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FINANCIAL LEVERAGE RISK REVISITED – THEORY, DEFINITIONS AND DETERMINANTS

Summary: The paper proposes a new general definition of financial leverage, which underlines the role of increased probability of getting extreme values of *ROE* (both negative and positive) after the introduction of debt. The illustration of leverage is presented with the help of folded cumulative distribution functions of *ROE*. The definition allows various interpretations. In particular, it allows identifying financial leverage with either increased volatility of *ROE* measured by variance or with the elasticity of *EPS* measured by degree of financial leverage, *DFL*. These two interpretations are shown not to be equivalent. In contrary, they concentrate on two distinct aspects of debt impact on profitability. The former focuses on the act of taking debt ("simple leverage"), the latter on the act of paying interest on debt ("cost leverage"). The financial leverage definition proposed in the paper allows many other interpretations, including those which emphasize e.g. bankruptcy risk, value at risk (*VaR*) etc.

Key words: financial leverage, financial risk, DFL, ROE.

1. Introduction

Over the last few decades financial leverage has become a standard topic of any corporate finance and investment courses, playing a prominent role in explaining the effect of raising debt on the financial performance of a company. As such the topic is well represented in all academic textbooks and non-academic professional training materials. The financial leverage literature revolves around the impact of debt on earnings per share (*EPS*), net income and/or return on equity (*ROE*). Indeed, the question how these measures change after the introduction of interest bearing liabilities has been for years synonymous with financial leverage itself. In [Berent 2008a] I extend this analysis beyond debt impact on the levels of profit measures *Xs*, i.e *ROE*, *EPS*, and/or net income and investigate the impact of debt on measures such as "the absolute distance" between any two profitability indices $X_1 - X_2$, "relative distance" measured as X_1/X_2 etc. As a result, the nature and the size of this impact can be understood more thoroughly. In particular, this approach helps to see precisely what profitability measure (and to what extent) does actually change when debt is introduced. I conclude that the change in profitability is determined by two distinct effects, which are called **simple leverage effect** and **cost leverage effect**. Simple leverage effect stems from the fact that in the presence of debt the investment is no not wholly financed by equity; cost leverage effect arises from the fact that debt taken is costly.

As mentioned above, a lot of financial leverage literature focuses on the relationship between ungeared and geared profitability measures. However, putting too much emphasis on the algorithm, which determines the way any individual ungeared profit number translates into a geared one may be misleading. It is only when investigated from the perspective of the whole distribution of potential outcomes registered before and after debt that one can detect and appreciate the overall impact of debt on profitability, hence one can see "financial leverage in action". The impact of debt on the first moments of *ROE* distribution (including the impact on the coefficient of variation) is presented in [Berent 2008b][1].

One can also argue that the real source of confusion surrounding the measurement of financial leverage comes simply from the lack of agreement regarding what financial leverage actually is. It is all too often that financial leverage (as a theoretical concept) is introduced by mere reference to the act of taking debt, i.e. its association with debt seems to be a sufficient explanation what one should understand by leverage [Brealey, Myers 2000, p. 228; Ostrowska 2002, p. 46-47]. However, the issue is somewhat more complicated. Should financial leverage be associated with the capital structure and measured consequently by various capital structure measures (if so which ones?). Or maybe it should be associated with the increase (change?) in profitability measures such as *EPS*, *ROE*, net profit after the addition of debt? Should this be more specifically identified with elasticity of geared results to ungeared numbers using measures such as degree of financial leverage *DFL* [Duliniec 2001, p. 59].

Yet another approach is to associate financial leverage with the risk financial leverage generates. Hence the popularity of identifying financial leverage with financial risk. Once again, it is not obvious what exactly this proposal means[2]. Should leverage be calculated by the increase in beta, variance [Bednarski, Waśniewski 1996, p. 520--521; Levy, Sarnat 1986, p. 384; Arnold 2002, p. 813], the likelihood of bankruptcy [Rutkowski 2007, p. 214, 345; Jerzemowska 1999, p. 31; Gitman, p. G-9] etc. In addition, many measures of financial leverage capture both risk and reward[3]. As a result, the notion of financial leverage as risk concept remains blurred.

