to 2006	Cluster analysis
Raboni *et al.* (2008)	1999 to 2006	Simple exponential smoothing. PEG index
Mazzeu, Costa and Santos (2013)	1987 to 2010	OLS (Ordinary Least Squares), Kalman filter
Guimarães, Carmona and Guimarães (2015)	1995 to 2013	Treynor index, Jensen's alpha, Sharpe index, multiple linear regression
Found no evidence on the validity of the CAPM		
Galdi and Securato (2007)	1999 to 2006	Volatility measures, regressions of the portfolio excess returns with lagged volatility measures. Robustness tests
Rabelo *et al.* (2007)	2003 to 2006	Standard deviation. Jensen's alpha (α). Treynor index (T), M2 index and Sortino index (S)
Rogers and Securato (2008)	1995 to 2006	Sharpe-Litner-Mossin version of the CAPM, model of 3 factors by Fama and French, and Reward Beta Model
Castro Silva *et al.* (2009)	2005 to 2008	Log-return, Shapiro-Wilk Test and Anderson Darling Test, OLS (Ordinary Least Squares)
Blank, Samanez, Baidya and Aiube (2014)	2004 to 2014	Kalman filter, AIC (*Akaike Information Criteria*) and BIC (*Bayesian Information Criteria*), *cross-sectional* regression
Brunhera, leismann and Corrêa (2015)	2004 to 2014	We used the Solver tool in the optimization process of the low, medium and high risk portfolios

As it can be observed briefly in Table 1, there are studies that find empirical evidences on the validity of the CAPM and studies where those evidences can't be found. In this review, we sought to analyse the most recent studies on CAPM in Brazil. From the studies that find empirical evidences on the validity of the CAPM, first we identified the one by Rochmans and Eid (2006), who have researched if it is better to invest in active funds or passive funds, during the period 2001-2006, dividing those funds into the following categories: equity funds, exchange funds, multimarket funds and fixed income funds. The equity funds and the multimarket funds show a common result: the active management adds value to the investor,

i.e., managers are better able to administer the investors' resources. In the case of fixed income funds, the main evidence is contrary to active management. In the case of exchange funds, the alphas in general weren't relevant and the few that were clearly showed the value destruction on the part of managers. With respect to alpha determinants, in the case of equity and multimarket funds, evidence shows that the investor must seek active funds, with the highest net worth, and even older. In the case of fixed income funds, the result is more vague/widespread, clearly showing only the relationship between fund size and alphas. They concluded that the CAPM was valid in the estimate of fund risk.

Along the same lines but extending the study period, Silva and Munhoz (2006) sought to determine if it was possible to use net profit and its dispersion as an approach to beta. They used a sample of Brazilian listed companies, between 1995 and 2005, trying to verify if there's a relationship between beta and some of the existing measures. The result was negative, which shows that probably the account measure is not adequate to replace beta in its several situations. The estimated correlations were minor.

In the same year the study of Tambosi, Costa and Rossetto (2006) was presented, whom have tried to show the advantages of conditional models over the static model from 1994 to 2002. In order to confirm the facts, they studied the tests of conditional models, which aren't usually studied in literature. Those tests are appropriate to incorporate variances and covariances that change over time. From the conditional models tests they point out the one from Jagannathan and Wang (1996). They conclude that the model satisfactorily explains the cross-sectional variation of the Brazilian and north-American markets' returns, with the Consumption Capital Asset Pricing Model (C-CAPM**)** being more efficient than the CAPM.

Lins, Silva and Marques (2009) sought to identify groups of actions with identical characteristics (hypothetical portfolios), with a view to allocate the capital available for investment, in order to know the potential risk and the possible returns for a potential investor. They used the cluster analysis technique, on the basis of the shares traded in São Paulo Stock Exchange between 1998 and 2002, to build cluster. The period used to assess the performance of the portfolios created based on that cluster analysis ranged from 2002 to 2006. The results identified five hypothetical portfolios, three of them deemed ideal for a potential investment. The assessment of the behaviour of the hypothetical portfolios performed as expected for the study period, which proves the adequacy of the cluster analysis technique.

Raboni *et al*. (2008) tested a strategy of investment in shares between 1999 and 2006. To invest in shares from companies that are growing might generate good investment opportunities in the capital market. To this end, they divided the shares from companies according to an index known as PEG (profitearnings-growth). Furthermore, the PEG variable was incorporated in the Capital Assets Formation Model, and has proven to be relevant.

