DETERMINANTS OF VOLATILITY CHANGES

Leverage, Buybacks and Interest Rates Effects

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Abstract

This paper studies the relation between equity volatility and numerous firm characteristics. It is proven, through the stock returns and a measure of leverage, that an increase in the Debt to Equity ratio raises the equity volatility, which is known as the Leverage Effect. Relying on this effect, it is demonstrated that buybacks have a positive impact on stock return volatility. In addition, this paper concludes that interest rates have a negative effect on the stock return volatility, and that this effect is stronger for financial firms.

1. Introduction

Understanding the equity or stock volatility behavior has played a transcendental role in the academic work in finance, mainly explained by the relevance for firms and investors in this matter. For the former to plan the optimal capital structure, and for the latter to invest accordingly to his risk aversion. A better knowledge of the stock volatility is traduced in higher participation level from both parties, which is crucial for the development of capital markets. In order to so, it is necessary to determine what has an influence on it. Nelson (1996) lists five main factors for volatility: serial correlation, trading and non-trading days, recessions and financial crisis, leverage, and interest rates. The last two are classified as the long-term factors (Daly, 2011), and are the focus of this research.

Black (1976) stated that when stock prices decline, the Debt to Equity ratio increases, raising the financial risk of the firm, which leads to a higher equity – return volatility. He called it “The Leverage Effect”. Nowadays it is part of the common knowledge in capital markets. This effect has been confirmed by Christie (1982) and Cheung and Ng (1992). After the seminal work

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of Black (1976), Christie (1982) was the first one to truly assess the relationship between variance and stock price. He found an average relation of -0.23 between volatility and stock return that was attributable to financial leverage. Cheung and Ng (1992) also confirmed the leverage effect even controlling for bid-ask spreads and trading volume. In addition, Cheung and Ng found a stronger effect for small firms.

However, several academic works have shown some special characteristics of this effect, and even tried to offer alternative explanations for it. Nelson (1991) established an asymmetric effect in the change of volatility between upwards and downwards movements in stocks, meaning that the volatility declines in a bigger proportion from a positive return that what it climbs from a negative return. Figlewski and Wang (2000) stated that only changes in the stock price have an effect but not the change in outstanding shares or debt. Hasanhodzic and Lo (2011) found similar responses between all-equity-financed and debt-financed firms in the stock volatility from changes in the stock price, concluding that the leverage effect is not due to leverage but to human cognitive perceptions of risk. Still, they could not provide a clear alternative to the leverage effect, yet they claim some misleading perceptions of risk from recent experiences that affect the investor behavior. Nevertheless, at the end, no matter what the source of explanations are, there is a settlement in the literature that the Leverage effect should exist (Ait-Sahalia, Fan and Li, 2013)

On the basis of the Leverage Effect, changes in the outstanding shares must have an effect on the stock return volatility since these changes modify the financial structure of the firm and the risk on Equity. One way to do it is through Buybacks programs or share repurchases. Buybacks have become so common in the last years, as in those previous to the financial crisis in 2008, up to the point that the S&P 500 companies spent on them 33% of their cash flow in 2013[2]. Vermaelen (2005) defines the buybacks as a microcosm of the corporate finance that mixes an investment and payout decision, with the capital and ownership structure. Hence, the impact of these programs on the risk of the firm and, in consequence, the stock's firm is irrefutable.

The buybacks produce two different effects: one, it reduces the outstanding shares, which increases the leverage of the firm as the value of equity declines with respect to the debt (this effect is the focus of this research). And second, it might limit the investment opportunities for the firm. These two consequences of the buybacks raise the risk in the firm's equity. In this paper, through the effect of the outstanding shares, and consequently in leverage, it is going to be assessed the hypothesis that buyback programs increase the stock return volatility. In this process, and using the theoretical model develop in Section 2, the Leverage Effect is going to be tested, using the stock return's as it was made by Christie (1982), Duffee (1995), Cheung and Ng (1992) but also directly by the leverage, following the procedure from Figlewski and Wang (2000).

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[2] "The repurchase revolution". The economist. September 13th 2014. New York. Third paragraph.

The second determinant to assess is the Interest Rate Effect. On one side, Fama and Schwert (1977) and Christie (1982) found a positive relationship between volatility and interest rates. The former found that stocks have a negative performance from expected and unexpected inflation; while the latter concluded that debt and equity values decline with interest rates hikes but equity suffers more, which upturns the financial leverage of the firm. However, on the other side, the claim model developed by Black and Scholes (1973) and the pricing theory for corporate debt established by Merton (1974), indicate a positive relationship between the value of equity and the interest rates. From Merton's model, it is possible to see that Equity is a residual claim on the value of the firm after the promised payment of the Debt. If the value of Debt depends negatively on the interest rates - as it is suggested by Merton -, then the opposite must occur with the value of Equity: it must have a positive relationship with the interest rates. Consequently, as the value of Equity increases with the interest rates, the leverage declines, implying a decrease in the stock return volatility.

Supporting the response from interest rates in Merton's model, there is some recent evidence that shows how low-interest rates are increasing the risk of equity. Ma (2016) established that nonfinancial corporations are acting as cross-market arbitrageurs in their own securities, meaning that depending on relative valuations they issue debt to repurchase shares, or vice versa. This suggests that low-interest rates might be enough incentive to increase the leverage of the firm. However, this increase in leverage is not to invest in new projects to expand the firm or to improve the revenues, is to buy-back shares that, as was mentioned before, should increase the stock return volatility. Standing for the financing of the payout policy, Farre-Mensa, Michaely and Schmalz (2015) stated that 33% of the aggregate discretionary payout is being simultaneously financed by debt issuing. In such a way, the hypothesis to assess in this paper is that an increase in the interest rates, due to less leverage, causes a decline in the stock return volatility. A deeper analysis of Merton's model is evaluated in Section 2, with some extended interpretation of the recent evidence found by Ma (2016) and Farre-Mensa, Michaely and Schmalz (2015).

The model developed at Section 2 jointly with the analysis of Merton's model, provides numerous tested regressions for Leverage, Buybacks and Interest Rates Effects. The empirical results of these can be found at Section 4, which are based on the data described in Section 3. The results at Section 4 corroborate the Leverage Effect stated by Black (1976) but with stronger results to those established by previous academics, and closer to those developed at the theory in Section 2. Also, it is shown that the Buybacks indeed increase the stock volatility as it was indicated in the hypothesis. For the Interest Rate Effect, it is negatively correlated with the stock volatility as the residual claim model suggested. In addition, it is shown that for financial firms, the Interest Rate Effect is stronger than for the non-financial since the revenue of them depends positively on the interest rates. Finally, the last section covers the main results and concluding comments.

2. Volatility, Leverage and Interest Rates

2.1 Leverage

Consider a firm in Modigliani-Miller world where the debt is risk-free[3]. The value of the firm is

$$V = E + D \tag{1}$$

Where V, E and D, are the total firm value, equity, and debt, respectively. Equity is defined as $E = NS$, where N is the number of outstanding shares and S is the current market price of the stock. If the debt is risk free, all the risk is absorb by the equity. This means that any change in the firm's value is taken through the equity.

Assume first that the outstanding shares do not change. Under this assumption, the change in the value of equity is just proportional to the change in the stock price, but since equity absorbs the change of the firm's value:

$$\frac{\Delta S}{S} = \frac{\Delta V}{V}\frac{V}{E} \tag{2}$$

Recalling (1), the percentage change in the stock price depends on the change of the firm's value and its leverage L, defined as (1+D/E)

$$\frac{\Delta S}{S} = \frac{\Delta V}{V}L \tag{3}$$

This means that the higher is the leverage, higher would be the movements in the stock price. Traducing this into volatility we find that:

$$\sigma_s = \sigma_V L \tag{4}$$

Where σ_s and σ_V are the stock and firm volatilities, respectively. Now, to evaluate how the change in equity affects the stock's volatility that is the elasticity of the equity's volatility (θ_S):

$$\theta_E = \theta_S = \frac{\frac{\partial \sigma_S}{\sigma_S}}{\frac{\partial S}{S}} = \frac{\partial \sigma_S}{\partial S}\frac{S}{\sigma_S} = -\frac{D/_E}{\left(1 + D/_E\right)} = -\frac{D}{D + E} \tag{5}$$

[3] According to our sample, which is based in large capitalization companies that have survived for 16 years, including the financial crisis in 2008 is a reasonable assumption.