[1] The changes in *ROE* distribution's moments after the introduction of debt are shown once again to come from two conceptually distinct notions: simple and cost leverage effects (see [Berent 2008a] and [Berent 2008b]).

[2] In [Berent 2009], I define financial leverage risk as a subcategory of more general concept of financial risk. I believe that financial leverage (risk) should be limited only to the increase in risk that comes as a result of taking debt. In [Berent 2008b] I propose some financial leverage ratios, which capture this "magnifying/amplifying" effect. In contrast to such popular measures as degree of financial leverage (*DFL*), these ratios are defined at *ROE* population level and are intuitively appealing (they assume values greater then one, hence implying the notion of "magnification/amplification" usually associated in basic mechanics with "levers", "gearing boxes" etc."

[3] This is the case when financial leverage is identified with e.g. the increase in *ROE* rather than with the increase in the variance of *ROE* after debt taking.

This article is an attempt to describe step-by-step the impact of taking debt and/or charging interest for it on the distribution of company's *ROE*. This is done in the hope that the increased risk associated with debt, i.e. financial leverage, will be clearly visible. In addition, it is believed that the distinction between taking debt ("simple leverage effect") and charging interest for it ("cost leverage effect") will be clearly demonstrated. By doing so I hope to shed some more light onto the discussion what financial leverage actually is and why the metaphor of leverage/gearing borrowed from basic mechanics is still justified. In order to escape from problems relating to mixing risk with reward measures, the analysis is performed without direct reference to return levels. Instead, the focus is on the variability of returns itself.

2. Leverage cumulative distribution function, *LCDF*

As mentioned above, there are numerous attempts to illustrate the impact of financial leverage on the profitability and financial performance of a company. Basic mechanics tools are often referred to as a helpful illustration, hence the concept of "gearing" and "leverage". There are also countless formulas which describe financial leverage. However, they usually focus on some specific features of leverage rather than on the financial leverage itself. To provide a comprehensive analysis of financial leverage, the notion of cumulative distribution function (*CDF*) of company's *ROE* before and after debt is taken is now introduced.

Let $F(x)=P(ROE \leq x)$ be a strictly increasing cumulative distribution function[4], where the right-hand side represents the probability that the company's *ROE* takes on a value less than or equal to x[5]. The Figure 1 illustrates *CDF* for a normal distribution of *ROE*, with expected value of 20% and standard deviation of 30%[6].

To distinguish between *CDF* function for ungeared and geared *ROE*, two different notations are introduced: $F_U(x)$ and $F_G(x)$ respectively. Knowing that[7]:

$$ROE_G = (1 + d) \times ROE_U - id, \tag{1}$$

where: ROE_U – return on equity calculated for an all-equity company,
ROE_G – return on equity calculated for a company with debt,
i – interest rate charged on debt,
$d = D/E$ – debt-to-equity ratio, hence $1+d=(D+E)/E$,

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[4] To be precise, strict monotonicity (and continuous density distribution function) is not necessary in the definition of *CDF*. It however simplifies the analysis without loss in generality of conclusions.

[5] The cumulative distribution function of *ROE* can also be defined in terms of the probability density function *f* as: $F(x) = \int_{-\infty}^{x} f(ROE)dROE$.

[6] Normality of *ROE* distribution is not necessary.

[7] For simplicity, no taxes are assumed. It is also assumed throughout that *i* and *d* are not stochastic.