Mazzeu, Costa and Santos (2013) analysed the conditional CAPM model performance with learning when applied to series of returns of the most liquid shares of the Brazilian market in the period from 1987 to 2010. Using data from 25 portfolios classified by size and by the index book value-market value, they concluded that the conditional CAPM with learning is able to substantially reduce the adjustment errors in comparison with the original version of the CAPM. They chose the 30 most liquid shares from Brazilian market during the period 1987-2010, using the average index of yearly liquidity of each share by 31 December

of each year to select the shares, they calculated the average of the yearly liquidity index of each share, and the shares were classified in decreasing order in relation to the average of its liquidity index. Thus, they obtained a ranking of the most liquid shares. From the 30 shares with the higher liquidity index they excluded those that didn't have quotations in the analysis period. They selected the following conditioning variables: the excess returns of the market (PRM), the interests' spread (SPREAD) and the value spread (HML). The excess market returns was derived from the difference between Ibovespa's returns and Selic rate returns, used as proxy of the risk-free asset. The interests' spread was derived from the difference between Selic rate and CDI taxa. Finally, the value spread was build based on the difference between the returns of a portfolio comprised of value equities and the returns of a portfolio made up of growth equities. This variable is usually known in financial literature as risk factor HML (high value minus low value). The results show a decrease in assessment errors of the conditional CAPM with learning in relation to the original version of the CAPM. Therefore, those empirical results suggest that the learning of betas should be taken into account in the estimation of unconditional and conditional CAPM.

Guimarães, Carmona and Guimarães (2015) verified if portfolios built by means of fundamentalist variables show a good market performance after the Sharpe index extended between 1995 and 2013. The portfolios were built by means of asset ranking based on the scores obtained in a model of factor weighing, which corresponds to the variables: Tobin's q ratio, Beta, Financial leverage, Price/Profit, Price/Sales. The results demonstrated that the portfolios built by means of fundamentalist variables had a good performance in 28,72% of the occurrences/events, compared to market proxies. To build the portfolios they adopted a model based on its fundamentalist variables. The results weren't unanimous and therefore can't infer that an share portfolio built by means of fundamentalist variables has a good market performance. Nevertheless, there are indications that that portfolio can have a good performance on the basis of the conventional indexes of performance analysis.

Conversely, in what no CAPM validity is concerned, there are studies such as the one by Galdi and Securato (2007), who have analysed the relationship between the idiosyncratic risk and the returns of a diversified portfolio of Brazilian market assets. They used volatility measuring measures in order to capture the effects of systemic risk and of the idiosyncratic risk of the portfolios under review. To identify the relationship between idiosyncratic risk and the returns they used a time series approach, doing regressions between the volatility measures and the portfolio monthly one-step-ahead returns for the period 1999 to 2006. In addition, robustness tests were made to validate the results. No evidences were found that the idiosyncratic risk helps explain the returns of a diversified asset portfolio in the Brazilian market. In order to do so, they used volatility measures that seek to represent systemic risk and idiosyncratic risk. To investigate the existence of significance of time relationship between idiosyncratic risk and portfolio returns, they made regressions of excess portfolio returns with lagged volatility measures. The results show the non-existence of significance between the adopted volatility measures and the returns of the weighed portfolio and of the balanced portfolio. Additionally, robustness tests were made to validate the results obtained and all the results were consistent with the evidence that there's no significant relationship between idiosyncratic risk and systemic risk and the one-step-ahead returns of a diversified share portfolio in the Brazilian market.

In order to know if companies that adopt better corporate governance practices perform better than those who don't, Rabelo *et al*. (2007) developed a portfolio study that consists of two types of portfolio with three different diversification strategies. To that end, through the bootstrap resampling method they compared portfolio averages regarding returns, risk and returns adjusted to risk between 2003 and 2006. To determine the returns they used monthly real rates and regarding risk measures of the monthly real returns, standard deviation, variation coefficient, semi-variance and beta coefficient. In what returns adjusted to risk is concerned, they used the Sharpe Index (IS), the Treynor Index (T), the M2 Index, Jensen's Alpha (α) and the Sortino Index (S). They concluded that, despite there are no statistical differences, the share portfolios from companies with better corporate governance practices show signs of better performance than the share portfolios from companies that don't adopt differentiated corporate governance practices, at least in the period under review.

