



## Volatility, Earnings and Leverage

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## Introduction

That low volatility stocks outperform high volatility stocks over the long run is a relatively well-established empirical fact, extensively documented in academic literature and for which there is unusual consensus among both researchers and financial professionals. Starting with the first study by Haugen and Heins (1975), the so-called *low volatility anomaly* has survived the inflation of research papers dedicated to it, as well as the proliferation of related investment vehicles available to investors, including index funds and ETFs. While general wisdom is that once an *anomaly* has been discovered, it tends to fade away and eventually disappear, this has not been the case for the volatility premium. Over time and across geographies, researchers keep measuring higher returns (absolute or risk-adjusted) for low volatility stocks (see, for example, Ang et al. (2009); Haugen and Baker (2012); Blitz et al. (2013); Li et al. (2016)).

The question that looms is, what are the actual causes of this anomaly and how do they relate to well-known stylized facts concerning the stock market? It is indeed possible to classify the reasons that lie behind the low volatility anomaly into two categories of approach: Fundamental and behavioral. Already in Baker et al. (2010) and later Baker et al. (2011), the higher return earned by low volatility stocks appears as a phenomenon with roots in behavioral finance: Some investors' preference for risky stock and the limits on leverage of other investors who therefore need to invest in higher-risk stocks (as measured by Capital Asset Pricing Model (CAPM) beta, for example) to match their risk budgets. Fang and Peress (2009) instead provide indirect evidence that the volatility premium is also related to media coverage of companies which, in turn, leads to overreaction by market participants. In addition, Hsu et al. (2013) provide evidence that, for both global and emerging market stocks, the low volatility premium can be linked to the widespread tendency of sell-side analysts to inflate earnings' forecast for high volatility stocks, leading to overreaction from investors, deviations from fair valuation and - finally - underperformance. In the same conceptual framework, the volatility premium has also been linked to the quality factor, whether considered through the prism of profitability (Walkshäusl, 2013) or operating profitability (Dutt and Humphery-Jenner, 2013). Interestingly, the addition of a volatility factor (low-minus-high) in a standard four-factor Fama-French model has been used by Jordan and Riley (2015) to explain a significant component of residual alpha for a mutual fund that would otherwise "...lead to substantial mismeasurement of fund manager skill...". For an overview of the volatility effect in the context of classic CAPM we refer to Blitz et al. (2014).

These explanations (fundamental and behavioral) are reasonable, economically sound and testable. As the number of potential explanations of the volatility effect increases, it is likely that none of them significantly dominates. On the contrary, it is perhaps the combination of them that gives a complete picture of the volatility premium. In other words, it is possible that each explanation in the literature has a sizeable impact, without overwhelming the others, and their combination provides a better way to capture the volatility effect. Nevertheless, the possibility of a unified theory, bringing together all these explanations, remains a very complex task, not least because of the heterogeneity of the explanations in the literature. To overcome these difficulties, we provide a relatively simple framework where we can deal with proxies of the fundamental and behavioral-based explanations in a way that makes the volatility effect testable and, more importantly, to account for the mutual effect of the two explanations.

We decompose the variance of (i.e. percentage change of) stock returns into a fundamental component - proxied here by the variance of their earnings; a behavioral component - proxied by the price-to-earnings ratios' variance; and a joint component. The first result is that, by sorting stocks according to each of the three components, we found the usual low volatility pattern, where stocks with low variance outperform high variance ones on an absolute as well as risk-adjusted basis. In our framework, this evidence confirms the findings in existing literature that both behavioral and fundamental reasons lead to the volatility effect. We further investigated the mutual effect of each component, by applying standard double-sorting techniques in order to neutralize one component while building sorted portfolios according to the other component. Interestingly, when we consider the behavioral effect, the cross-sectional differences in the fundamental component disappear: There is almost no difference between low and high variance stocks. On the contrary, even when we neutralize the fundamental component, and sort according to the behavioral component, we find evidences of the volatility effect.

Our results do not rule out fundamental reasons behind the volatility effect. They instead stress the pervasive effect of the behavioral component, which remains significant even after accounting for the fundamental component. This evidence joins a growing stream of growing financial literature, related to the behavioral research, that aims to understand the relationship between "...[changing] narratives and economic fluctuations..." (Shiller, 2017).

## Data

Stock prices and earnings are sourced from CRSP/Compustat databases, covering the period January 1960 to April 2019. The reference investment universe (the *Benchmark*) is a capitalization weighted portfolio made up of the largest 500 US listed companies classified by CRSP as "ordinary common shares" (corresponding to Share type code field 10 or 11). The portfolio was rebalanced quarterly, at the end of March, June, September and December, starting on September 1965. Gross dividends were reinvested in the stocks themselves. The twelve-months trailing earnings data was sourced at quarterly frequency.

## Variance portfolios

An already extensive body of literature has provided empirical evidences for higher premia earned by low volatility stocks compared to high volatility ones over the long run. See for instance Haugen and Heins (1975); Haugen and Baker (1991); Ang et al. (2006); Blitz and Van Vliet (2007); Haugen and Baker (2010); De Franco et al. (2017a,b) and references therein. Findings in these empirical pieces of work can change depending on the particular portfolio construction (e.g. whether or not other factor exposures are managed, whether or not volatility-sorted portfolios are diversified), or depending on the volatility signal applied (e.g. short- versus long-term, or absolute volatility versus CAPM beta), but overall the results confirm the statistically significant extra risk-adjusted return that low-volatility stocks earns compared to high volatility equivalents.

Exhibit 1 shows annualized performance, volatilities and Sharpe ratios of ten volatility-sorted portfolios, using equally weighting and capitalization weighting schemes. Volatilities were computed over 12 consecutive quarters (therefore over a 3-year window), ending the month before the portfolios are rebalanced (March, June, September and December). In the rest of the paper we shall refer to these portfolios, interchangeably, as *buckets* or *sortings*.