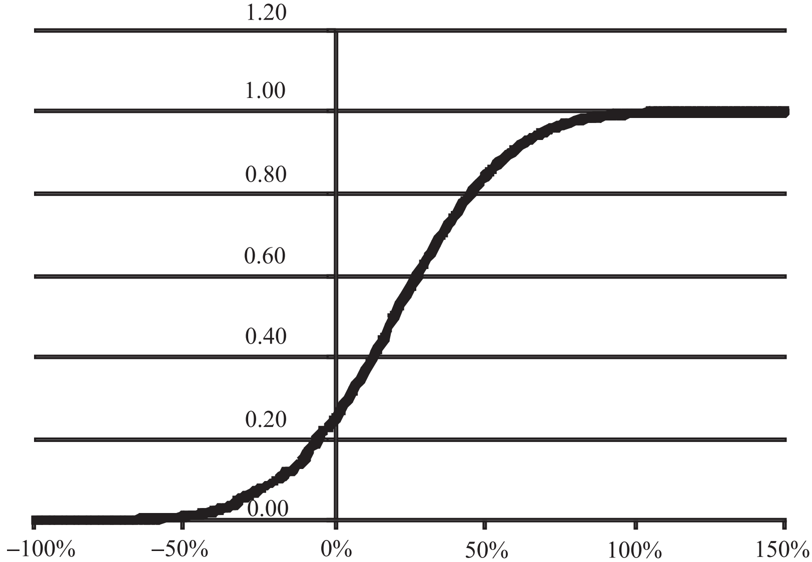

Fig. 1. The cumulative distribution function *CDF* for normally distributed *ROE* with *E*(*ROE*) = 20%, stdev(*ROE*) = 30%.

the relationship between $F_U(x)$ and $F_G(x)$ can be established as follows:

$$F_G(x) = F_U\left(\frac{x+id}{1+d}\right) = \begin{cases} > F_U(x) & for\, x < i \\ = F_U(x) & for\, x = i \\ < F_U(x) & for\, x > i \end{cases} \tag{2}$$

Figure 2 presents *CDF* for three geared companies with three different values of *d*=*D*/*E* ratios: *d*=0.5; *d*=1.0; *d*=2.0 as well as one ungeared company (*d*=0). All CDFs intersect at *x*=*i*.

An alternative illustration of the cumulative distribution function, which itself has usually an S-like shape (see Fig. 1 and 2), is the folded cumulative distribution function, which folds the top half of the *CDF* graph over. This form of illustration emphasizes the dispersion of the distribution. The folded cumulative function turns from an increasing to a decreasing function at median, therefore it is a continuous function, whose shape is mountain-like, hence it is sometimes referred to as a mountain function (see Fig. 3)[8].

[8] The folded *CDF* implies the graph uses two scales, one for the upslope and the other for the downslope. For simplicity, there is only one scale on Fig. 3. The secondary scale for the downslope would be 1-s_u, where s_u is the scale for the upslope.

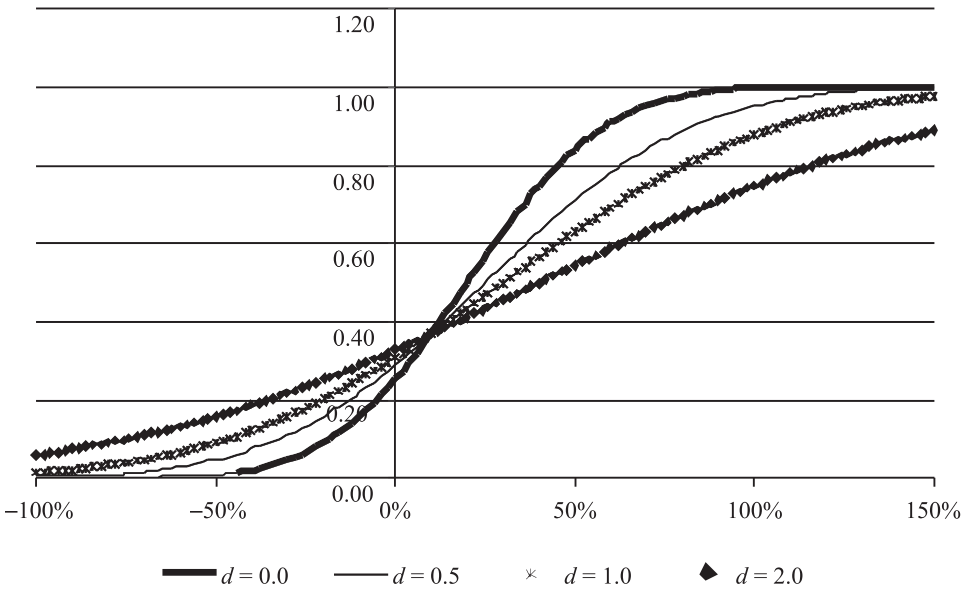

Fig. 2. The *CDF* for normally distributed *ROE* with *E*(*ROE*) = 20%, stdev(*ROE*) = 30% and four different values for debt-to-equity ratios: $d = 0$, $d = 0.5$, $d = 1.0$ and $d = 2.0$.