Further, by this simple model can be shown that there is a negative relationship between volatility and the value of equity. It is also important to calculate the elasticity with respect to leverage (θ_L):

$$\theta_L = \frac{\frac{\partial \sigma_S}{\sigma_S}}{\frac{\partial L}{L}} = \frac{\partial \sigma_S}{\partial L}\frac{L}{\sigma_S} = \sigma_V \frac{L}{\sigma_S} = 1 \tag{6}$$

This implies that the stock volatility is explained completely by the change in leverage. However, it is not consistent with previous empirical results (Cheung and Ng ,1992; Christie, 1982; Figlewski and Wang, 2000). Thus, it is possible that the volatility of the firm changes with the value of the firm, implying that there are second momentum variables affecting equity´s volatility. Relaxing the assumption that the number of outstanding shares does not change, from (3) the stock volatility would be

$$\sigma_s = \sigma_V(1 + \frac{D}{NS}) \tag{7}$$

Evaluating the elasticity of equity volatility with respect to the outstanding shares (θ_N):

$$\theta_N = \frac{\frac{\partial \sigma_S}{\sigma_S}}{\frac{\partial N}{N}} = \frac{\partial \sigma_S}{\partial N}\frac{N}{\sigma_S} = -\frac{D}{(D+E)} \tag{8}$$

Under this result, a decrease in the outstanding shares should have a positive impact on equity´s volatility. Thus, a buyback program of shares, that decreases the outstanding shares, should have a positive impact on equity´s volatility. Therefore, the elasticity of stock volatility with respect to shares repurchasing must be positive but probably in a smaller quantity than θ_N because share repurchase only explains part of the change in the outstanding shares[4]. Because of this, to evaluate the elasticity with respect to share repurchases, is necessary to do it relatively to the total outstanding shares N. The ratio of repurchased shares over outstanding shares (RS/N) is then implemented to assess the elasticity of stock volatility with respect to buybacks programs θ_{BB}.

The result in (8) is equal to the one obtained in (5), meaning that the effect in the stock's volatility from a change in the stock price S or in the outstanding shares N must be the same. In addition, both effects are stronger depending on how large is the ratio $D/(D+E)$ as it is shown in equations (5) and (8). For example, if a firm has this ratio higher than another firm (*ceteris*

[4] A company can issue new shares to cover Employee Stock Options programs or because of capital needs, but also it can increase the outstanding shares by moving treasuries stocks back to the market; all at the same time with a buyback program.

paribus), then its stock volatility will be greater for changes in the outstanding shares or in the stock price. Hence, θ_{BB} and θ_S must be conditional to the size of $D/(D+E)$.

The data available to assess previous results comes from DataStream for the stock prices, returns and volatilities; and from Compustat for the firm-specific data. In order to evaluate both elasticities with respect to the buybacks θ_{BB} and to the stock price θ_S, is necessary to obtain for each firm the repurchased and outstanding shares, and the value of Debt and Equity. Compustat reports the repurchased and outstanding shares per quarter, from where is possible to obtain the Buyback Ratio that is defined as the shares repurchased at period *t* over the outstanding shares at *t-1* for each firm *i* ($RS_{i,t}/N_{i,t-1}$). The outstanding shares per firm obtained from Compustat are multiplied by the stock price acquired from DataStream; to get the market value of Equity. However, for the value of Debt, Compustat only has available the face value. Consequently, as it is not possible to obtain the market value of Debt, the ratio to test both elasticities will be the "quasi" Debt/Assets ratio (QDA), where Debt is the face value of debt and Assets is the sum of Debt´s face value and the market value of Equity (*D*+*E*).

Finally, the three elasticities to assess are:

1. Elasticity of stock volatility with respect to leverage θ_L, where leverage is define as (1+*D/E*), *D* as the face value of Debt and *E* as the Equity´s market value. The estimated version of this elasticity, expressed at equation (6) is defined as follow:

$$\Delta Ln\ \sigma_{S_{i,t}} = \beta_0 + \beta_1 \Delta Ln\ L_{i,t} + \varepsilon_{i,t} \tag{9}$$

   Where $\Delta Ln\ \sigma_{S_{i,t}}$ is the first difference of the natural logarithm of the stock volatility for the firm *i* between time *t* and *t-1*: $(Ln\ \sigma_{S_{i,t}} - Ln\ \sigma_{S_{i,t-1}})$, and $\Delta Ln\ L_{i,t}$ is the first difference of the natural logarithm of leverage for the firm *i* between time *t* and *t-1*: $(Ln\ L_{i,t} - Ln\ L_{i,t-1})$. According to equation (6) the hypothesis to assess is $\beta_1 = 1$.

2. Elasticity of stock volatility with respect to the stock price θ_S. Equation (5) shows the estimates for this elasticity where the resulting variables were previously defined. The model is defined as follow:

$$\Delta Ln\ \sigma_{S_{i,t}} = \beta_0 + \beta_1 (QDA_{i,t} * \Delta Ln\ S_{i,t}) + \varepsilon_{i,t} \tag{10}$$

   Where $\Delta Ln\ \sigma_{S_{i,t}}$ is the first difference of the natural logarithm of the stock volatility for the firm *i* between time *t* and *t-1*: $(Ln\ \sigma_{S_{i,t}} - Ln\ \sigma_{S_{i,t-1}})$; $\Delta Ln\ S_{i,t}$ is the first difference of the natural logarithm of the stock price for the firm *i* between time *t* and *t-1:* $(\ln S_{i,t} - \ln S_{i,t-1})$, and $QDA_{i,t}$, which is the Quasi Debt/Assets ratio form the firm *i* at time *t*. According to equation (5) the hypothesis to assess is $\beta_1 = -1$.

3. Elasticity of stock volatility with respect to the Buyback ratio θ_{BB}. From equation (8) and the variables previously defined, the model to assess this elasticity is as follow:

$$\Delta Ln\ \sigma_{S_{i,t}} = \beta_0 + \beta_1 (QDA_{i,t} * BBR_{i,t}) + \varepsilon_{i,t} \tag{11}$$

Where $\Delta Ln\ \sigma_{S_{i,t}}$ is the first difference of the natural logarithm of the stock volatility for the firm *i* between time *t* and *t-1*: $(Ln\ \sigma_{S_{i,t}} - Ln\ \sigma_{S_{i,t-1}})$; $BBR_{i,t}$ is the Buyback Ratio that is the repurchased shares at period *t* $(RS_{i,t})$ over the outstanding shares at *t-1* $(N_{i,t-1})$ for each firm *i*; and $QDA_{i,t}$ is the Quasi Debt/Assets ratio form the firm *i* at time *t*. The hypothesis to asses following equation (8) is $\beta_1 > 0$.

In order to capture the true effects of the leverage, price[5], and buybacks in the stock volatility, is necessary to control by the market volatility. As the sample comprehends only S&P 500 firms, the variable to control for is the Volatility Index (VIX) constructed by the Chicago Board Options Exchange (CBOE). However, the change in market volatility already captures part of the change in leverage, implying an *over-controlled* that might dilute the true impact of the variables previously mentioned. For this reason and toward a comparison with the results of Black (1976), Christie (1982), Duffee (1995) and Cheung and Ng (1992), the effects are also going to be estimated without the VIX. Furthermore, eq. (9) to (11) are also evaluated by levels.

2.2 Interest Rates

It can be seen from the previous section that the firm has two concrete claimants: equity and debt holders. Suppose that the firm has a debt repayment at maturity T called *B*. Relaxing the assumption that debt is risk-free, debt holders have a senior claim over the firm, meaning that in case of default debt holders can take control of the firm *V*, and if not, they reclaim *B*. Default can occur if at maturity T, $V \leq B$. If the opposite occurs ($V > B$), equity holders pay *B* to the debt holders and reclaim the remaining value $V - B$. This can be expressed by the following formulas:

$$Debt = \min\{B, V\} \tag{12}$$

$$Equity = \max\{\mathrm{V} - B, 0\} \tag{13}$$

[5] From this point, the Leverage Effect is divided in two: the Leverage effect that is from the change in Leverage – as Figlewski and Wang (2000) did it -, and the Price effect that comes from a change in the stock price, which is the approach used by Black (1976), Christie (1982), Duffee (1995), Cheung and Ng (1992).