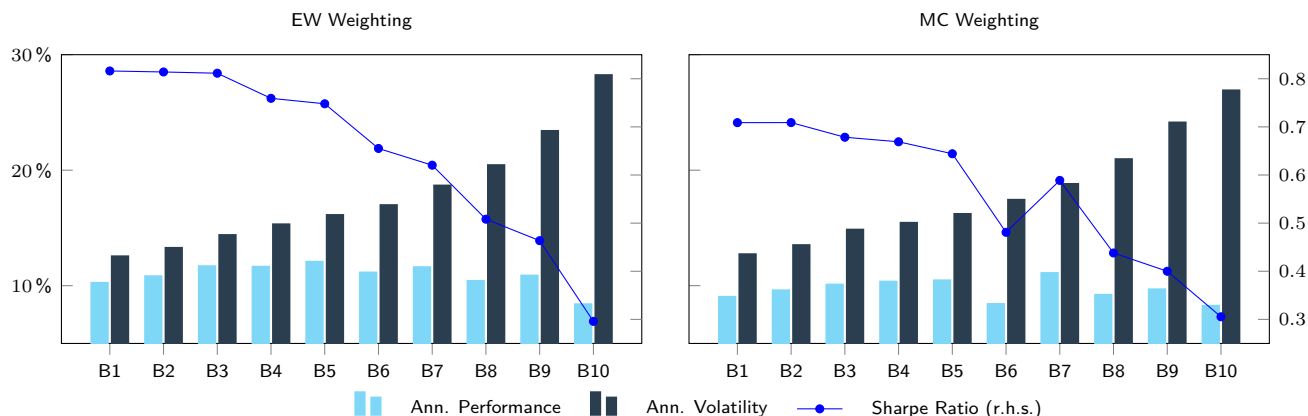


Exhibit 1: Annualized performances, volatility and Sharpe ratios for the ten volatility sorted portfolios. Left: Equally weighted buckets. Right: Capitalization weighted buckets.

As expected, realized volatility increased with the buckets, while the Sharpe ratio decreased. Annualized performance depended on the weighting scheme, but in both cases, they did not increase with risk. On the contrary, risk adjusted performance, measured here by the Sharpe ratio, decreased in both cases.

In the equally-weighted case, the decrease was very smooth, while in the capitalization-weighted case we saw few variations in the middle of the volatility spectrum, around buckets B5, B6 and B7. Looking at Exhibit 2 we see that, in both cases, the annualized performances for low-volatility buckets (B1 and B2) are in line, if not higher, than the high-volatility buckets (B9 and B10).

		EW weighting									
	Bench.	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Perf. (%)	9.84	10.19	10.76	11.63	11.59	12.02	11.09	11.55	10.36	10.82	8.34
Vol. (%)	15	12.49	13.22	14.33	15.26	16.06	16.92	18.62	20.38	23.34	28.18
Sharpe	0.66	0.82	0.81	0.81	0.76	0.75	0.66	0.62	0.51	0.46	0.3
Alpha (%)	-	3.82 (***)	3.2 (***)	3.13 (***)	2.39 (***)	2.24 (***)	0.73	0.11	-2.11	-2.81	-7.45 (***)
		MC weighting									
	Bench.	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Perf. (%)	9.84	8.98	9.54	10.04	10.3	10.41	8.36	11.04	9.15	9.63	8.2
Vol. (%)	15	12.67	13.46	14.8	15.39	16.16	17.38	18.76	20.9	24.08	26.85
Sharpe	0.66	0.71	0.71	0.68	0.67	0.64	0.48	0.59	0.44	0.4	0.31
Alpha (%)	-	2.28 (***)	1.68 (**)	1.13	1.01	0.61	-2.34 (***)	-0.48	-3.4 (***)	-4.27 (**)	-6.83 (***)

Exhibit 2: Annualized performances, volatilities, Sharpe ratios and CAPM alphas for the ten volatility sorted portfolios. Top: equally weighted portfolios. Bottom: Cap-weighted portfolio. Stars refer to statistical significance at 1% (\*\*\*) , 5% (\*\*) and 10% (\*).

As shown in Exhibit 2, annualized CAPM alphas are significant and positive for the low volatility buckets: From positive and statistically significant 3.82% for bucket B1 and 3.2% for bucket B2 we go down to -2.81% for B9 and -7.45% for

B10. In the capitalization weighted scheme, alphas are more irregular and decrease less smoothly from B1 to B10, but the global picture remains unchanged: High volatility stocks underperformed on an absolute and risk-adjusted basis, contrary to the standard theory that posits a positive relationship between risk and returns.

Our result is not new, since existing literature already provides several compelling reasons behind this puzzling effect. The compounding effect, constrained investors' need for leverage, the time-varying nature of other equity factors, psychological factors, and the asymmetric profile of low-volatility stocks (i.e. their tendency to capture more in rising markets than lose in declining markets) are among the most quoted explanations for this effect.

## Variance decomposition: Earnings and Multiples

The simplest models for equity prices link market prices to their fundamental valuations. For example, market participants usually think of prices as the product of (a measure of) earnings and a valuation multiple, the most popular of which remains the classic PE ratio:

$$P = E \times PE \quad (1)$$

where the earning variable E captures the profit-generating power of the company, and the PE ratio measures the expensiveness of the company, or how many earning-years at which the market currently values it. It is straightforward to link prices' percentage changes to percentage changes in the two separate variables.

**Lemma 1.** *The percentage changes in prices  $\Delta P/P$  is given by:*

$$\frac{\Delta P}{P} = \frac{\Delta E}{E} + \frac{\Delta PE}{PE} + \frac{\Delta E}{E} \times \frac{\Delta PE}{PE} \quad (2)$$

Details on this result are given in the Appendix.