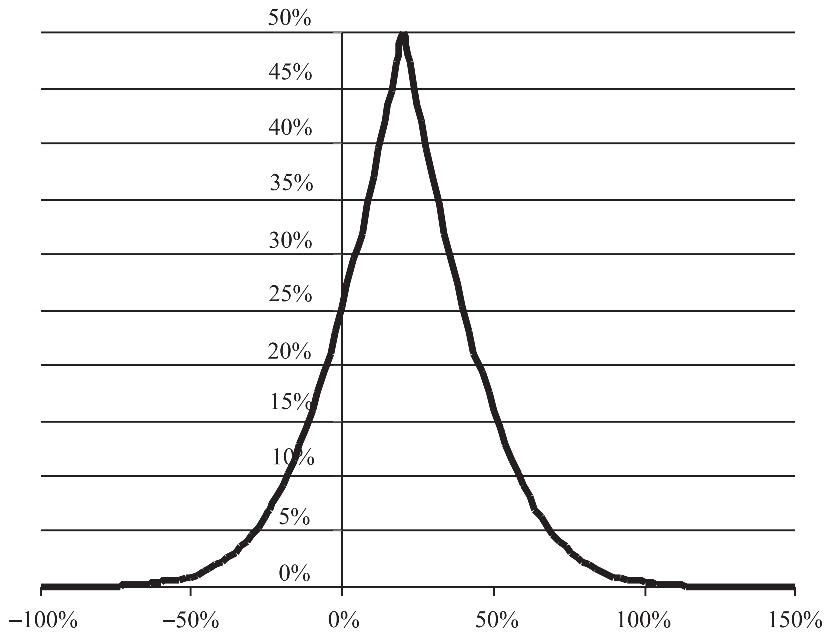

Fig. 3. The folded *CDF* (mountain function) for normally distributed *ROE* with *E*(*ROE*) = 20%, stdev(*ROE*) = 30%.

In order to illustrate the impact of financial leverage on ROE distribution and on the dispersion of the rates of return in particular, the cumulative distribution function is redefined as a variant of a mountain function, $H(x)$:

$$H(x) = \begin{cases} F(x) & for\, x < i \\ 1 - F(x) & for\, x > i \end{cases} \quad (3)$$

$H(x)$, hereafter referred to as a folded leverage cumulative distribution function, or simply leverage cumulative distribution function *LCDF*, has the following features:

- $H(x)$ determines the probability of reaching *ROE* lower than or equal to x_L ($x_L < i$, referred to as a lower boundary) for the upslope and the probability of reaching *ROE* greater than or equal to x_H ($x_H > i$ referred to as an upper boundary) for the downslope;
- $H(x)$ is defined for all $x \neq i$[9];
- The point at which *LCDF* folds over is determined to be at i, the interest charged by debtholders, which may no longer be (and is unlikely to be) the median of *ROE* distribution (as it was the case with classical mountain functions, see Fig. 3);