From the seminal work of Black and Scholes (1973), Merton extended their work in option pricing to a pricing theory of corporate debt (Merton, 1974). Following Black and Scholes lines, Merton found a parabolic partial differential equation where any security that depends on the firm value and time can be described. Together with the boundary conditions of nonnegative values for equity or debt, and the limit on debt value ($D \leq V$); was able to find an identical equation for a European call option on a non-dividend paying stock to that one established by Black and Scholes. The Black-Scholes-Merton formula for Equity is then

$$E = VN(d_1) - Be^{-rT}N(d_2) \tag{14}$$

Where *N (.)* is the cumulative normal distribution, *r* is the interest rate and

$$d_1 = \frac{Ln\left(\frac{V}{B}\right)+\left(r+\frac{\sigma_V^2}{2}\right)T}{\sigma_V\sqrt{T}} \quad \text{And} \quad d_2 = d_1 - \sigma_V\sqrt{T}$$

With σ_V as the firm´s volatility that is assumed to be constant. In this way, equity is a call option on the firm's value minus the promised payment of the debt at time *T* as the strike price, which is the value now at time *t*.

From (1) and (14), it is also possible to write the value of the debt[6], which is a function that depends positively on the value of the firm (*V*) and the repayment of debt at maturity *B*; and negatively on the firm´s volatility, the time to maturity and the interest rate. Therefore, since equity is a residual claim of the firm's value, equity must increase with the interest rate[7]. This can also be shown from how a European call reacts to changes in the interest rate to maturity *R*, known as Rho.

$$Rho = \frac{\partial E}{\partial R} = Be^{-R}N(d_2) \tag{15}$$

Since Rho is positive, equity is an increasing function of the interest rates. Nevertheless, the second derivative of equity with respect to the interest rate is negative, which implies that it is a convex function. Hence, the interest rate has a positive effect on equity but at a decreasing rate[8]. Consequently, with these results, an increase in the interest rates would reduce leverage as debt decreases and equity improves; implying that the stock volatility depends negatively on the interest rates.

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[6] See Merton (1974).

[7] It is important to clarify that as is a claim at maturity *T*, the interest rate should also be to maturity, thus the interest rate to evaluate is $R = rT$

[8] Figure 1 at the appendix shows a simulation for different levels of Debt/Equity Ratios of how equity is affected by changes in the interest rates to maturity.

However, this result is not consistent with the findings of Fama and Schwert (1977), who established that equity returns have a negative relation with the expected component of the inflation rate (interest rate). Still, they could not provide the economic origins of this result rather than a possible market's inefficiency in transmitting inflation expectations into stock prices. Hull (2014, p. 237) also suggested that in practice stock returns and interest rates have a negative relation and, in addition, that the previous result expressed by Rho can only work if the stock price does not change – in this case, the value of the firm *V*. Supporting these results, Christie (1982) also found a strong positive relationship between interest rates and equity volatility, despite the opposing predictions of option pricing.

Against these previous empirical results (without an economic explanation) and supporting the results for Merton's model, Ma (2016) and Farre-Mensa, Michaely and Schmalz (2015) showed how low-interest rates can motivate firms to increase their leverage, and consequently their stock's volatility. Ma (2016) found that companies issue and repurchase in both markets (debt and equity) according to relative valuations. For example, low expected returns for debt (low-interest rates) increases the net equity repurchases that lead to a rise in leverage. In fact, Ma (2016) exhibited a strong positive relation between net equity repurchases and the net debt issuance relative to the value of assets of 0.5. These results are related with those established by Farre-Mensa, Michaely and Schmalz (2015), who found that most of the capital payouts are financed (in average, firms are not using their cash) and most of them by debt issuance, indicating also that its key driver is the desire for more leverage (mainly explained by tax compensations and agency problems). If the firm not only repurchases its own stock - decreasing N - but also issues debt to do that, the change in leverage is larger, which at the end indicates that low-interest rates are leading to a higher stock volatility.

Fama and Schwert (1977) and Christie (1982) were not able to capture this phenomenon because share repurchases programs became popular after the adoption of the SEC rule 10b-18 in 1982, where the SEC set the rules for open market repurchases without incurring in a market manipulation. Vermaelen (2005) showed how the share repurchases announcements increased from an average of 30 per year before 1980, to its highest point in 1998 of 1420 announcements in that year, just in the US. Nick (2016) precisely plots the shift in the correlation between interest rates (10-year Treasury) and stocks (S&P 500 Index) from negative to positive, being the late nineties the inflexion point.

In conclusion, following the results from Merton´s model and the evidence presented by Ma (2016) and Farre-Mensa, Michaely and Schmalz (2015), it is expected that interest rates have a negative impact on the stock volatility. Controlling by the leverage effect mentioned in the previous section, the model to assess the effect of the interest rates in the stock volatility is:

$$\Delta Ln\ \sigma_{S_{i,t}} = \beta_0 + \beta_1 \Delta Ln\ L_{i,t} + \beta_2 \Delta R_t + \varepsilon_{i,t} \tag{16}$$

Where $\Delta Ln\ \sigma_{S_{i,t}}$ and $\Delta Ln\ L_{i,t}$ are already defined in equation (9), and ΔR_t is the first difference of the constant 10-Year constant maturity rate between time t and *t-1:*$(R_t - R_{t-1})$, where the rates are obtained from the Federal Reserve Data Base (FRED); and the hypothesis to evaluate in this model, according to the previous analysis, is that $\beta_2 < 0$, meaning that the interest rates are negatively related to the stock volatility. As well as with equations (9) to (11), eq. (16) is also controlled by the market volatility through the VIX, with the foresight that it can over-controlled the regressions, undermining the results.

3. Data

Four data sources are used in this study: market data from DataStream (Thomson Reuters) and the Chicago Board Options Exchange (CBOE), firm specifics from Compustat, and the interest rates from the Federal Reserve. The price per share and volume of shares traded are acquired from DataStream on a daily basis. The prices are corrected for splits. This data is used to calculate quarterly returns and volatility. Volatility is estimated as the standard deviation of the opened market days per quarter and annualized multiplying it by the square root of 252. The Volatility Index for the S&P500 (VIX) is obtained from the Chicago Board Options Exchange on a quarterly basis.

The Compustat file is obtained on a quarterly basis. From this database, is taken the outstanding shares, long and current liabilities, shares repurchased and the average repurchase price per quarter, and some other balance sheet variables. Debt is defined as the sum of current and long-term liabilities.

The interest rates are the 10-Year Constant Maturity Rate (10Y CMR) acquired from the Federal Reserve Data Base (FRED). The time span is 16 years, from January 2001 to December 2016 which corresponds to 64 quarters per firm. The companies used are those that survived during the time span and are part of the S&P 500 by the end of 2016. Therefore, there might be some survival bias, however, it deletes the extreme cases for companies with probably the highest leverage and consequently, the highest sensibility to interest rates. This implies that the results might have negative skewness in terms of volatility[9]. In addition, only companies with fiscal year ending in December were taken into account. The final sample corresponds to 205 firms.

Table 1 gives the summary statistics for the most relevant variables of the data set, covering all the sample period. The data covers 64 quarterly observations for each of the 205 firms including market data, firm-specific variables, and the 10-year constant maturity rate. The mean firm has a face value of debt of \$13.1 billion and an equity market value of \$39.6 billion. The high standard deviation - more than the double of the mean - shows the variation across firms in terms of the face value of debt, equity market value, and cash and short-term investments. In addition, the

[9] Stocks of bankrupted companies must experience extremely high volatility before that event as the leverage approaches to infinite.

difference between the percentile 75 and the standard deviation in leverage and the quasi D/A ratio, gives an idea of the difference in size among firms on the right side of the distribution. The low level in the percentile 25 of the quasi D/A ratio suggests there are a few companies that are mainly financed by equity.

The Buyback Ratio is defined as the shares repurchased in one-quarter over the total outstanding shares at the end of the previous quarter. The Buyback ratio registers most of the values between 0 and 1% as it is shown through the percentiles, however, the high value of its standard deviation suggests strong buybacks at some specific quarters for some companies. Therefore, the percentiles 25 and 50 display that most of the firms buy shares in small quantities (relative to the total outstanding shares) or they do not have a buyback program.