The first term in the right-hand side of (2) represents the percentage change of earnings and the second terms is the corresponding percentage change of PE ratios. The third and last term stands for the joint earnings and PE ratios percentage changes. It should be noted that this is a simple but general decomposition which can be applied to any other fundamental metric such as book-to-market value, dividends or cash-flow.

With (2) in hand, we can build sorted portfolios based on the variance of each percentage term (the right-hand side of (2)) and compare them with the initial volatility-sorted portfolios (built with the variance of the percentage changes in the left-hand side of (2))<sup>1</sup>. Exhibit 3 shows key performance indicators of ten equally-weighted portfolio built by sorting stocks according to the variance of  $\Delta E/E$ .

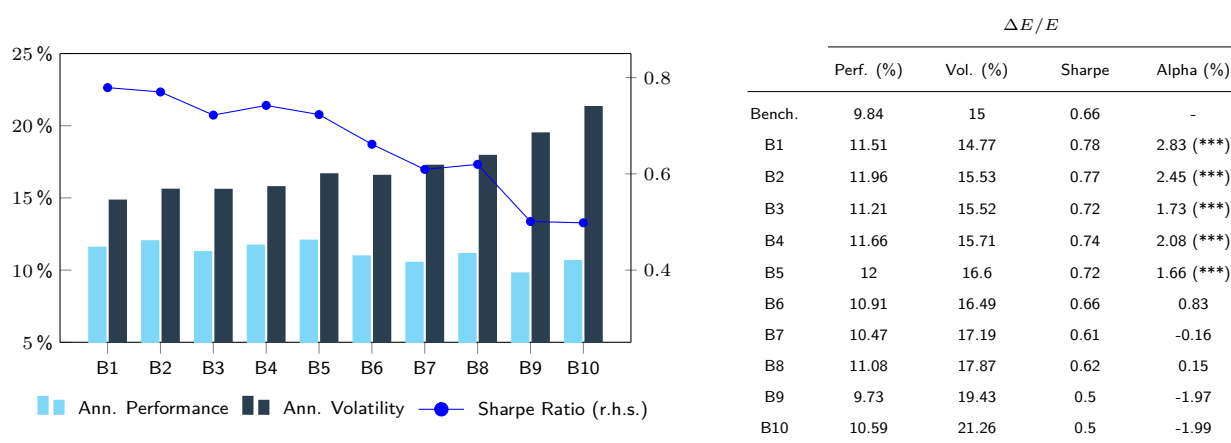


Exhibit 3: Annualized performances, volatilities, Sharpe ratios and CAPM alphas for the ten portfolios built using the variance of  $\Delta E/E$ . Stars refer to statistical significance at 1% (\*\*\*) , 5% (\*\*) and 10% (\*).

Exhibit 3 shares many similarities with the standard case in Exhibit 1. The portfolios built with the variance of  $\Delta E/E$  show an increase in ex-post volatility as we move from bucket 1 to 10. But the gap between B1 and B10 is now much lower. According to Exhibit 2, the volatility-sorted bucket B1 had an annualized volatility of 12.67% versus 26.85% for B10. For the portfolios built with the variance of  $\Delta E/E$  reported in Exhibit 3, we have B1 with volatility of 14.77% and B10 only 21.26%. The gap in realized volatility then goes from 14% circa in the standard case to 6.5% circa in this framework.

The Sharpe ratio profile is also like that of Exhibit 1, decreasing as volatility increases. Stocks with high earnings variance tend to underperform stocks with lower earnings variance, both on an absolute and a risk-adjusted basis, although the Sharpe ratio profile is not as steep as we experienced in Exhibit 1. Over the last 50 years US companies with volatile earnings have underperformed companies whose earnings have been stable. Moreover, corresponding market returns have also been more volatile. Interestingly, CAPM alphas decreased in their magnitudes compared to the standard case: For example, B1 went from 3.82% annualized alpha in Exhibit 1 to 2.873% in Exhibit 3, although it was still statistically significant. At the other end, high  $\Delta E/E$  variance buckets showed somehow better CAPM alphas: They remained negative, but not as small as in the standard case, and the last bucket B10 alpha' was no more statistically significant at -1.99%.

We also built ten equally-weighted portfolios based on sortings of the stocks' variances of  $\Delta PE/PE$ . Exhibit 4 shows these results.

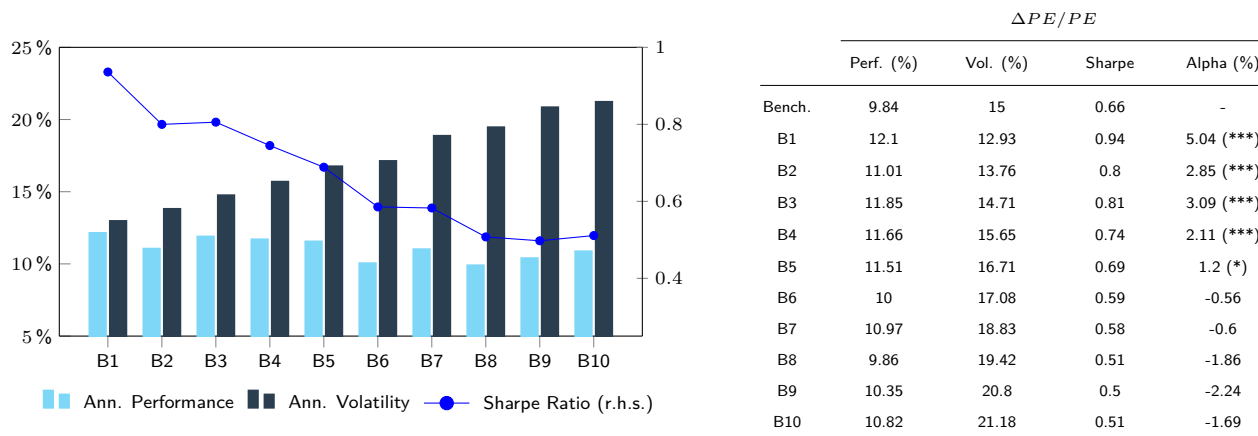


Exhibit 4: Annualized performances, volatility, Sharpe ratios and CAPM alphas for the ten portfolios built using sortings of price-to-earnings variance  $\Delta PE/PE$ . Stars refer to statistical significance at 1% (\*\*\*) , 5% (\*\*) and 10% (\*).