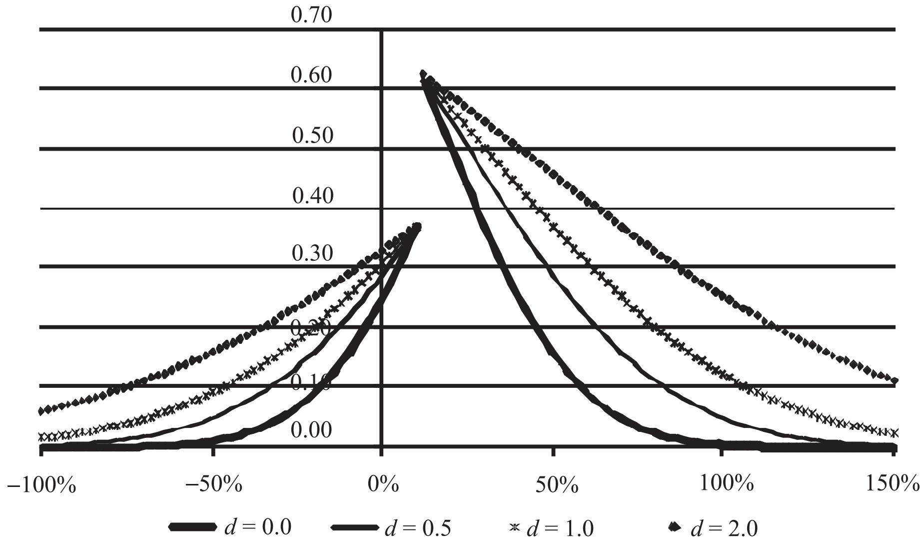

Fig. 4. The leverage cumulative distribution function, *LCDF* for normally distributed *ROE* with *E*(*ROE*) = 20%, stdev(*ROE*) = 30% and four different values for debt-to-equity ratios: $d_0 = 0$, $d_1 = 0.5$, $d_2 = 1.0$ and $d_3 = 2.0$.

[9] As it is the dispersion of the distribution around i which is studied here, there is little interest in the value of $H(x)$ for $x = i$. If $H(x)$ was to include x=i, one could add it in the definition of $H(x)$ either for $x \geq i$ or in the definition of $H(x)$ for $x \leq i$. For continuous distribution functions it is mere convention which of the two: the "higher than or equal to" sign "≥" or "lower than or equal to" sign "≤" is selected. For discrete functions it is only important in that the set of values for $H(x)$ may be affected, something which is immaterial in the analysis of *ROE* dispersion.

- *LCDF* is discontinuous at $x = i$, unless median of *ROE* distribution happens to fall at $x = i$.
- In contrast to a typical mountain function, the scale for the upslope and downslope are identical.

Once again, $H(x)$ is defined separately for ROE_U and ROE_G and denoted as $H_U(x)$ and $H_G(x)$ respectively. Condition (2) can now be reformulated in terms of leverage cumulative function $H(x)$:

$$H_G(x) = \begin{cases} > H_U(x) & for\, x < i \\ > H_U(x) & for\, x > i \end{cases} \tag{4}$$

Condition (4) means that $H_G(x) > H_U(x)$ for all $x \neq i$, i.e. the probability of getting extreme values increases after taking debt. In Fig. 4 this increase can be seen in thicker tails of *LCDF* for geared companies. It is believed that this very characteristic is the most important feature of financial leverage and as such will constitute the basis for the new definition of financial leverage presented in the next section.

3. Definition of financial leverage

As already mentioned, there is no much agreement on the definition of financial leverage. The financial leverage literature emphasizes the act of measurement of various financial leverage effects with little attention being paid to the formal, rigorous definition of the term. The adequate definition of financial leverage should be general in nature. It should not be limited to statements, some would argue, which identify financial leverage rigidly with either higher variance, higher probability of bankruptcy or higher *DFL* etc. In contrary, such a definition should precede many of these statements and many more (including e.g. the probability of making losses, various variants of value at risk metrics, *VaR*, etc.), so that they themselves could be derived from it.

The introduction of *CDF* in (2) in general and *LCDF* defined in (3)-(4) and seen in Fig. 4 in particular leads to the definition of financial leverage, which is believed to meet all the above criteria:

Financial leverage should be understood as/identified with the increase in the probability of getting "extreme values" of ROE after taking debt. This in turn implies that the probability of getting "middle" values of ROE diminishes with debt.

By "extreme values" one should understand: values lower than $x_L < i$ (a lower boundary) or higher than $x_H > i$ (an upper boundary). Consequently "middle values" are values of *ROE* which fall in-between x_L and x_H.

One should note that the definition of "extreme values" is very general[10]. It also emphasizes the role of the cost of debt i in measuring financial leverage. The reasons

[10] Lower and upper boundaries can be arbitrarily chosen. The only condition for x_L (x_G) is that it should be lower (higher) than *i*.

for *ROEs* spreading away from i can easily be seen from the formula, which links ROE_G with ROE_U:

$$ROE_G = i + (1 + d)(ROE_U - i) \qquad (5)$$

The return on equity moves away from i for all $ROE_U \neq i$. If ROE_U is greater than i, its distance from i increases from $|ROE_U - i| > 0$ to $|ROE_G - i| = (1+d)|ROE_U - i| > 0$, i.e. towards more positive values of *ROE*. Similarly, if ROE_U is lower than i, its distance from i increases again from $|ROE_U - i| < 0$ to $|ROE_G - i| = (1+d)|ROE_U - i| > 0$, i.e. to the left towards negative *ROEs*.