Table 1

Summary Statistics

This table displays descriptive statistics for the variables used in the analysis, such as number of observations, mean or simple average, standard deviation, percentile 25, percentile 50 or median, and percentile 75. The variables Face Value (FV) of Debt, Market Value (MV) of Equity, and Cash and Short-term Investments are measured in millions of dollars; while Buyback Ratio, Volatility and Interest Rate are expressed in percentage. Leverage is defined as the sum of Debt (FV) and Equity (MV), over the MV of Equity. Quasi D/A Ratio corresponds to Debt (FV) over the sum of Debt (FV) and Equity (MV). Buyback Ratio is defined as the shares repurchased in one-quarter over the total outstanding shares at the end of the previous quarter. Volatility is the annualized standard deviation of the opened market days per quarter. Interest Rare corresponds to the 10-year Constant Maturity Rate (CMR) at the end of each quarter.

Variables	Number of Observations	Mean	Std.	Percentile 25	Percentile 50	Percentile 75
Face Value of Debt	13.120	13.100,1	23.583,4	1.488,1	5.376,6	14.521,0
Market Value of Equity	13.120	39.605,0	122.312,6	6.735,8	14.917,5	32.465,2
Leverage	13.120	1,73	1,45	1,13	1,39	1,83
Quasi D/A Ratio	13.120	0,30	0,23	0,12	0,28	0,45
Buyback Ratio (%)	13.120	0,60	1,25	0,00	0,03	0,87
Cash & Short Term Investments	13.120	9.433,4	42.758,4	397,9	1.358,0	4.012,0
Volatility (%)	13.120	28,92	19,28	18,03	23,89	33,15
10-Year CMR (%)	13.120	3,51	1,05	2,49	3,55	4,47

Finally, in concordance with the heterogeneity of all the previous variables, the volatility also displays a non-symmetrical distribution with positive skew, with the mean higher than the median. In addition, the relative proximity between the percentiles 75 at the mean also suggests extreme positive values. The average stock has a volatility of 28.92% (Volatility is the annualised standard deviation of the daily returns over a quarter). By last, the 10-Year Constant Maturity Rate (CMR) also shows a more symmetrical distribution, with most of its observations between 2.5% and 4.5%. It is assumed that the interest rate (or CMR) varies along time but not by firm.

4. Empirical Results

In Section 2, it was shown how leverage, prices, buybacks, and interest rates affect the stock return volatility. Now, in this section, several regressions are estimated to assess those effects. At section 4.1 the Leverage Effect is tested through the leverage itself and the stock price, in addition to the Buyback Effects, according to equations (9) to (11). In the same way, the Interest Rate Effect expressed by equation (16) is assessed at section 4.2. Following this, at section 4.3, a comparison between the complete and the non-financial sample is made, since leverage and interest rates have different effects for financial and non-financial firms. Finally, at section 4.4, as a robustness check, the three effects are estimated again but this time in levels.

4.1 Leverage, Price and Buyback Effects

The Leverage Effect

The first hypothesis to evaluate is that an increase in the firm's leverage leads to an increase, in the same proportion, in the stock return volatility as it was developed at equation (6). The results for panel data regressions to assess this hypothesis through the model expressed by equation (9) are in Table 2. The test for possible heteroscedasticity was significant[10]. For that reason, regressions (1) and (2) in Table 2 are estimated using robust standard errors (also known as White estimators). In addition, clustering by firm was also implemented for possible correlation across firms, however, the results from Table 2 did not change, whereby those results are not presented. Besides this reason, clustering by firm did not contribute to more accurate estimates of the standard errors for the following effects in the next subsections. Some possible time effects such as business cycles must be captured by the constant.

The two regressions presented in Table 2 are implemented using First-Differences (FD), where regression (1) includes a control for market's volatility (measured by the first difference of the natural logarithm of the VIX). For both regressions, the elasticity β_1 is significantly different from zero at the 1% level. However, the estimates result to be different from 1 at 1% confidence level[11]. Nevertheless, at regression (2), which does not control for market's volatility, the elasticity is 0.831, meaning that an increase of 1% in leverage causes an increase of 0.83% in the stock return volatility. The result approaches substantially to the one found at the model in Section 2, which is consistent with the theory established by Black (1976), representing an improvement from previous works, as in the case of Figlewski and Wang (2000) who found an average elasticity of 0,38 for their whole sample.

[10] The test is performed manually. The variance of the errors at the regressions of equation (9) is explained by the first difference of the natural logarithm of leverage (the independent variable), at the 1% level (*t-statistic*: 8.41).

[11] The test is applied for regression (2). Null hypothesis: β_1=1. *P-value:* 0.002

Table 2

The Leverage Effect: Regression Results

This table presents results for Pooled OLS Panel Data regressions for stock return volatility on leverage. The results correspond to the first-difference (FD) estimator with robust standard errors. The dependent and independent variables are the first difference of the natural logarithm of the stock return volatility, and leverage, respectively, as it is shown in the equation below. Regression (1) is controlled by the change in market's volatility (measured by the natural logarithm of the VIX). Leverage has been previously defined. Standard errors are reported in small font size below the estimates and the significance is defined by stars according to: 3 stars for statistical significance at the level 1%, 2 stars for 5% and 1 star for 10%. Likewise, the table presents R^2, the number of observations N, and the residuals.

$$\Delta Ln\ \sigma_{S_{i,t}} = \beta_0 + \beta_1 \Delta Ln\ L_{i,t} + \varepsilon_{i,t}$$

	First-Difference (FD) Estimator Robust Std. Err.	
	(1)	(2)
Δ Ln Leverage	0,432***	0,831***
	0,043	0,055
Δ Ln VIX	0,510***	
	0,009	
Constant	-0,003	-0,007**
	0,003	0,001
R^2	0,227	0,050
N	12915	12915
Residuals	0,294	0,326

However, after controlling by the market's volatility, the relevance of leverage is reduced almost by half (from 0.831 at (2) to 0.432 at eq. (1). This suggests that the market volatility is also playing an important role in the stock volatility. Measured by the VIX, it might explain half of the change in the stock return volatility, close to having the same relevance of the leverage effect. One possible way to enlarge the significance of this result is to use the market value of debt, which unfortunately is not available. The relatively low *r-squares* (22.7% and 5%) suggest that there might be more variables explaining the change in volatility. The constant turns to be not significant, suggesting the absence of time invariant effects when it is controlled by the market's volatility.

The Price Effect

From equation (5) it is obtained the second hypothesis to test: an increase in the stock price leads to a decrease in the stock return volatility, which is proportional to the $D/(D+E)$ ratio that in this case is evaluated through the Quasi Debt/Assets ratio (QDA) explained before. Table 3 registers the results for this Price Effect hypothesis through the regressions driven by equation (10). Likewise the previous case, the test for heteroscedasticity was significant[12], consequently, at

[12] The test is performed manually. The variance of the errors at the regressions of equation (10) is explained by the first difference of the natural logarithm of price times the Quasi Debt/Assets ratio, at the 1% level (*t-statistic*: -6.6).

regressions (1) and (2), Huber/White robust standard errors are implemented. In addition, both regressions were also estimated using clusters by firm for some possible correlation between the prices across firms, but the standard errors did not improve. For that reason, those results are not presented. As in the previous case, some possible time effects from business cycles are capture by the constant.

Table 3

The Price Effect: Regression Results

This table presents results for Pooled OLS Panel Data regressions for stock return volatility on stock price in interaction with "quasi" Debt/Assets Ratio (QDA). The results correspond to the first-difference (FD) estimator with robust standard errors. The dependent variable is the first difference of the natural logarithm of the stock return volatility. The independent variable is the first difference of the natural logarithm of the stock price multiplied the Quasi D/A Ratio (QDA). Regression (1) is controlled by the change in market's volatility (measured by the natural logarithm of the VIX). The equation below shows the executed regression. Quasi D/A Ratio has been previously defined. Standard errors are reported in small font size below the estimates and the significance is defined by stars according to: 3 stars for statistical significance at the level 1%, 2 stars for 5% and 1 star for 10%. Likewise, the table presents R^2, the number of observations N, and the residuals.

$$\Delta Ln\,\sigma_{S_{i,t}} = \beta_0 + \beta_1(QDA_{i,t} * \Delta Ln\,S_{i,t}) + \varepsilon_{i,t}$$

	First-Difference (FD) Estimator Robust Std. Err.	
	(1)	(2)
QDA *Δ Ln Price	-0,726***	-1,340***
	0,056	0,066
Δ Ln VIX	0,487***	
	0,010	
Constant	-0,002	-0,006**
	0,003	0,003
R^2	0,236	0,081
N	12915	12915
Residuals	0,292	0,320

The same type of regressions as in Table 2 are estimated in this case, however, there is an interaction between the change in price and the quasi D/A ratio (QDA) in order to assess the results from equation (5). At both regressions, the elasticity β_1 result to be different from -1 at 1% confidence level[13], however it has the expected sign and is significantly different from zero at the 1% confidence level. The coefficient has the expected sign according to the hypothesis explained before, implying that an increase in the stock price indeed reduces the stock return volatility.