In this case too, the results are like those in Exhibit 3. Realized volatility increases with the buckets, but the increase is more linear and closer to that in Exhibit 1. Indeed, we see from Exhibit 3 that ex-post volatilities from bucket B1 to bucket B4 are all close to 15% and then only after they start to increase. With respect to  $\Delta PE/PE$  instead, we see that ex-post volatilities increases linearly.

The sortings on the variance  $\Delta PE/PE$  clearly have the ability to granularly differentiate stocks from a risk perspective, while this was not the case for the sortings on the variance  $\Delta E/E$ , where we can only see a difference between low risk stocks (buckets B1-B4 in Exhibit 4) and high-risk ones (B5-B10).

The Sharpe ratio decreased, as in the standard low-volatility case (Exhibit 1, even if it flattened toward the final buckets B9 and B10). Even more than in the  $\Delta E/E$  case, stocks whose PE ratio changed less outperformed those whose PE ratio was more volatile, both on an absolute and on a risk-adjusted basis.

For the lowest bucket B1 we see a significant increase in its CAPM annualized alphas: From 3.82% in the standard case we now have 5.04%. For B2 up to B4 the alphas are instead lower than the in standard case, even if by less than in the  $\Delta E/E$  case. Again, the alphas of the highest buckets have increased and lost their statistical significance.

Finally, Exhibit 5 reproduces the same analysis for portfolios of stocks sorted by the variance of their joint percentage changes  $\Delta E/E \times \Delta PE/PE$ .

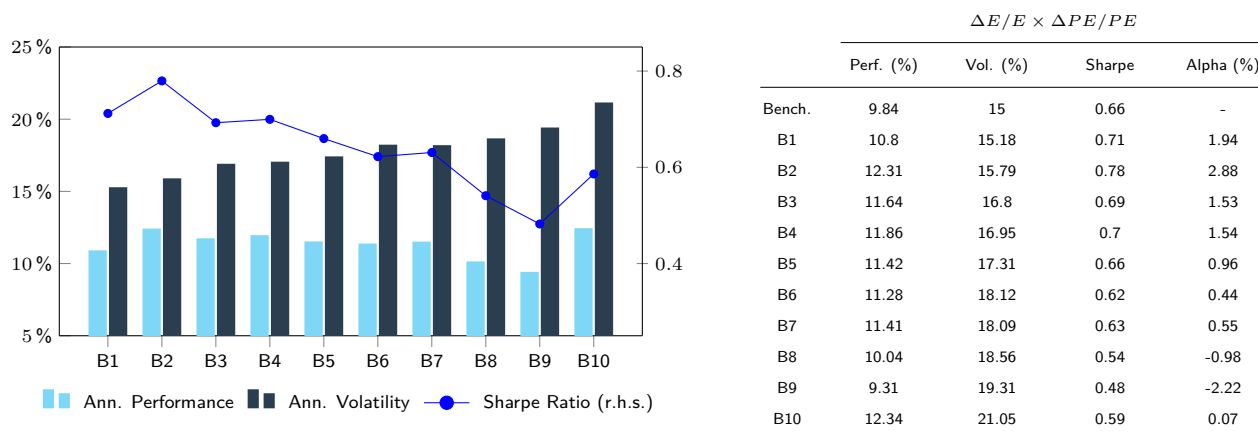


Exhibit 5: Annualized performances, volatility, Sharpe ratios and CAPM alphas for the ten portfolios built using sortings of joint earnings and price-to-earnings variance  $\Delta E/E \times \Delta PE/PE$ . Stars refer to statistical significance at 1% (\*\*\*) , 5% (\*\*) and 10% (\*).

Here the results were less conclusive: On the one hand, the realized buckets' volatility increased from low to high buckets, even if the gap between the lowest B1 and highest B10 was less than in the standard case.

On the other hand, the Sharpe ratio was not a smooth decreasing line. It was instead noisy for the lowest buckets, increasing from B1 to B2, then relatively stable up to B7 and again quite chaotic toward the higher buckets, with a B10 that showed a 0.59 Sharpe ratio, higher than B9 at 0.48.

Finally, the CAPM alphas were all smaller in magnitude and no more statistically significant. In other words, by sorting on the variance of the joint percentage changes  $\Delta E/E \times \Delta PE/PE$  we did not find evidences of an effective premium of low versus high buckets. Out of the three components in (2) the joint percentage changes were the least effective in mimicking the behavior of portfolios built on standard price volatility.

We plotted the Sharpe ratios of the volatility-sorted portfolios in comparison to the Sharpe ratios of alternative sortings (Exhibit 6). Graphically we can see how sortings on the variance of the multiples  $\Delta PE/PE$  gave the best fit and mimicked relatively well the standard case. The sortings based on the variance of earnings  $\Delta E/E$  also did a relatively good job at reproducing the Sharpe ratios in the standard case, while the sortings on the joint earnings-and-price-to-earnings volatility mimicked somehow less well the standard case, especially in the very extreme buckets B1-B2 and B10.