The process of *ROE* spreading away from i gets momentum with higher d. As shown in equation (5), higher $(1 + d)$ catapults *ROE* away from i with a force proportional to $(1 + d)$. This in turn inflates the probability of getting extreme values of *ROE*. The increasing force of leverage can be seen in Fig. 4 in the growing distance between *LCDF* for geared companies ($d = 0.5$; 1.0; 2.0) and a folded *CDF* for ungeared company ($d = 0$). Increasing the contribution of debt to total financing increases therefore leverage as defined above.

Below, a formal definition of simple and cost leverage is proposed. These two concepts are first introduced and examined in [Berent 2007; Berent, 2008a; Berent 2009b].

3.1. Simple (financial) leverage

Let now assume that $i = 0\%$ but $D > 0$. This implies that the company gets debt financing without being charged for it. Equation (5) still holds and with it all major conclusions regarding the pull of returns away from i. The only change is that *LCDF* folds now over at $i = 0\%$[11]. Such a situation is called simple financial leverage, or simple leverage for short.

Simple leverage, induced by taking debt, rather than by charging fixed financial costs, means that negative rates of return become more negative, while positive rates of return gets more positive. Consequently, the probability of recording losses greater than any predetermined level of *ROE* is now higher. Similarly, the probability of registering profit at any given level of *ROE* also increases. It is evident therefore that the variance of *ROE* gets higher too.

3.2. Cost (financial) leverage

Let now assume that the company does not raise any debt, yet it pays fixed financial charges to a debtholder[12]. Then the fixed financial cost C can no longer be determined as $C = iD$. It can however be calculated with the reference to total investment I as $C = i^* \times I$, where $i^* = C/I$ is the interest charge per unit of total investment. In such a case equation (5) is no longer applicable. Instead the following holds:

[11] The graph of a simple leverage is identical to Fig. 4 *if* i=0%.

[12] This may happen when the debtholder (bank) charges its client for mere readiness to extend debt without actually granting any loan.

$$ROE_G = ROE_U - i^*. \tag{6}$$

To see the cumulative distribution function for an all equity company which pays $C = i^* \times I$ (F_G), *CDF* for ungeread company (no $C = i^* \times I$ charged) must be moved by a vector [-i^*,0]. The probability of ROE_G reaching any given level of x is now the same as the probability of ROE_U reaching $x + i^*$ (see Fig. 5).

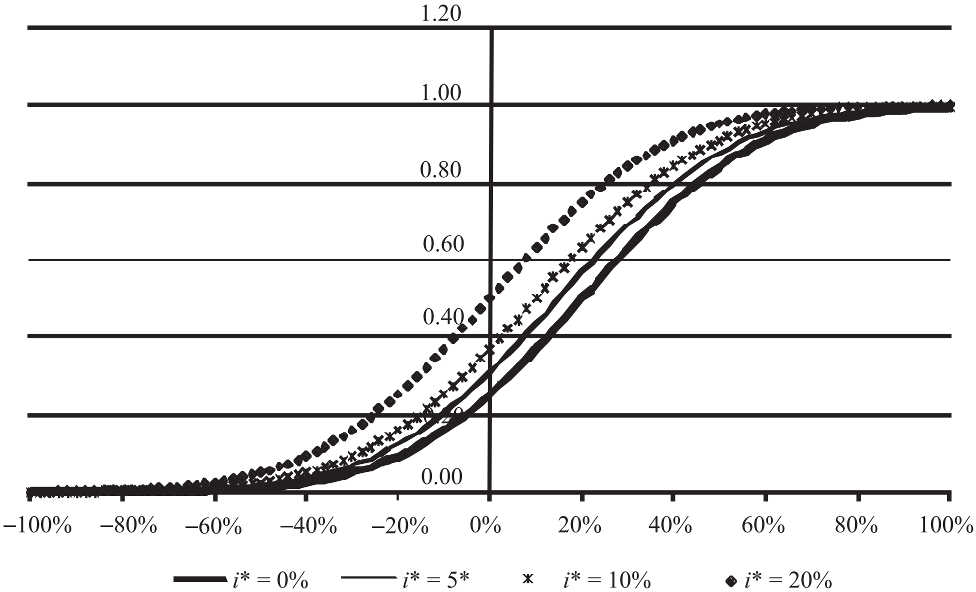

Fig. 5. The cumulative distribution function for normally distributed *ROE* with *E*(*ROE*)=20%, stdev(*ROE*) = 30% and four different values for i^*: $i^*_0 = 0\%$, $i^*_1 = 5\%$, $i^*_2 = 10\%$ and $i^*_3 = 20\%$.