The result at regression (2), that is comparable to those estimated by Christie (1982), Cheung and Ng (1992), Duffee (1995), Figlewski and Wang (2000) - since they do not control for the market volatility - establishes an elasticity of -1.340 while they found coefficientes that are from -0.06 in the case of Cheung and Ng (1992) until -0.73 for Duffee (1995). This closer result

[13] Null hypothesis: β_1=-1. Regression (1): *P-value*: 23.95. Regression (2): *P-value*: 26.86.

to the one predicted by Black (1976) determines that The Leverage Effect, estimated from the leverage itself or by the stock price, is still present. Moreover, the result, in this case, is even higher than one (in absolute terms), implying an over reaction from changes in the stock price. Indeed, it is more than proportional to the QDA, which suggests that there might be some extra effect in the volatility from changes in the prices. It might be possible that changes in the stock price send some kind of signal to the agents that extra affects the volatility.

Controlling by the change in market's volatility (regression 1) the elasticity drops to -0.72, indicating that the market volatility is explaining part of the change suggested at regression (2). The result is coherent with the significance of the constant at (2), which might not only be capturing time invariant effects. Therefore, an increase in 1% in the stock price, leaving QDA constant, leads to a decrease of 0.726% in the stock volatility. The *r-squared* remains close to the 20%, mainly driven by the inclusion of the VIX that increases the measure from 8.1% at regression (2).

The Buyback Effect

The last outcome to assess in this section is the Buyback effect. As it is expressed by equation (8), an increase in the outstanding shares causes a decline in the stock volatility. However, because this study mainly focuses on the impact of buybacks programs on volatility, the hypothesis to test changes as share repurchasing decreases the outstanding shares, hence: an increase in buybacks or shares repurchased relative to the outstanding shares (Buyback Ratio), drives to an increase in the stock return volatility. Consequently, with the results on equation (8), the Buyback effect also remains proportional to the $D/(D+E)$ ratio but with a positive sign as it was mentioned before. Table 4 shows the results for the Buyback Effect hypothesis driven by equation (11).

As well as with the Leverage and Price effects, a test for possible heteroscedasticity was conducted, however, in this case, it is not significant[14]. For that reason, it is not necessary to implement Huber/White robust standard errors. Additionally, the repurchase of shares is not continuous by firm or time, and there is not an intuitive invariant effect, meaning that clustering by firm is not necessary.

Following the same kind of regressions as in previous results, it is possible to conclude that the Buyback hypothesis is correct: an increase in the buyback ratio causes a rise in the stock return volatility at the 1% confidence level. From the results in Table 4 regression (2), an increase of 1% in the Buyback ratio drives to an increase of 4.508% in the stock return volatility (for a given QDA). It is important to notice that an increase of 1% in the Buyback Ratio represents a movement of one standard deviation (See Table 1), which might explain the high impact in the stock volatility.

[14] The test is performed manually. The Buyback ratio (Repurchased shares/Outstanding Shares) times the Quasi Debt/Assets ratio does not explain (at the 10% level: *t-statistic*: -1.35) the variance of the errors at the regression of equation (11).

Table 4

The Buyback effect: Regression results

This table presents results for Pooled OLS Panel Data regressions for stock return volatility on the Buyback Ratio (BBR) in interaction with "quasi" Debt/Assets Ratio (QDA). The results correspond to the first-difference (FD) estimator. The dependent variable is the first difference of the natural logarithm of the stock return volatility. The independent variable is the interaction between the Buyback Ratio (BBR), which is defined as the shares repurchased at period *t* over the outstanding shares at *t-1* for each firm *i* ($RS_{i,t}/N_{i,t-1}$); and the Quasi D/A Ratio (QDA), which has been previously defined. Regression (1) is controlled by the change (first difference) in market's volatility (measured by the natural logarithm of the VIX). The equation below shows the executed regression. Standard errors are reported in small font size below the estimates and the significance is defined by stars according to: 3 stars for statistical significance at the level 1%, 2 stars for 5% and 1 star for 10%. Likewise, the table presents R^2, the number of observations N, and the residuals.

$$\Delta Ln\ \sigma_{S_{i,t}} = \beta_0 + \beta_1(QDA_{i,t} * BBR_{i,t}) + \varepsilon_{i,t}$$

	First-Difference (FD) Estimator	
	(1)	(2)
Buyback Ratio*QDA	2,636***	4,508***
	0,563	0,633
Δ Ln VIX	0,542***	
	0,009	
Constant	-0,008***	-0,018***
	0,003	0,003
R^2	0,216	0,004
N	12915	12915
Residuals	0,296	0,333

Even after controlling for the market's volatility at regression (1), the effect of buybacks in the stock return volatility is still strong (2.636) and significant at the 1% level. The low *r-squared*, when the regression is not controlled by the VIX, is consistent with the results from previous regressions and with the theory, as there are more factors to take into account in order to explain the change in volatility.

These results contradict, in some way, those obtained by Kim (2007) and Råsbrant (2011). Kim (2007) showed that volatility decreases thanks to active buyback trading, which is the most common way, mainly because firms repruchase shares when the share price falls, supporting the price and reducing the volatility. However, after the buyback is finished, the volatility comes back to the previous level. Even it seems opposite to the results from this paper, those results are not completely comparable since Kim's work is an event study with a 60 day window and the measure of volatility is through the bid-ask spread at the end of each day. Nevertheless, it might be possible that indeed there is a reduction in the stock volatility but just for a small period of time but, as Kim (2007) stated, it comes back to the previous level, and according to the results of this paper, it increases. In the same way, Råsbrant (2011) found a 2% abnormal return in the stock price after the announcement of a open market buyback program but it disappears rapidly through time. This support the evidence from Kim (2007) in the sense that there is some price effect that might reduce the volatility, however, once again, that effect seems to fade rapidly.

4.2 The Interest Rate Effect

According to the model developed in Section 2, the hypothesis to assess the Interest rate effect is: an increase in the interest rates (measured by the constant 10-Year to maturity rate: CMR) causes a decline in the stock return volatility. This hypothesis is developed through Merton's model as it can be seen from equations (14) and (15). The empirical model to evaluate this hypothesis is described at equation (16) and the results are presented in Table 5.

Table 5

The Interest Rate Effect: Regression results

This table presents results for Pooled OLS Panel Data regressions of stock return volatility on leverage and interest rates. The results correspond to the first-difference (FD) estimator with robust standard errors. The dependent variable is the first difference of the natural logarithm of the stock return volatility. The independent variables are the first difference of the natural logarithm of leverage, and the first difference in the interest rate. Regression (1) is controlled by the change in market's volatility (measured by the natural logarithm of the VIX). The 10-year constant maturity rate (10Y CMR) is used as a proxy for interest rates to maturity (R_t). The equation below shows the executed regression. Standard errors are reported in small font size below the estimates and the significance is defined by stars according to: 3 stars for statistical significance at the level 1%, 2 stars for 5% and 1 star for 10%. Likewise, the table presents R^2, the number of observations N, and the residuals.

$$\Delta Ln\ \sigma_{S_{i,t}} = \beta_0 + \beta_1 \Delta Ln\ L_{i,t} + \beta_2 \Delta R_t \ + \varepsilon_{i,t}$$

	First-Difference (FD) Estimator Robust Std. Err.	
	(1)	(2)
Δ Ln Leverage	0,416***	0,803***
	0,043	0,054
Δ 10Y CMR	-2,929***	-4,308***
	0,410	0,470
Δ Ln VIX	0,506***	
	0,009	
Constant	-0,004	-0,009***
	0,003	0,003
R^2	0,230	0,057
N	12915	12915
Residuals	0,293	0,325

Once again, a test for heteroscedasticity is estimated for the regression expressed by equation (16). The result shows heteroscedasticity in both variables (Leverage and 10Y CMR) at the 1% confidence level[15]. Therefore, at regressions in Table 5, White robust standard errors are implemented. In addition, as it is assumed that all firms are exposed to the same interest rate, there is no need of clustering by firm.