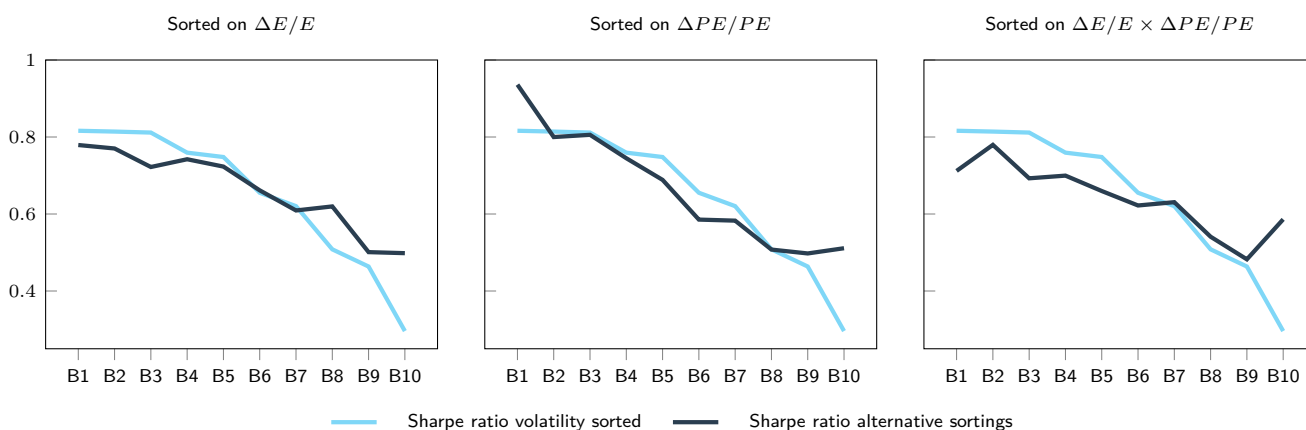


Exhibit 6: Sharpe ratios across buckets sorted by volatility compared to earnings' variance (rep. price-to-earnings and joint earnings-price-to-earnings) sorts.

Similarly, if we look at annualized CAPM alphas, we find that for the sorts based on the variance of multiples  $\Delta PE/PE$  and variance of earnings  $\Delta E/E$ , the output is relatively similar to the standard case (Exhibit 7).

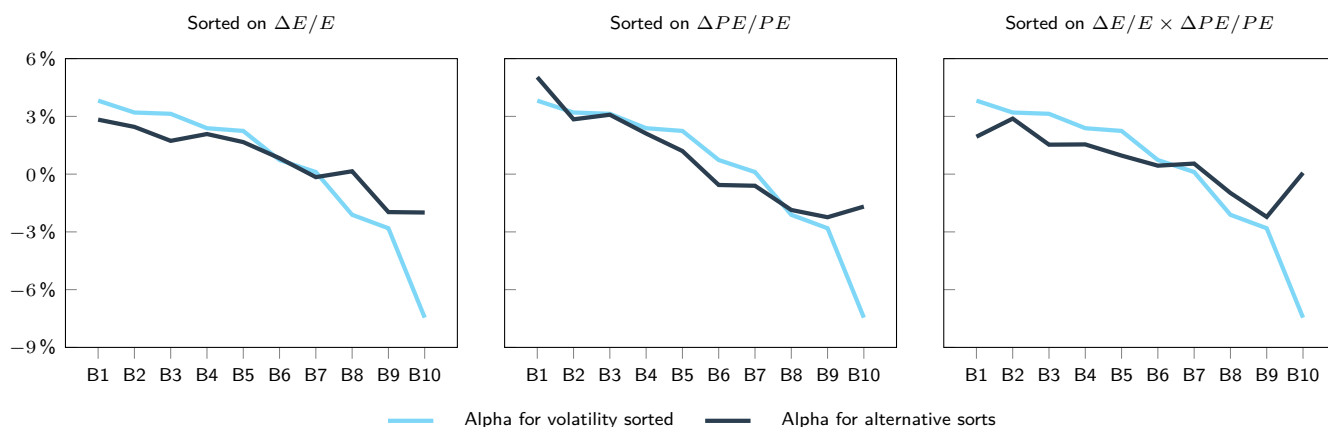


Exhibit 7: Annualized CAPM alphas across buckets sorted by volatility compared to earnings' variance (rep. price-to-earnings and joint earnings-price-to-earnings) sorts.

We can thus define the *risk-adjusted premium* as the difference between CAPM alphas of B1 and B10 for the different sorting metrics. As Exhibit 8 shows, the premium is large and positive for all the sorts, whether we use equal-weighting or capitalization-weighting schemes in the portfolio construction.

Nevertheless, we observed that the premium related to the price-to-earnings variance buckets is higher than the premium relative to earning variance buckets.