In a wider analysis period, Rogers and Securato (2008) tested and compared three alternative models to predict the expected returns in the Brazilian capital market: the Sharpe-Litner-Mossin version of the CAPM, the three-factors model by Fama and French and the Reward Beta Model, documented by Bornholt (2007). As empirical procedure they used the test methodology in two steps for general equilibrium models: the first step is to estimate the models' parameters on the basis of regressions in time series; in the second step, the estimated parameters are used as explanatory variables in cross sectional regressions. They made the tests by portfolio, according to the methodology by Fama and French (1993) and Bornholt (2007), applied to two subsamples of shares, with data available at the Bovespa from 1995 to 2006. The results tend to support the 3-factors model by Fama and French (1993) aimed at explaining future returns, but the factor that captures the book-to-market effect isn't relevant. Therefore, the predictable effect of the CAPM wasn't found.

In order to know which model is more adequate and which adjusted itself better to the estimates of expected returns of representative indexes of securities traded in the Bovespa between 2005 and 2008, Castro Silva *et al*. (2009) investigated three versions of the general equilibrium relationship to predict the expected returns – the static version of CAPM, the downside (D-CAPM) and the conditional (C-CAPM). They concluded that the C-CAPM was slightly more stable, but, despite that evidence, the presence of structural changes in the time series, also indicated that the beta is not the only factor that explains the risk.

And finally, the study of Blank, Samanez, Baidya and Aiube (2014) and Brunhera, leismann and Corrêa (2015) analyses a more recent period until 2014. Blank, Samanez, Baidya and Aiube (2014) analysed alternative samplings regarding the adjustment of the data of portfolios ordered by market value and book-to-market ratio, as well as the ability to explain the adjustment errors in relation to unconditional CAPM, from 1999 to 2013, through tests based on approaches to time series and cross-sectional. The model according to which the beta follows a random path combined with conditioning variables is the one that has better results by reducing adjustment errors, but, despite the decrease, they remain significant. The cross-sectional tests indicate that the book-to-market variable loses power to explain the returns, but they show an influence of the variable regarding past returns. The results obtained in the analysis show that the modelling used may have satisfactory results in what data adjustment is concerned, indicating a time variable of the betas. However, the gains in terms of explaining the adjustment errors identified based on unconditional CAPM are limited. Based on the estimate of unconditional CAPM, they identified the presence of abnormal

returns for share portfolios of higher book-to-market ratio and smaller size. Considering the adjustment tests, the random path model when combined with conditioning variables is able to explain part of the estimated alphas of the portfolios analysed on the basis of unconditional CAPM. Nevertheless, this decrease is relatively small, therefore the adjustment errors remain significant in the portfolios with higher book-to-market ratio and smaller size. Despite the evidences on beta time variation, the models analysed weren't able to fully explain the deviation of unconditional CAPM.

Brunhera, leismann and Corrêa (2015) tried to verify the efficiency of the CAPM in the prediction of future returns of a given asset portfolio, between 2004 and 2014. The research is of exploratory type, using the Solver tool in the optimization process of low, medium and high risk portfolios, based on the series of collected data. To that end, they estimated the β coefficients, established after acquiring the historic data of the assets' returns and of the portfolio returns and built 3 low, medium and high risk portfolios, taking into account a 20% variation in the beta of the lower and higher beta that make up the portfolio. They then compared the expected returns with the actual returns using the CAPM model, having classified each portfolio as efficient or non-efficient according to the variation degree of the returns expected by the CAPM in relation to the obtained returns, assuming a maximum variation of -2%. In this scenario of market complexities, one observes that the CAPM doesn't explain accurately all the returns occurred in that period, and that the non-effective results show a significant variation.

Thus, and as we determined in the review made, none of these studies adopts an approach like the one adopted by Levy and Roll (2012) and Gómez-Bezares *et al*. (2012). We therefore believe we can contribute to deepen the subject adding a new approach and, consequently, strategies that lead to the realisation of extraordinary gains.

3. METHODOLOGY

The asset appreciation is, without a doubt, essential to modern finance (Santos and Montezano, 2017). Therefore, it's only logical that the appreciation models and the way that value reflects in the asset prices are paramount to the paradigm named by Gómez-Bezares (1995) as seventy's paradigm, which is the foundation of finance as it is understood today and put in place all over the world. Gómez-Bezares and Gómez-Bezares (2014) simplified the paradigm calling it the efficiency – CAPM paradigm and tried to answer two fundamental questions: i) does the market appreciate properly the securities listed on it? and ii) do the securities appreciate according to the systemic risk measured by beta?