[15] The test is performed manually. The first differences of the natural logarithm of leverage and the 10Y CMR, are significant at the 1% level (respective *t-statistics*: 7.63, -2.62), in order to explain the variance of the errors at the regressions of equation (16).

Using First-Differences (FD) and taking into account the Leverage effect described in the previous section, the results are consistent with the Interest rate effect hypothesis explained at the beginning of this subsection. For both regressions estimated, the results show a negative impact on the stock volatility for an increase in the interest rates at the 1% confidence level. From regression (2) at Table 5, which does not control for the market's volatility, an increase of 1% in the interest rates (10Y Yield) drives a decrease in the stock return volatility of -4.308%.

Even though it seems from the regressions that the volatility is more sensitive to changes in the interest rates than for changes at leverage, it is important to notice that a one percent increase in the interest rates is almost equivalent to one standard deviation (See Table 1). While for Leverage, a 1% increase can be easily achieved, according to the sample's distribution. A similar case to the Buyback Effect explained in the previous subsection. In addition, the inclusion of the interest rates as an explanatory variable slightly improves the *r-squared* from 22% to 23% but it remains low, suggesting again that there are more variables explaining the stock volatility. The constant - that is capturing some time-invariant effects - remains insignificant as in Table 2 and 3, probably driven by the inclusion of VIX as a control variable. Also, it reduces the economic significance of the Leverage and Interest Rates, but they are still significant and with the expected sign.

This result contradicts the one obtained by Christie (1982), who actually found an average positive effect of the interest rates of 0.4 in the stock volatility. Also, this positive effect subtracted the statistical significance of Leverage in most of his results, which did not happen in the previous outcomes. It is important to note that Christie instead of using the rate to maturity, uses the riskless short term rate, which might have been a mistake evaluating the Equity since it is a residual claim on the value of the firm at *T*.

4.3 Non-financial firms

Up to this point, the sample has included financial firms[16], but for them, leverage and the effect of interest rate differ in comparison with non-financial. Leverage in financial firms is difficult to measure because, in the case of a bank (e.g.), which its first purpose is to attract money and lend it, deposits are at the same time an asset and a liability. Taking the definition of Leverage from section 2, $L = (1+D/E)$, this difficulty is then captured by the Debt D, that is the sum of current and long-term liabilities, where deposits are included in the current liabilities. Thus, if the deposits of a bank surge - which will also increase its assets - then its leverage will do the same since the raise in assets might not be fully taken by the value of Equity, or it usually takes some time to absorb the change. Therefore, the growth in leverage comes from a direct raise in assets, meaning that there is not an increase in the firm´s risk, thus the change in the stock volatility must be weaker for financial firms.

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[16] The sample comprehends 205 firms, where 40 firms are financial. Hence, the non-financial sample corresponds to 165 firms.

In terms of the Interest rate effect, it should be stronger for financial firms because higher interest rates give to the banks more space to increase their Net Interest Margin (NIM), which is the difference between the rate at which they attract money and the one that they lend. Higher the NIM, higher would be the revenue, leading to a stronger increase in the value of equity. Hence, there must be a stronger negative Interest rate effect for financial firms on the stock return volatility. Consequently, the exclusion of financial firms from the sample should lead to a higher effect of leverage and a lower influence of the interest rates in the non-financial sample. In addition, there should not be a drastic change in the Price and Buyback effects, as both effects are in a way independent of the nature of the firm. The results assessing these hypotheses for the Leverage, Price, Buyback and Interest rates effects are in Table 6 for the non-financial sample. For each of the effects, there are two regressions: one controlled by the market´s volatility and the other one is not. These regressions are estimated using the First-Difference estimator.

Table 6

Non-Financial: Regression results

This table presents results for Pooled OLS Panel Data regressions of stock return volatility on leverage, price, buyback ratio and interest rates. The results correspond to the first-difference (FD) estimator with robust standard errors, except for the regressions evaluating the Buyback effect. Regressions (1) and (2) correspond to the Leverage Effect, (3) and (4) to the Price Effect, (5) and (6) to the Buyback Effect, and regressions (7) and (8) to the Interest Rate Effect. The dependent variable is the first difference of the natural logarithm of the stock return volatility. The independent variables are the first differences of: the natural logarithm of leverage (1-2), the natural logarithm of the price in interaction with the QDA (3-4), the natural logarithm of the buyback ratio (BBR) in interaction with the QDA (5-6), and the interest rate (7-8). The first regressions for each of the effects are controlled by the change in market's volatility (measured by the first difference in the natural logarithm of the VIX). The 10-year constant maturity rate (10Y CMR) is used as a proxy for interest rates to maturity. Standard errors are reported in small font size below the estimates and the significance is defined by stars according to: 3 stars for statistical significance at the level 1%, 2 stars for 5% and 1 star for 10%. The table presents R^2, the number of observations N, and the residuals.

	First-Difference (FD) Estimator							
	Leverage		Price		Buyback		Interest Rate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Ln Leverage	0,458***	0,824***					0,444***	0,799***
	0,044	0,055					0,044	0,054
QDA *Δ Ln Price			-0,773***	-1,322***				
			0,057	0,065				
BBR*QDA					2,768***	4,559***		
					0,507	0,635		
Δ 10Y CMR							-2,598***	-3,776***
							0,465	0,513
Δ Ln VIX	0,470***		0,440***		0,511***		0,467***	
	0,010		0,010		0,009		0,010	
Constant	-0,003	-0,007**	-0,009***	-0,005	-0,010***	-0,019***	-0,004	-0,008***
	0,003	0,003	0,003	0,003	0,003	0,003	0,003	0,003
R^2	0,218	0,063	0,230	0,102	0,202	0,005	0,220	0,068
N	10458	10458	10458	10458	10458	10458	10458	10458
Residuals	0,289	0,316	0,287	0,310	0,292	0,326	0,289	0,315

All the results for nonfinancial firms are quite similar to those obtained with the complete sample. However, there is a notable improvement in the goodness of fit (*r-squared*) of all the regressions (one to three percent), meaning that indeed financial firms react differently to the evaluated effects. This is probably explained by the difficulty of finding a correct measure for leverage for financial firms. If indeed leverage cannot be easily determined, then the effects of changes in price or buyback programs also differ. Probably this is the reason why previous academical works always neglect financial firms from the sample. However, the Interest Rate effect must remain valid and certainly stronger for financial firms as it is strongly linked to the value of equity through the revenues. In order to assess this hypothesis correctly, in Table 7 is possible to find regressions evaluating the interest rate effect just to financial firms. The regressions are estimated using the First-Difference estimator with White robust standard errors to correct for heteroscedasticity.

Table 7

Interest Rate Effect (Financial Firms): Regression results

This table presents results for Pooled OLS Panel Data regressions of stock return volatility on interest rates. The results correspond to the first-difference (FD) estimator with robust standard errors. The dependent variable is the first difference of the natural logarithm of the stock return volatility. The independent variable is the first differences of the interest rates. Regression (2) and (3) are controlled by the change in market's volatility (measured by the first difference in the natural logarithm of the VIX). Regression (3) also includes the first difference of the natural logarithm of leverage. The 10-year constant maturity rate (10Y CMR) is used as a proxy for interest rates to maturity. Standard errors are reported in small font size below the estimates and the significance is defined by stars according to: 3 stars for statistical significance at the level 1%, 2 stars for 5% and 1 star for 10%. The table presents R^2, the number of observations N, and the residuals.

	First-Difference (FD) Estimator		
	(1)	(2)	(3)
Δ 10Y CMR	-6,664***	-4,222***	-4,181***
	1,154	0,926	0,923
Δ Ln VIX		0,665***	0,661***
		0,022	0,022
Δ Ln Leverage			0,654
			0,543
Constant	-0,013*	-0,004	-0,004
	0,007	0,006	0,006
R^2	0,013	0,282	0,284
N	2457	2457	2457
Residuals	0,361	0,308	0,308

For all the three regressions estimated, the Interest Rate effect is negative and significant at the 1% level for the financial sample. In addition, supporting the hypothesis mentioned before, the effect is stronger than for the non-financial sample: the coefficient jumps from -3.776 (regression 8, Table 6) to -4.181 (regression 3, Table 7). Therefore, an increase in 1% in the interest rates leads to a decrease of -4.181% in the stock return volatility for financial firms. Also, it is important to notice that the leverage effect is not significant at the 10% level for the financial sample. This corroborates the hypothesis that the measure of leverage for financial firms is not correct.