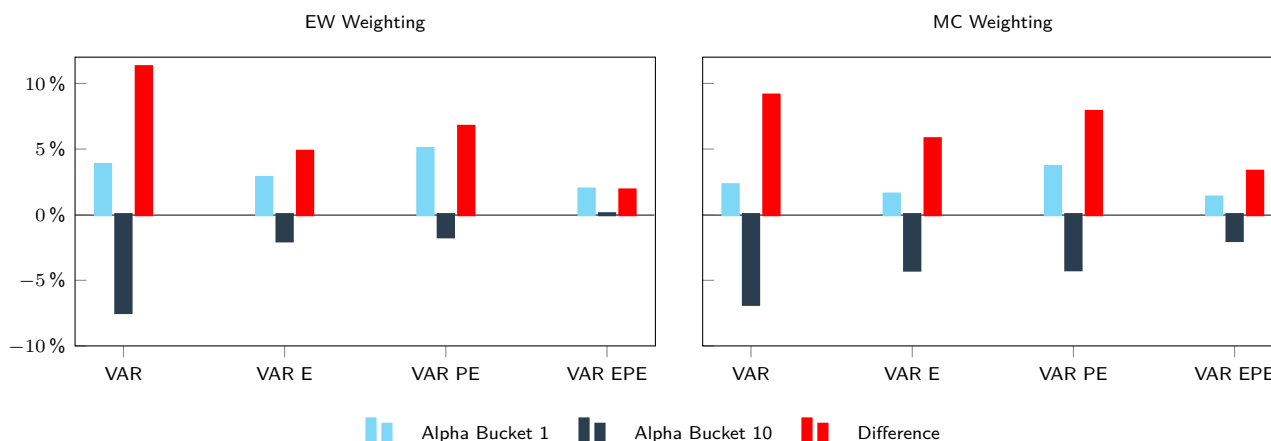


Exhibit 8: Annualized CAPM alphas for the low volatility Bucket 1 and the high volatility bucket 10 and their differences (risk-adjusted premium) for different sorting methodologies (VAR: Sorts on standard variance, VAR E: Sorts on earnings' variance, VAR PE: Sorts on PE variance).

## Double sorting on earnings and leverage

We saw in the previous section that the volatility premium is related to two different sources: One linked to fundamentals - companies with stable, less volatile earnings deliver higher performances, both absolute and risk adjusted; the other linked to companies whose valuation multiples are also stable and less volatile deliver higher performances. Interestingly, the first component -  $\Delta E/E$  - is clearly related to the company's business and its earning power. The second component  $\Delta PE/PE$  is instead related to the way the market values the company.

In order to further explore the relationship between these two main components of the volatility premium, we built ten portfolios based on sorts of earnings and price-to-earnings variance, where we now neutralize their mutual effect by using a standard double-sorting procedure.

More precisely, to neutralize variations of earnings variance, we first built ten portfolios based on the earnings variance and we indexed them with  $j \in \{1, 2, \dots, 10\}$ . We then ranked stocks within each bucket  $j$ , according to their price-to-earnings variance. Therefore, each  $j$  bucket was sliced into ten sub-portfolios. These sub-portfolios had different levels of price-to-earnings variance, but they shared similar earnings variance. Finally, the  $i$ -th bucket in this double-sorting procedure was the union of the ten buckets indexed by  $j$  of all stocks that belong to the  $i$ -th sub-portfolio. Similarly, the double-sorted earning portfolios were built by swapping the order of rankings: First price-to-earnings and then earnings' variance. Both sets of buckets were equally weighted. We collectively refer to the double-sorted earnings' variance buckets as  $EDSPE$  while  $PE DSE$  denotes the symmetric double-sorted price-to-earnings variance buckets.

Exhibit 9 collects annualized performance, volatilities, Sharpe ratios and annualized CAPM alphas for the double-sorted portfolios, while Exhibit 10 provides a graphical visualization of long-term performance statistics for both sets of buckets.

Sorts on $\Delta PE/PE$ , neutral $\Delta E/E$											
	Bench.	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Perf. (%)	9.84	11.25	10.7	11.05	9.94	11.19	11.29	11.88	11.28	11.37	10.52
Vol. (%)	15	13.74	14.41	15.29	15.5	15.81	16.88	17.49	18.06	19.55	21.45
Sharpe	0.66	0.82	0.74	0.72	0.64	0.71	0.67	0.68	0.62	0.58	0.49
Alpha (%)	-	3.19 (***)	2.02 (***)	1.77 (***)	0.37	1.51 (**)	0.84	1.1 (*)	0.16	-0.57	-2.42

Sorts on $\Delta E/E$ , neutral $\Delta PE/PE$											
	Bench.	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Perf. (%)	9.84	11.12	11.42	11.64	11.01	11.64	12.16	11.6	9.95	10.78	10.29
Vol. (%)	15	17.66	17.57	17.78	17.45	16.46	16.29	16.14	16.36	16.2	16.7
Sharpe	0.66	0.63	0.65	0.65	0.63	0.71	0.75	0.72	0.61	0.67	0.62
Alpha (%)	-	0.26	0.51	0.58	0.2	1.54 (**)	2.13 (***)	1.83 (***)	0.03	0.9	0.12

Exhibit 9: Annualized performances, volatility, Sharpe ratios and CAPM alphas for the ten double-sorted portfolios build on price-to-earnings' variance neutral on earnings' variance (top) and earnings' variance neutral on price-to-earnings variance (bottom). Stars refer to statistical significance at 1% (\*\*\*) , 5% (\*\*) and 10% (\*).

When we neutralized the earnings variance and build buckets based on price-to-earnings variance (Exhibit 9 - top) we saw that the realized volatility of the portfolios increased with the buckets. The ex-post volatility ranking was preserved when we ranked by price-to-earnings variance, if we neutralized the earnings' variance component. Put another way, it appears that the cross-sectional volatility dispersion is still effective, even after considering the differences in companies' earnings regularity. This in turn suggests that market volatility is a phenomenon that can only be partially explained by rational expectations of earnings' variability (a similar argument for dividend variability was made in Shiller (1981)).

The Sharpe ratio also decreased, which in turn signaled that the risk-adjusted premium earned by low price-to-earnings variance stocks was higher than that of high price-to-earnings variance, even if we neutralized the earning variance component. Finally, CAPM alphas for the lowest buckets B1-B3 remained high, positive and statistically significant, while the alphas for the highest buckets B8-B10 were negative even if with unsatisfactory statistical precision. The top panel of Exhibit 9 compares relatively well with Exhibits 1 and 4.

If we turn to the buckets for which we neutralized the price-to-earnings variance component (Exhibit 9 - bottom), we first remark that there was almost no difference between buckets. The ex-post volatility is similar across buckets, spanning 16.2% (for B9) to 17.78% (for B3). The Sharpe ratios did not show the kind of risk-adjusted premium between low and high buckets that we saw previously. Put simply, when we neutralize the price-to-earnings variance component, the earnings' variance effect disappeared.