Regarding the second question, they feel that more realisation is needed: if it complies with the CAPM, the expected returns of an asset must correspond to the risk-free asset plus a risk premium, which will be estimated multiplying the product of the risk premium of the market portfolio by the amount of systemic risk measured by beta, which will be the only risk measure, according to the following equation,

$$E\ (r_i) = r_f + \left[E\ (r_{m)} - r_f\right] * \beta_i$$

where $E\ (R_i)$ is the security's expected returns, r_f is the risk-free type, $E\ (r_m)$ is the market portfolio expected return and β_i is the security's systemic risk.

If the securities are overvalued in a month and undervalued in the next, then we could beat the market based on the CAPM if we bought those securities. But it is more normal that the securities overvalued in a certain period, in the following month are 50% undervalued and 50% overvalued. However, if the opposite happens, and the securities that are undervalued remain undervalued, then the investor will have found a strategy that will allow him to obtain extraordinary gains.

It seems to us that it is easy to understand that if the investor's strategy doesn't beat the market, the results would be simultaneously consistent with the efficiency and with the CAPM, otherwise we would have found a way to obtain extraordinary gains, which would be not only very interesting but also a strategy very easy to implement.

In order to test the proposed target, we developed an investment strategy which relies on buying companies that are undervalued according to the CAPM and then including them in a portfolio and verifying if one can beat the market. To assess the efficiency of the portfolios built based on these strategies there have been used not only the Jensen's Index (1968) but also the modified Jensen's Index. Although they're classic measures, they are still used to assess the performances in recent articles, such as, Silva *et al.* (2003), Nielsen and Vassalou (2004) and Gómez-Bezares *et al.* (2004, 2012).

With the aim of making the understanding of elaborate strategies more intuitive, and verifying the level of interest that the CAPM may have to the investment decision-making, they have intentionally avoided too complex comparisons and approaches, which doesn't mean that they've waivered the thoroughness and scientific accuracy. However, in the study they approached certain aspects that were criticized about the CAPM model, in order to incorporate several improvements pointed out in the literature.

Thus, along the lines of the criticism made by Liu (2006), who highlights the importance of including liquidity in the model, since this parameter can be very relevant in certain markets or time periods, we've only selected companies that are listed on the IBOVESPA at all times. The first criterion of inclusion and exclusion of companies in or from the Index on the part of CAT (Technical Advisory Committee) of IBOVESPA is the liquidity with which the securities can be traded. Therefore, the study shows only the companies with the highest liquidity level.

Another criticism made to the model is how complex it is to know the actual market portfolio it identifies (Roll, 1977). Exploiting this potential weakness to develop investment strategies, which is something new, we measure the securities that are undervalued in relation to IBOVESPA.

Furthermore, Jagannathan and Wang (1996) and Heinen and Valdesogo (2008), among others, criticize the invariability assumed in the betas through the years in some studies. That's why, in order to create enough momentum in the parameters, each analysis period was re-estimated: the beta was re-estimated monthly for each security.

The proposed strategies aim to verify if, using the CAPM, one can systematically obtain returns adjusted by risks higher than those of the market. If so, the expected share returns wouldn't be explained by the betas. Nevertheless, as observed by Gómez-Bezares *et al.* (2012), that should be clarified, since it would correspond to the expected actual returns, but as one obtained extraordinary returns, it would progressively incorporate the logical model.

3.1. Procedure to build the investment strategy based on the CAPM

Initially, at the end of each month, the composition of IBOVESPA is examined and the companies undervalued in relation to the Index are chosen. In order to identify the undervalued and overvalued companies we compare the monthly actual performance of all securities with the performance that should have been obtained according to the CAPM.

To build the CAPM, first we calculate, based on Bovespa prices, the monthly returns of each one of them, to use them as reference points and verify later if the marketable securities of each one of them are undervalued or overvalued.

Then, we calculate the monthly returns obtained for each one of the securities in order to obtain its betas. Beta is a risk measure assumed by the CAPM. This model only considers relevant the significant risk that can't be eliminated by a good diversification, i.e., the systematic risk. It is calculated through the regression between monthly returns obtained by a certain security in a given period, in this case the monthly return obtained by the market index in the same period. Thus, we have:

$$\beta_i = \frac{COV\ (R_i, R_M)}{\sigma_M^2}$$

where β_i is the systematic risk of security *i*, $COV\ (R_i, R_M)$ is the covariance between the returns of security *i* and the market, and σ_M^2 is the variance of market returns.