4.4 Robustness Check

Up until this point, the hypotheses have been tested using the First-Difference estimator, following the procedures of Christie (1982) and Figlewski and Wang (2000). However, as a *robustness check*, the regressions of the equations (9) to (11) and (16) are estimated in levels using Fixed Effects. Both estimators, First-Difference and Fixed Effects, must have equal results only when time *T* is equal to 2, which it is not the case. For *T>2* the estimators are different. Both estimators are unbiased and consistent under some assumptions, implying that the main difference between them is in terms of efficiency. This depends if there is or not serial correlation in the errors. The tests for serial correlation in the first difference of the errors ($\Delta u_{i,t}$) are in Table 8 for each of the Effects estimated. All the following results correspond to the non-financial sample, which means that are based on the results of Table 6.

Table 8

Serial correlation: FD

This table presents results for OLS regressions of the residuals (Uhat) at the regressions for Leverage, Price, Buyback Ratio, and Interest rate Effects estimated in Table 6. The independent variable is the first lag of each set of the residuals (L1.Uhat).

	Uhat		
	Coefficient	Std. Errors	t
L1. Uhat Leverage	-0,248	0,00859	-28,85
L1. Uhat Price	-0,254	0,00858	-29,55
L1. Uhat Buyback	-0,228	0,00864	-26,23
L1. Uhat Interest Rate	-0,263	0,00857	-30,74

Table 8 shows a significant negative serial correlation in the first difference of the residuals. Thus, if the first difference of the idiosyncratic error is indeed serially correlated, it indicates that the original residuals were uncorrelated, which in that case using Fixed Effects will produce more efficient estimators[17]. Thus, all the effects estimated in Table 6 are again estimated using Fixed Effects estimators. The results can be found in Table 9. In the same way as before, all the regressions are estimated using White robust standard errors, except for the Buyback effect as its test for heteroscedasticity was not significant.

[17] The standard errors of the Fixed Effects estimator are less than the standard errors of the First-Difference estimator.

Table 9

Fixed Effects: Regression results

This table presents results for Fixed Effects (FE) Panel Data regressions of stock return volatility on leverage, price, buyback ratio, and interest rates. The results correspond to the FE estimator with robust standard errors, except for the regressions concerning the Buyback effect. Regressions (1) and (2) correspond to the Leverage Effect, (3) and (4) to the Price Effect, (5) and (6) to the Buyback Effect, and regressions (7) and (8) to the Interest Rate Effect. The dependent variable is natural logarithm of the stock return volatility. The independent variables are the natural logarithm of leverage (1-2), the natural logarithm of the price in interaction with the QDA (3-4), the natural logarithm of the buyback ratio (BBR) in interaction with the QDA (5-6), and the interest rate (7-8). The first regressions for each of the effects are controlled by the change in market's volatility (measured by the natural logarithm of the VIX). The 10-year constant maturity rate (10Y CMR) is used as a proxy for interest rates to maturity. Standard errors are reported in small font size below the estimates and the significance is defined by stars according to: 3 stars for statistical significance at the level 1%, 2 stars for 5% and 1 star for 10%. Likewise, the table presents R^2, the number of observations N, and the residuals.

	Fixed Effects (FE) Estimator							
	Leverage		Price		Buyback		Interest Rate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln Leverage	0,149***	0,378***					0,117***	0,357***
	0,037	0,054					0,038	0,054
QDA * Ln Price			-0,039	0,036				
			0,024	0,031				
Buyback Ratio*QDA					-2,772***	-5,242***		
					0,609	0,820		
10Y CMR							4,652***	3.270***
							0,595	0,650
Ln VIX	0,713***		0,742***		0,728***		0,721***	
	0,012		0,012		0,008		0,013	
Constant	-3,552***	-1,576***	-3,511***	-1,426***	-3,516***	-1,378***	-3,879***	-1,680***
	0,036	0,028	0,047	0,039	0,024	0,004	0,043	0,036
R^2	0,465	0,066	0,456	0,001	0,451	0,004	0,480	0,073
N	10624	10624	10624	10624	10458	10458	10624	10624
Residuals	0,285	0,377	0,287	0,389	0,288	0,388	0,281	0,375

Results using Fixed Effects (FE) turn out to be strongly different to those obtained by the First-Difference (FD) estimator. The Leverage Effect reduces its economic significance to more than the half, going from 0.824 to 0.378, when it is not controlled by the VIX. In the case of the Price effect, it results to be not significant at the 10% level. And, for the Buyback and Interest Rates Effects, they are significantly different from zero at the 1% level, but with the opposite sign suggested by the theory in section 2 and the results from the FD estimator. Nevertheless, checking again for serial correlation in the errors, this time from the regressions using FE, the results show a positive and strong serial correlation which can lead to wrong inferences and the possibility of a type-I error[18] increases.

[18] Incorrect rejection of a true null hypothesis.

Table 10

Serial correlation: FE

This table presents results for OLS regressions of the residuals (Uhat) at the regressions for Leverage, Price, Buyback Ratio, and Interest rate Effects estimated in Table 9. The independent variable is the first lag of each set of the residuals (L1.Uhat).

	Uhat		
	Coefficient	Std. Errors	t
L1. Uhat Leverage	0,755	0,00565	133,64
L1. Uhat Price	0,751	0,00570	131,52
L1. Uhat Buyback	0,746	0,00585	127,55
L1. Uhat Interest Rate	0,751	0,00571	131,53

Putting aside the results for serial correlation for one moment, it is important to evaluate which of the two estimator's suit better to assess the hypotheses for Leverage, Price, Buyback and Interest Rates. Also, as the estimators are similar, is essential to keep in mind that both have at least one notable flaw: FD drops one period of time while FE considerably reduces the variation of the variables.

First of all, the Price Effect: in FE, the difference of the natural logarithm of the price with respect its average ($Ln\ S_{i,t} - \overline{Ln\ S_i}$) does not give the expected information in order to explain the change in the stock volatility, since it is the return against its average price. Consequently, changes in price and volatility against their respective means, are not telling the needed information and are substantially reducing their variation. On the contrary, the first difference of the natural logarithm is the actual return of the stock, which is actually what it wants to be tested: how the return of the stock affects its volatility. Then, because of this, FE is not the correct estimator for the Price Effect.

Second, the Buyback Effect: FE estimator is regressing the difference between the Buyback ratio and the mean of it per firm in time ($BBR * QDA_{i,t} - \overline{BBR * QDA_i}$) as the independent variable to evaluate the change in volatility against its mean. However, the buybacks are not present in every period and they have a lot of variation between firms that the estimator is not capturing. For that reason, FD is preferred because it can capture the difference between firms.

Third, the Interest Rate Effect: the data set for the 10Y Constant Rate to Maturity (10Y CMR) is quite stable on time (See Appendix, Figure 2). For several periods the 10Y CMR can remain in a small range, for example, as it can be seen in Figure 2, during 26 periods it remains between 2%-3% and 27 periods between 4%-5%, where almost most of them were consecutive. Having in mind that the sample comprehends 64 periods, it is possible to say that the variation of the 10Y CMR is quite limited. When this happens, using FE can generate spurious results (Choi, 2013). And what of the ways to determine that this is definitely what is happening with the results, is that the FD estimator results are strongly different. Consequently, the FD estimator is also preferred in this case.

Putting back the serial correlation issue in the three previous estimators, the choice is still with the FD as it corresponds to the actual effects that want to be estimated, and because even the serial correlation is significant, it is relatively small (-0.22 in average). Finally, for the Leverage Effect, both estimators seem to be valid despite the difference in the results. This might be caused for the small serial correlation in the FD estimator but it is possible to conclude that having both results significant and in the same direction, gives a sense of stability to the final results. However, there is a slight preference for the FD estimator because of the strong positive serial correlation in FE, and for comparison matters with previous academics publications.

As a final part of this *robustness check*, in order to correct the small serial correlation in the FD estimator, the regressions (9) to (11) and (16) are again estimated, this time using Feasible Generalized Least Squares (FGLS). This procedure allows the estimation in the presence of serial correlation within panels and heteroscedasticity across panels. In addition, it also helps to correct for possible cross-sectional correlation between firms. The results are in Table 11 for the Leverage, Price, Buyback and Interest Rates Effects.