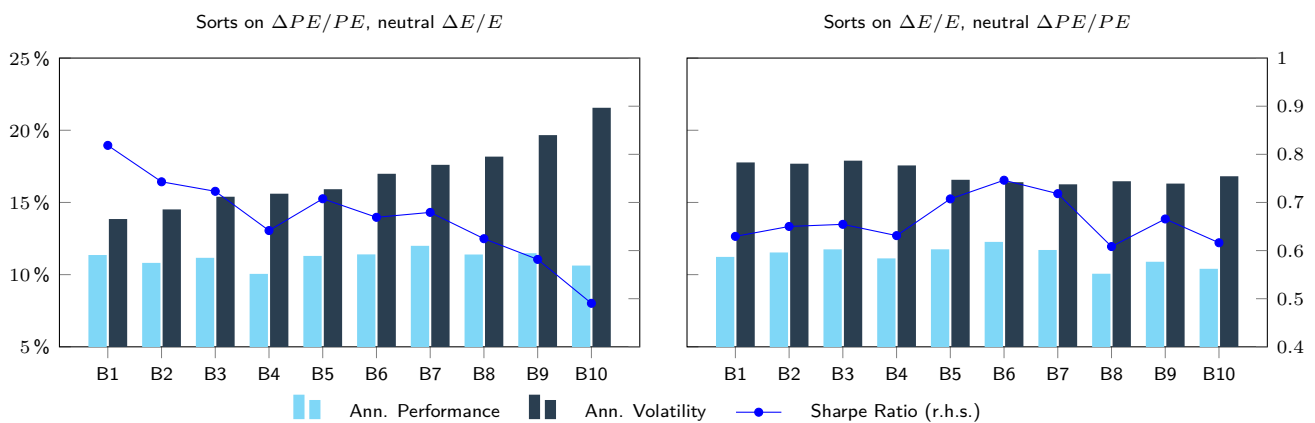


Exhibit 10: Annualized performances, volatilities and Sharpe ratios for the ten double-sorted portfolios built on price-to-earnings' variance neutral on earnings' (left) and earnings' variance neutral on price-to-earnings (right).

This phenomenon is clear when we look at Exhibit 10: In the left panel, the Sharpe ratio line is decreasing and relatively smooth; in the right panel it is also relatively flat.

This analysis suggested that, if both components (earnings and price-to-earnings) are roughly equally important in the volatility premium, the price-to-earnings component is more pervasive, and remains significant when we take into account differences in earnings' variance among stocks. Exhibit 11 completes Exhibit 8 by adding the risk premium for the two double-sorted families.

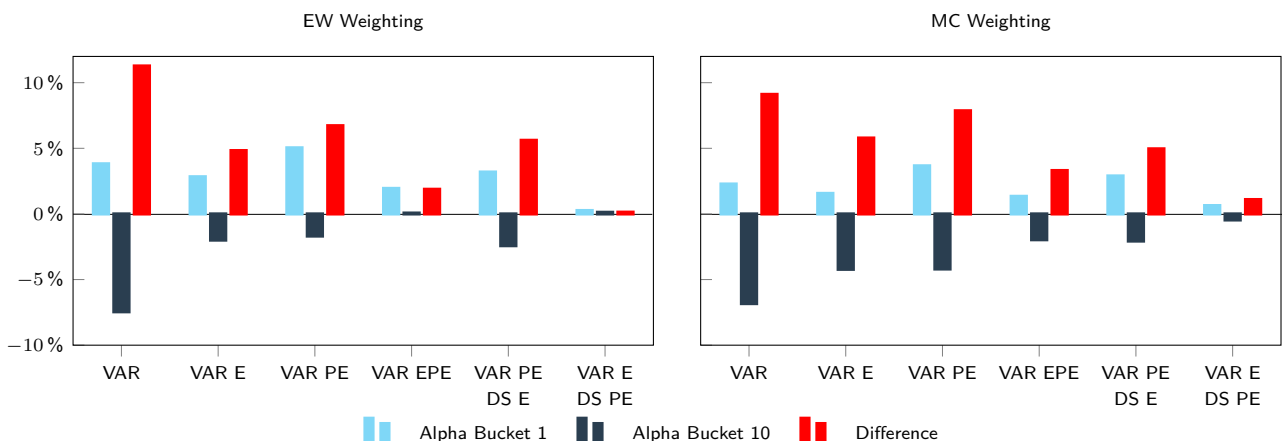


Exhibit 11: Annualized CAPM alphas for the low volatility Bucket 1 and the high volatility bucket 10 and their difference (risk-adjusted premium) for direct sorting methodologies (VAR: Sorts on standard variance, VAR E: Sorts on earnings' variance, VAR PE: Sorts on PE variance) and double-sorting ones (VAR PE DS E: Sorts on PE variance neutral on E, VAR E DS PE: Sorts on earnings' variance neutral on PE).

In both cases (equally weighting and capitalization weighing schemes), the risk premium between buckets B1 and B10 remains positive for the price-to-earnings variance buckets neutral on earnings (VAR PE DS E), while it is negligible and statistically not different from zero for the earnings' variance buckets neutral on price-to-earnings (VAR E DS PE).



Dynamic risk premia are shown in Exhibit 12. On a five-year rolling period, we look at the difference between CAPM alphas relative to the lowest bucket B1 and the highest B10 for different sorting methodologies. As expected, these dynamic risk premia tend to change with market conditions and, by construction, they spike during or shortly after major equity downturns, as one can see, for example, by looking at the classical volatility premium (line VAR).

On the left of Exhibit 12 we can see how the risk premia relative to the direct sorting methodologies (VAR E and VAR PE) follow the one relative to the standard variance sorting VAR, even if the VAR PE line seems to mimic its relatively better.