After attaining these results, we determine what should have been the monthly average return of each security in each month according to the CAPM:

$$E\ (R_i) = R_f + \left[E\ (R_{m)} - R_f\right] * \beta_i$$

whether $E\ (R_i)$ is the expected return of the security *i* in a given period, R_f is the risk-free rate, $E\ (r_m)$ is the expected return of the market portfolio to which the security *i* belongs and β is the systematic risk of security *i*.

Finally, we compare the monthly average returns obtained by each one of the securities with the one they should have obtained according to the CAPM. If the actual returns are higher than expected, the security is undervalued. On the other hand, if the actual returns are lower than expected, then the security is overvalued.

According to this portfolio composition methodology, we choose the undervalued companies in each month, which are then incorporated in the portfolio, eliminating those that in the previous month were overvalued.

However, to ascertain the validity of this analysis and assuming that the three most undervalued securities remained undervalued in the following period, we build another strategy according to which we only chose those companies that, in addition to being undervalued, were the three most undervalued of the market portfolio shares.

To determine the undervalued securities we apply the same procedure adopted for the individual securities, but instead of the monthly returns of the securities, we chose the monthly returns of the three most undervalued securities and, as benchmark index, the monthly returns of IBOVESPA.

3.2. Procedure to ascertain whether it is possible to beat the market with the CAPM

Once the securities that are going to make up the portfolio are known, we calculate the average yield also as a simple average of the returns of the individual securities that comprise them, as well as its beta, obtained as a simple average of the securities betas that are included in the portfolio.

Then, the portfolio securities betas are recalculated at all times, since these should be calculated in relation to the market portfolio. Therefore, if in the previous step to verify that the assets were undervalued in relation to the index, we took the return of each security and calculated the beta of the IBOVESPA index chosen to estimate the beta.

In order to ascertain that the adoption of these strategies allows to beat the market, we applied the Jensen's Index (1968):

$$\propto_p = [\bar{R}_p - R_f] - [E\,(R_M) - R_f] * \beta_p$$

where $\propto_p$ is the Jensen's alpha for the set up portfolio p, $\bar{R}_p$ is the average yield obtained by the portfolio a posteriori in the analysed period, $E\,(R_M)$ is the expected return of the benchmark index, in this case the IBOVESPA, R_f is the return provided by the risk-free securities and β_p is the systematic risk of portfolio *p*. If the index is positive, that means one was able to beat the market, otherwise one wasn't able to achieve the goals using the proposed strategies.

Finally, we test the robustness of the obtained results through the Malkiel *Z*-test (1995).

$$Z = \frac{(Y - np)}{\sqrt{np(1-p)}}$$

where Y is the number of periods in which the portfolio is able to beat the market, n is the number of months under analysis, to p we assigned a value of 0,5, since this corresponds to the probability to beat the market, if the logic of the CAPM and of the market efficiency hypothesis remains.

The purpose of this test is to know if the difference between (Y-np) is due to chance or a coincidence, or if, on the contrary, the results obtained are due to a well-defined strategy that is able to beat the market in a consistent way. If the value of $|Z|$ is higher than 1.96, it is not possible to accept the null hypothesis, which, therefore, means that the difference isn't due to chance.

4. DATABASE

The companies that are used for the analysis are the most liquid securities of the IBOVESPA at all times, between January 2000 and December 2016. Table 2 shows the sector components of IBOVESPA, a total of 43 companies divided by 24 sub-sectors, as illustrated in the table according to IBOVESPA's ranking.

To order to be as rigorous as possible and include the liquidity problems with the CAPM indicated by Liu (2006), we only considered the companies that comprise the index at all times. Therefore, if a company is on the index, leaves it for some time and then returns, it is not possible to incorporate in the portfolio the period when it was out. Thus, it only includes securities portfolios that have a high level of liquidity.