In simple leverage case ($i = 0\%$, $D > 0$), the fixed financial charge C could be calculated with the reference to D as $C = iD$ as well as with the reference to I as $C = i^* \times I$. However, in the case of cost leverage ($i^* > 0$, $D = 0$), the calculation of C with the reference to non-existent D is no longer obvious.

However, one can interpret paying fixed financial charge and no debt as being equivalent to paying $i = +\infty\%$ on $D = 0$. This comes from the definition of i, which is $i = C/D$, where $C > 0$ and $D = 0$. With this in mind, one can interpret *CDFs* from Fig. 5 as *LCDFs*, which fold over at $i = +\infty$. The only difference here is that i is no longer finite and the *LCDF* has no longer "two sides". Still one can claim that the probability of getting extreme values, which in this case would mean all values lower than or equal to $x_L < i = +\infty$ increases. If the definition of financial leverage as "*the increase in the probability of getting 'extreme values' of ROE after taking debt*" is invoked, one can argue that cost leverage should be regarded as financial leverage[13].

[13] One should also note that some previous conclusions regarding e.g. increased variance are no longer justified when i is not finite.

4. Total financial leverage vs. simple and cost leverage

The analysis of simple and cost leverage suggests four distinct cases, which are determined by various values of *i* and *D*. These cases differ from each other in many aspects, in particular in terms of their impact on the variance of the distribution[14] and degree of financial leverage, *DFL*. The latter claims that in the presence of fixed financial costs *EPS* rises more than proportionally compared to the increase in *EBIT*[15].

Table 1. Financial leverage vs. various values for *D* and *i*

	i	*D*	Variance	*DFL*
No leverage	zero	=0	no increase	=1
Simple leverage	zero	>0	increase	=1
Cost leverage	+∞	=0	no increase	>1
Total financial leverage	a finite number	>0	increase	>1

There is no dispute that in the absence of both debt and fixed financial charges there is no leverage at all ("no leverage" case in Table 1). There is also little controversy that in the case branded "total financial leverage" in Table 1, i.e. where both debt and interest charge are greater than zero ($D > 0$, $0 < i < +\infty$), financial leverage is present. However, as in such a case both simple and cost leverage effects are present, it is often not obvious which of the two components (or maybe both?) is responsible for leverage phenomenon. To answer this question, one should revert to the definition presented in this paper. In fact it is claimed that it is the interpretation of this definition that determines what is and what is not "financial leverage".

4.1. Financial leverage vs. variance

If one insists that leverage is present only if both upper and lower boundaries exist (x_L and x_U respectively) and consequently that "extreme values" should be present on both sides of the probability function, then financial leverage is limited only to cases where $D > 0$, regardless if the cost of debt is zero or not. An advocate of this appro-

[14] The impact of leverage on variance is important as it affects beta and the cost of equity. From (1) it can be shown that standard deviation of ROE_G will increase $(1 + d)$ times compared to standard deviation of ROE_U.

[15] It should be noted that in the presence of fixed financial charges, *DFL* needn't be greater than one. This is only the case if $ROE_U > i^*$ for $D \geq 0$ or $ROE_U > id/(1 + d)$ for $D > 0$. Otherwise *DFL* may assume all other values, i.e. those including fractions, negative values etc. It is true that the interpretation of *DFL* as a leverage coefficient is particularly appealing when $DFL > 1$ as this implies an "magnifying or amplifying" in financial performance, however this interpretation is less clear for values of $DFL < 1$.

ach would simply argue that it is the very nature of leverage that it improves “good” results and depresses “bad” results even deeper, hence necessity of both lower and upper boundaries.