On the right, we plotted the risk premia relative to the double-sorting methodologies. The line VAR PE DS E, the risk premium of the price-to-earnings variance sorts neutral on earnings' variance, is closely linked to the standard premium, even if there is a gap in the years 2000-2010. On the contrary, VAR E DS PE, the risk premium of the earnings' variance sorts neutral on price-to-earnings' variance, moves around zero over time, clearly signaling that this premium, after accounting for statistical estimation errors, is consistently zero over time.

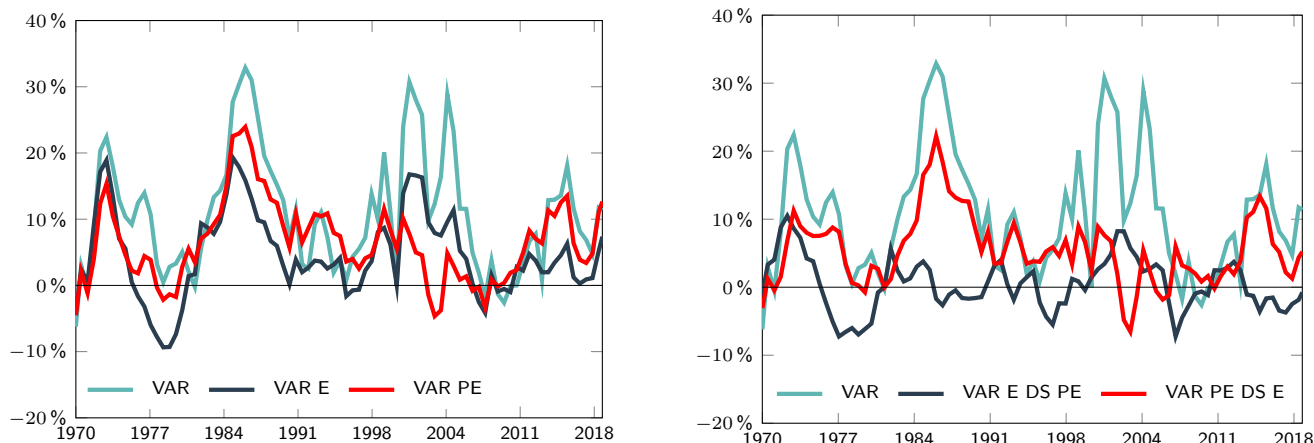


Exhibit 12: Left: 5-years rolling premiums (difference between first bucket's over last bucket's annualized CAPM alphas) for direct sorting methodologies (VAR: Sorts on standard variance, VAR E: Sorts on earnings' variance, VAR PE: Sorts on PE variance). Right: 5 years rolling premiums for the double-sorting methodologies. (VAR: Sorts on volatility, VAR E: Sorts on earnings' volatility, VAR PE: Sorts on PE volatility) and double sorts (VAR PE DS E: Sorts on PE variance neutral on E, VAR E DS PE: Sorts on earnings' variance neutral on PE).

## Conclusion

The analysis above seems to show that there is a strong relationship between the premium associated with low volatility stocks and the premium associated with low price-to-earnings variance equivalents. Low volatility in changes of PE ratios is achieved if market prices move in tune with stocks' earnings. The market therefore provides stable estimates of stocks' multiples earnings that are, to some extent, not revised up and down too frequently. It is a sign of the relative robustness of a business, which helps the market put a fair multiple on its earnings. Highly volatile price-to-earnings stocks are instead characterized by market prices that do not respond smoothly to changes in earnings. PE ratios are more erratic, and this in turn suggests that the market struggles to give a fair estimate for the multiples for such companies. These stocks tend to show a lottery-like feature: Good news on their earnings pushes their prices too high, which potentially may not be sustained in the following periods, leading in turn to disappointment and strong corrections in their market prices. This phenomenon is typically a symptom of overreaction in the market.

Our findings provide further evidences that a significant component of the volatility premium (the PE part)

- is not related to fundamentals (the E part)
- is significant even after accounting for structural characteristics (e.g. whether the company has more volatile earnings or not)
- and is directly related to behavior features of the stock market

Although this was intuitively one of the ex-post explanations for the large risk-adjusted outperformance of low volatility stocks, our approach provides a simple framework by which we have systematically isolated a fundamental component from a behavioral component in its effect on stock price volatility.

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# Appendices

## On Lemma 1

From  $P = E \times PE$ , we deduce

$$\begin{aligned} P_2 - P_1 &= E_2 \times PE_2 - E_1 \times PE_1 \\ &= (E_2 - E_1) PE_2 + (PE_2 - PE_1) E_1 \\ &= (E_2 - E_1) (PE_2 - PE_1) + (E_2 - E_1) PE_1 + (PE_2 - PE_1) E_1 \end{aligned}$$

so that dividing both sides by  $P_1$  yields

$$\begin{aligned} \frac{\Delta P}{P_1} &= \frac{(E_2 - E_1) (PE_2 - PE_1)}{P_1} + \frac{(E_2 - E_1) PE_1}{P_1} + \frac{(PE_2 - PE_1) E_1}{P_1} \\ &= \frac{E_2 - E_1}{E_1} \frac{PE_2 - PE_1}{PE_1} + \frac{E_2 - E_1}{P_1/PE_1} + \frac{PE_2 - PE_1}{P_1/E_1} \\ &= \frac{E_2 - E_1}{E_1} \frac{PE_2 - PE_1}{PE_1} + \frac{E_2 - E_1}{PE_1} + \frac{PE_2 - PE_1}{PE_1} \\ &= \frac{\Delta E}{E} \frac{\Delta PE}{PE} + \frac{\Delta E}{E} + \frac{\Delta PE}{PE} \end{aligned}$$

which proves the decomposition in (2).

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