TABLE 2 - Components of IBOVESPA

NAME	INDUSTRY GROUP	SECTOR
KLABIN UNITS	Containers & Package	BASIC MATERIALS
VALE ON	General Mining	
COMPANHIA SIDERURGICA NACIONAL ON	Iron & Steel	
FIBRIA CELULOSE ON	Paper	
AMBEV ON	Brewers	CONSUMER GOODS
BRF BRASIL FOODS ON	Food Products	
COSAN INDUSTRIA E COMERCIO ON		
HYPERMARCAS ON		
JBS ON		
MARFRIG FRIGORIFICOS ON		
NATURA COSMETICOS ON	Personal Products	
LOJAS RENNER ON	Apparel Retailers	CONSUMER SERVICES
RAIA DROGASIL ON	Drug Retailers	
ESTACIO PARTICIPACOES ON	Spec.Consumer Service	
KROTON EDUCACIONAL ON		
LOCALIZA RENT A CAR ON		
SMILES ON		

TABLE 2 - Components of IBOVESPA (Cont.)

NAME	INDUSTRY GROUP	SECTOR
BANCO BRADESCO ON BANCO DO BRASIL ON BANCO SANTANDER BRASIL UNITS	Banks	FINANCIALS
CIELO ON	Consumer Finance	
BB SEGURIDADE ON QUALICORP ON	Full Line Insurance	
BMF BOVESPA BLVAL. MEREFU.ON CETIP BALCAO ORGANIZADO DE ATIVOS ON	Investment Services	
BR MALLS PARTICIPACOES ON CYRELA BRAZIL REALTY ON MRV ENGENHARIA E PARTICIPACOES ON MULTIPLAN EMPE. IMOBS.ON	Real Estate Hold, Dev	
EMBRAER ON	Aerospace	INDUSTRIALS
WEG ON	Electrical Equipment	
CMPH.COCS. RODOVIARIAS ON ECOD.INFU.E LOG.ON RUMO LOG.OPD.MULTIMODAL	Transport Services	
CENTRAIS ELETR BRAS- ELETROBRAS ON ENGIE BRASIL ENERGIA ON	Alt. Electricity	OIL & GAS
PETROLEO BRASILEIRO ON	Integrated Oil & Gas	
TIM PARTICIPACOES ON	Mobile Telecom.	TECHNOLOGY
CPFL ENERGIA ON ENERGIAS DO BRASIL ON BRAZIL EQUATORIAL ENERGIA ON	Con. Electricity	UTILITIES
ULTRAPAR PARTICIPOES ON	Gas Distribution	
CPAD.SANMT.BASICO DE SAOP.ON	Water	

It should also be noted that the analysis period is divided into two sub-periods. The first in-sample period corresponds to a period of 60 months. The second out-of-sample period is used to test the efficiency of the developed investment strategies, i.e., to assess if the portfolio built by investing in the undervalued securities according to this strategy beats the market.

Table 3 shows the yearly descriptive statistics of our database. In the in-sample period, we show the monthly returns of the previous period. To that end we took as basis a 60 months period, so that the conclusions derived from the results don't depend on the range of the in-sample period. And in the out-of-sample period we show the monthly figures of the returns

for the same period: we consider only the returns of shares that we included in our study, i.e., those which were more liquid.

TABLE 3 – Descriptive Statistics

In sample	Rf	Rm
Average	0.01569	0.01511
Mean	0.01542	0.00953
Maximum	0.02208	0.15284
Minimum	0.01271	-0.17686
Standard deviation	0.00264	0.06143
Out of Sample		
Average	0.01013	0.00942
Mean	0.00979	0.00621
Maximum	0.01646	0.17865
Minimum	0.00604	-0.22548
Standard deviation	0.00261	0.06092

This table shows the yearly descriptive statistics of our database. Rm is the return of the market portfolio and Rf is the risk-free rate, whose components are those indicated in the table.

5. EMPIRICAL RESULTS

The investor observes, on a given month, the track record (of the previous 60 months) of the securities that make up the IBOVESPA at the time, and buys all that are undervalued according to the CAPM. Second, the aim of this study is to know if it can beat the market with the undervalued share portfolio. Table 4 shows the number of undervalued securities and the percentage it represents of the total of securities of the index for each study year, and every year there is around 50% of undervalued securities.