Table 11

Feasible Generalized Least Squares: Regression results

This table presents results for Feasible Generalized Least Squares (FGLS) Panel Data regressions of stock return volatility on leverage, price, buyback ratio, and interest rates. The results assumed autocorrelation within panels in all the regressions, and heteroscedasticity across panels except for the regression evaluating the Buyback effect. Leverage Effect regressions (1-2), Price Effect (3-4), Buyback Effect (5-6), and Interest Rate Effect (7-8). The dependent variable is the first difference of the natural logarithm of the stock volatility. The independent variables are the first differences of: the natural logarithm of leverage (1-2), the natural logarithm of the price times the QDA (3-4), the natural logarithm of the buyback ratio (BBR) times the QDA (5-6), and the interest rate (7-8). Standard errors are reported in small font size below the estimates and the significance is defined by stars according to: 3 stars for statistical significance at the level 1%, 2 stars for 5% and 1 star for 10%.

	Feasible Generalized Least Squares (FGLS)							
	Leverage		Price		Buyback		Interest Rate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Ln Leverage	0,463***	0,915***					0,426***	0,861***
	0,026	0,029					0,026	0,029
QDA *Δ Ln Price			-0,741***	-1,383***				
			0,032	0,034				
BBR*QDA					2,325***	4,431***		
					0,430	0,540		
Δ 10Y CMR							-5,322***	-6,648***
							0,428	0,488
Δ Ln VIX	0,571***		0,543***		0,615***		0,562***	
	0,010		0,010		0,009		0,010	
Constant	-0,002	-0,006***	-0,002	-0,004*	-0,009***	-0,019***	-0,005***	-0,009***
	0,002	0,002	0,002	0,002	0,002	0,003	0,002	0,002
N	10458	10458	10458	10458	10458	10458	10458	10458

Finally, all the results from Table 11 are quite similar to those obtain at Table 6 in terms of economic and statistical significance. Hence, it is possible to conclude that the results from FD are indeed robust and the analysis from each of the effects evaluated from those results are adequate.

Conclusions

The two purposes of this paper are, first, to evaluate the effect of buyback programs in the stock volatility through the leverage effect; and second, assess the impact of interest rates in volatility based on the evidence that firms are becoming arbitrageurs of their own securities.

The results from this paper show that the Leverage Effect is still present and stronger than before. Proven by stock returns and the leverage itself, the increase in the Debt to Equity ratio raises the stock return volatility. The results are closer to those predicted by Black (1976) and by the theory developed in this paper, supporting the results obtained by Christie (1982), Cheung and Ng (1992), Duffee (1995), and Figlewski and Wang (2000). Relying on this Leverage Effect, it is shown that buybacks have a positive impact on volatility. The buybacks that are usually associated with good news: confidence in the firm itself and higher payout for the investors, are modifying the equity's risk but still investors seem not to notice it. Furthermore, nowadays they are becoming so common that even the "old dividends" are disappearing. The fast growth of them and the results from this paper constitute a call for policy makers for more regulation. Currently, the directive has been focused on the quantity of repurchased shares per day to avoid price manipulation, however, it should also be attached to a certain proportion of the assets, and forbid the use of debt for this purpose.

Additionally, from these results, this paper shows that interest rates have a negative impact on the stock return volatility, and that is stronger for financial firms. The increase in interest rate limits the excess of debt, which has been used to finance the buybacks programs. Contrary to what Christie (1982) suggested, the equity holders seem to beneficiate from interest rate hikes while the debt holders suffer the losses. As well as it was mentioned above, policy makers should be cautious with extreme reductions in the interest rates as it can provoke an excess of leverage on firms.

It is important to notice that it is the first time that these effects are controlled by the market's volatility (VIX) and that even with it, the Effects remain significant and consistent with the theory. In addition, is relevant to remark the two main limitations of this paper: the face value of debt instead of its market value, and the assumption that the firm's volatility σ_v remains constant. Unfortunately, this information is not easy to find and probably might be necessary to be inside a firm to truly capture both issues.

Appendix

Figure 1
Equity Option Simulation

This graph exhibits nine scenarios for different levels of Debt/Equity ratio. They are constructed with the same firm information (Value *V* and volatility σ_V) and a time to maturity *T* equal to 10 years. All the scenarios show a positive relationship between interest rates and the change in the value of equity. For D/E ratios higher than one, the curve turns to be concave, showing a stronger increase in equity´s value when the interest rates move from 0% to 10%. After that peak, the marginal change decreases.

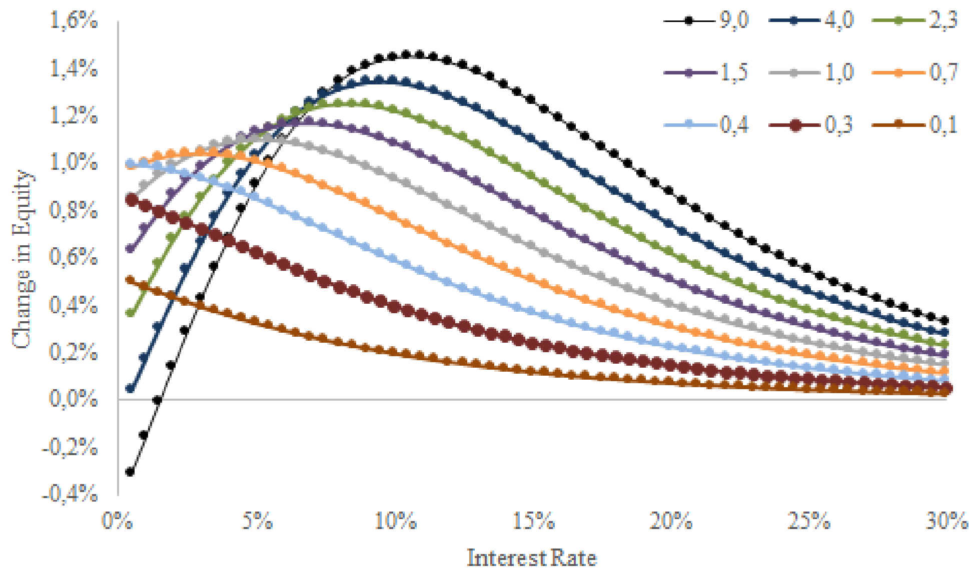
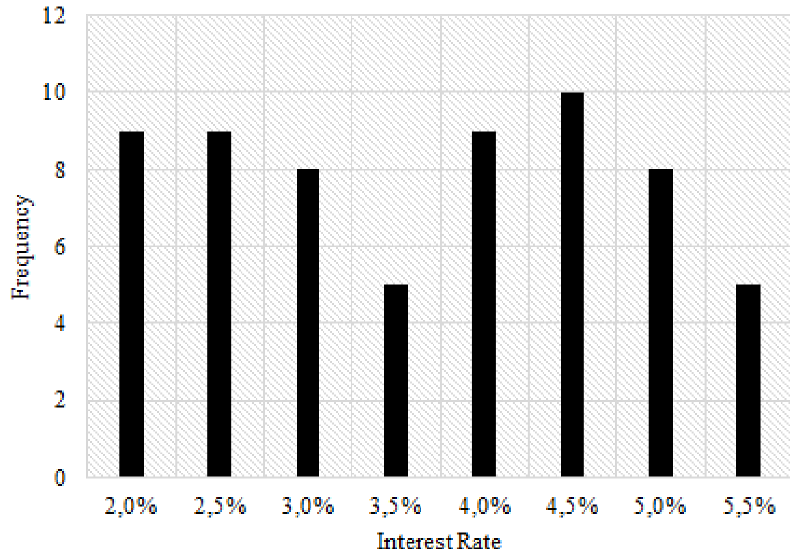


Figure 2

Histogram 10Year Constant Rate to Maturity (10Y CMR)

This graph displays the histogram of the 10Y CMR by quarterly frequency from 2001 to 2016. The histogram seems to follow a bimodal distribution that is similar to a combination of two normal distributions with different means. It illustrates a strong persistence between the levels 2% and 3%, and 4% and 5%. In the former range there are 26 observations while in the latter there are 27. The sum of both ranges comprehends 83% of the total sample.



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