In Table 1 these cases are denoted as “simple” and “total financial leverage”. This implies that it is the increase in variance, which is vital to leverage. In addition, this claims that *DFL* is not an adequate measure of leverage and the fixed costs are not a necessary attribute of leverage.

4.2. Financial leverage vs. variance or/and *DFL*

If one further accepts that leverage is also present if there is only lower boundry x_L, so that one can observe “extreme values” at both sides of the distribution or only at the left hand side of the distribution, then financial leverage concept can justifiably be extended to cases when $D = 0$ and $i = +\infty$. In short, either $D > 0$ or $i > 0$ (finite or infnite) or both must be greater than zero for the process to be called financial leverage. With such an interpretation, neither the increase in variance nor “greater-than-one” *DFL* is necessary but they are both sufficient conditions for the existence of financial leverage.

4.3. Financial leverage vs. *DFL*

If one understands “extreme values” narrowly as those which are smaller than “lower boundary” then financial leverage concept can be used if and only if $i > 0$, finite or infinite. What counts here is the existence of fixed financial costs. In this approach financial leverage is identified with fixed financial costs and its force is measured by *DFL*.

The attractiveness of this approach is caused by its intuitive link with liquidity and bankruptcy risks, which indeed increase in the presence of financial costs. The similarity of this approach to operating leverage, measured by degree of financial leverage *DOL*, is also important. It should be noted that with such an interpretation simple leverage would not be classified as financial leverage anymore.

5. Conclusions

In practice both (simple and cost) leverage effects tend to accompany each other: taking debt is usually linked with paying interest. This does not make the distinction between the two components of leverage any less important. Quite the opposite. One should be even more careful not to confuse the roots of increased risk introduced by debt. For example, higher level of debt means, inter alia, both higher variance and higher financial costs, hence higher *DFL*. However, the reversal is not true: higher *DFL* due to higher i does not affect the variance of the company’s ROE. Similarly, taking on more debt affects variance but needn’t to affect *DFL* (if total financial costs are not changed). The correlation between the two effects is likely to be strong though, as there is one-to-one function, although not linear, between $(1 + d)$ and *DFL*.

The question which of the two effects is pivotal to financial leverage is clearly a matter of an opinion as it depends on the interpretations of the leverage definition proposed in this paper. It was shown above that it is this interpretation, which determines what financial leverage is and what is not. As for the author of the paper, I believe that "financial leverage" should not exclude cases where there is a clear increase in volatility of returns measured by variance. After all this increase is transmitted into undiversifiable risk growth, and hence beta, too. The emphasis on fixed financial charges alone (and therefore on *DFL*), which themselves do not have any impact on neither variance nor beta, is in my opinion not fully justified. The use of elasticity measure in metrics such as *DFL* is certainly appealing, although one should also remember that *DFL* has weak points, which render it less useful than many may think[16].

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RYZYKO DŹWIGNI FINANSOWEJ – NOWE PODEJŚCIE, TEORIA I DEFINICJE

Streszczenie: Artykuł podejmuje kwestię zdefiniowania dźwigni finansowej w taki sposób, aby łączyła w sobie różne możliwe interpretacje. Zaproponowana definicja uwypukla rolę zwiększonego prawdopodobieństwa otrzymania krańcowych wartości ROE po zaciągnięciu

[16] See footnote 14.

długu, co graficznie zostało zaprezentowane za pomocą zmodyfikowanego wykresu dystrybuanty rozkładu ROE. Definicja dźwigni finansowej sformułowana jest na tyle ogólnie, że pozwala wyprowadzić z niej dwie główne, konkurujące ze sobą interpretacje: pierwsza wskazuje na wzrost wariancji ROE po zaciągnięciu długu, druga na elastyczność EPS mierzoną stopniem dźwigni finansowej DFL, jako istotę dźwigni. Powyższe interpretacje zwracają uwagę na dwa odmienne aspekty zadłużenia: pierwsza koncentruje się na samym akcie zaciągnięcia długu („dźwignia prosta"), druga na akcie płacenia odsetek od zaciągniętego długu („dźwignia kosztowa"). Zaproponowana definicja pozwala również na inne interpretacje dźwigni finansowej, w tym te, które podkreślają rolę ryzyka bankructwa, wartości zagrożonej (VaR) itp.