Table 5 shows the results of this strategy. We present, for each of the 14 years of our study, the number of months (and the percentage) in which the investor portfolio overcame the market. Moreover, we present the result for the *Z* statistics. Specifically, in 67 months of the 144 months under analysis in our study the market is beaten, which corresponds to 46% of the total of months. In addition, the *Z*-stat (which is lower than 1.96) confirms that the CAPM doesn't offer a strategy significantly better than investing in the market portfolio. In other words, we could say that the investor's success (in the months in which he is able to beat the market) can be due to chance. This conclusion is confirmed in the appendix by the average tests, that allow to accept that the average of Jensen's alphas is zero, and by the binomial test, that enables to accept a success of 50% of the probability rate. Figure 1 confirms the results shown in the table, since the proposed investment portfolio doesn't outperform the market portfolio.

TABLE 4 – Undervalued Securities

Portfolio composition based on the CAPM		
YEAR	Number of Undervalued Companies	% of undervalued companies
2005	10	50%
2006	12	51%
2007	12	49%
2008	16	51%
2009	14	42%
2010	25	67%
2011	19	49%
2012	18	45%
2013	24	59%
2014	19	45%
2015	22	51%
2016	21	48%

This table shows the results of the number of undervalued companies according to the CAPM and its percentage of the total of the market portfolio.

TABLE 5 – Results of the strategy of investing in undervalued securities

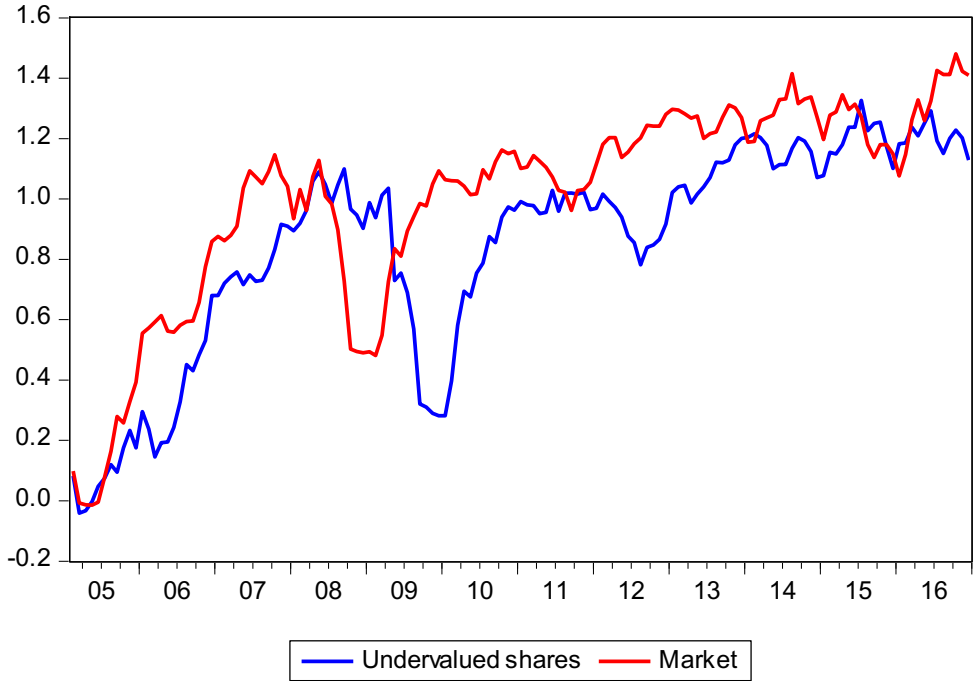
YEAR	Number of months it beats the market	Accumulated average yield	% of success	Z-Test
2005	4	4.676	33%	
2006	6	6.169	50%	
2007	7	3.882	58%	
2008	6	12.369	50%	
2009	3	4.645	25%	
2010	9	8.416	75%	
2011	6	5.702	50%	
2012	5	1.824	42%	
2013	9	4.678	75%	
2014	3	7.612	25%	
2015	5	7.596	42%	
2016	4	8.664	33%	-1.3155

This table shows the results of a strategy according to which our hypothetical investor buys all undervalued shares in the market portfolio. Specifically, we provide for each of the 12 years of our study the number of months and the percentage in which the strategy outperforms the market strategy.

If now we focus on each year of our time period, we can see that only 1 year of the 12 years covered in the study, more specifically from May 2008 to May 2009 and in another period under one year from May 2015 to February 2016, the CAPM proves to be a useful tool for the investor, allowing him to use a strategy to beat the market. Indeed, in the months when

the investor outperforms the market, one can confirm the model performance or the market inefficiency.

FIGURE 1 – Cumulative returns



Since the adoption of this strategy leads to results that don't allow beating the market using the CAPM, which may be due to the fact that we have selected all the undervalued securities or even the range used, we are going to do two robustness tests. On the one hand we are going to adopt a range that corresponds to half of the first range, namely 30 months, in order to confirm if the conclusions derived from the results don't depend on the considered in-sample period. On the other hand, we are going to analyse an alternative strategy that consists in investing exclusively in the three most undervalued securities. The idea underlying this new strategy is that the most undervalued securities in a given month remain predictably undervalued in the following month according to the CAPM. If this strategy can't beat the market, that will be another evidence on the efficiency of the Brazilian market. Although this strategy is in line with what was proposed by Ferruz *et al.* (2010), we were even more restrictive by choosing only the three most undervalued securities.

As we can observe in Table 6, for a range of 30 months, the market is beaten only in 84 of the 168 months that were analysed in our study, which corresponds to 50%. Furthermore, the *Z*-stat (under 1.96) confirms that the CAPM doesn't offer a strategy significantly better than investing in the market portfolio. In other words, we could say that the investor's success (in the months in which he is able to beat the market) can be due to chance. This conclusion is confirmed in the appendix by the average tests, that allow accepting that the average of Jensen's alphas is zero, and by the binomial test, that allows to accept a success of 50% of the probability rate.

TABLE 6 – Results of the first robustness test

YEAR	Number of months it beats the market	Accumulated average yield	% of success	Z-Test
2003	3	6.125	25%	
2004	8	4.755	67%	
2005	6	7.636	50%	
2006	9	18.351	75%	
2007	4	4.665	33%	
2008	8	4.789	67%	
2009	5	8.214	42%	
2010	9	5.501	75%	
2011	4	5.519	33%	
2012	5	6.946	42%	
2013	9	5.891	75%	
2014	5	5.166	42%	
2015	5	5.462	42%	
2016	4	5.655	33%	0.077

This table shows the results of a strategy according to which our hypothetical investor buys all undervalued shares in the market portfolio. Specifically, for each of the 12 years of our study we provide the number of months and the percentage in which the strategy outperforms the market strategy.

TABLE 7 – Results of the second robustness test

YEAR	Number of months it beats the market	Accumulated average yield	% of success	Z-Stat
2005	10	14.747	83%	
2006	11	22.395	92%	
2007	11	22.548	92%	
2008	12	24.699	100%	
2009	11	10.143	92%	
2010	12	22.980	100%	
2011	12	14.579	100%	
2012	12	12.029	100%	
2013	12	22.504	100%	
2014	12	13.232	100%	
2015	12	14.784	100%	
2016	12	14.509	100%	0.933

This table shows the results of a strategy according to which our hypothetical investor buys only the three most undervalued securities in the market portfolio. Specifically, for each of the 12 years of our study we provide the number of months and the percentage in which the strategy outperforms the market strategy.

In Table 7, where we present the results of the second robustness test, in which we only chose the three most undervalued securities to be part of the portfolio, we can observe that, for a range of 60 months, the market is beaten in 139 of the 144 months that were analysed in our study, which corresponds to 96%. Nevertheless, the *Z*-stat (under 1.96) confirms that the CAPM doesn't offer a strategy significantly better than investing in the market portfolio. In other words, we could say that the investor's success (in the months in which he is able to beat the market) can be due to chance.

6. CONCLUSIONS

The purpose of this study is to, through the usage of the CAPM, be able to beat or not beat the market and obtain extraordinary returns. To that end we created a strategy that consists in the undervalued securities according to the CAPM.

Through the proposed strategy we tested jointly the validity of the CAPM and of the Brazilian market efficiency. Thus, to confirm if the CAPM is complied with and if the market is efficient or if the CAPM is not complied with, without explaining the evolution of the securities and of the market, is not efficient. ´

The preliminary findings of our study indicate that the CAPM is valid, which implies the efficiency of the Brazilian market. These data were confirmed by the robustness tests, which proves that the conclusions derived from the results don't depend on the considered in-sample period, or on the considered undervalued securities.

Consequently, by not being able to beat the market through the adoption of our strategy, which was confirmed by the robustness tests, two implications follow: the first one is the confirmation of the validity of the CAPM and the second one is the confirmation of the Brazilian market efficiency.

The implications of this study are important for the investors: the strategies can be fully replicated, since the basic information uses closing prices and is fully available. And for the scholars: the confirmation that the Brazilian market is efficient.

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