

A Critique of Size-Related Anomalies

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This article argues that the size-related regularities in asset prices should not be regarded as anomalies. Indeed the opposite result is demonstrated. Namely, a truly anomalous regularity would be if an inverse relation between size and return was not observed. We show theoretically (1) that the size-related regularities should be observed in the economy and (2) why size will in general explain the part of the cross-section of expected returns left unexplained by an incorrectly specified asset pricing model. In light of these results we argue that size-related measures should be used in cross-sectional tests to detect model misspecifications.

Over the past 30, years researchers have identified a number of related regularities in asset prices that have come to be regarded as anomalies.¹ It has been found

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¹ Keim (1998, p. 35) traces the term *anomaly* to "Kuhn (1970) in his classic book *The Structure of Scientific Reductions*. Kuhn maintains that research activity in any normal science will revolve around a central paradigm and that experiments are conducted to test the predictions of the underlying paradigm and to extend the range of the phenomena it explains. Although the research most often supports the underlying paradigm, eventually results are found that don't conform. Kuhn (1970, pp. 52-3) terms this stage 'discovery': 'Discovery commences with the awareness of *anomaly*, i.e., with the recognition that nature has somehow violated the paradigm-

that the ratio of per-share earnings to price (E/P), the dividend yield and other yield surrogates, the amount of leverage, the size of the firm (as measured by the market value of equity), and the ratio of the book value of equity to the market value of equity (book-to-market equity) are all correlated (in the cross-section) with future asset returns. Moreover, these variables have been shown to explain the cross-sectional variation in asset returns better than the capital asset pricing model (CAPM) or any other (multi) factor model.² In this article we argue that, rather than being examples of asset pricing anomalies, these regularities are all consistent with an economy in which all asset returns satisfy any one of the well-known asset pricing models.

The size-related empirical regularities are widely regarded as anomalous because most researchers believe that they cannot be explained within the current asset pricing paradigm. The size anomaly, in particular, is generally recognized as the most prominent contradiction of the paradigm [see Fama and French (1992, p. 42711. Schwert (1983, p. 9), reflecting on the profession's understanding of the size anomaly, sums it up in this way:

The search for an explanation of this anomaly has been unsuccessful. Almost all authors of papers on the "size effect" agree that it is evidence of misspecification of the capital asset pricing model, rather than evidence of inefficient capital markets. On the other hand, none of the attempts to modify the CAPM to account for taxation, transaction costs, skewness preference, and so forth have been successful at discovering the "missing factor" for which size is a proxy. Thus, our understanding of the economic or statistical causes of the apparently high average returns to small firms' stocks is incomplete. It seems unlikely that the "size effect" will be used to measure the opportunity cost of risky capital in the same way the CAPM is used because it is hard to understand why the opportunity cost of capital should be substantially higher for small firms than for large firms.

As Schwert notes, it is generally recognized that the observed relation between the anomaly variables and return implies that these variables proxy for risk.³ Nevertheless, economists have had little success

induced expectations that govern normal science" (Keim's emphasis).

² A comprehensive review of the anomaly literature is beyond the scope of this article. The interested reader is referred to the many excellent reviews of the subject [e.g., Dimson (1988), Fama (1991), Ziemba (1994) or the special issue of the *Journal of Financial Economics* (vol. 12, no. 1)].

³ See Fama (1976), Ball (1978), Chen (1988), and Keim (1988). Recently, however, Black (1992) has taken issue with this conclusion.

explaining these regularities. Hence, Lo and MacKinlay (1990) and Black (1992) have recently objected to empirical procedures that implicitly use size as a proxy for risk. They point out that no satisfactory theoretical reason has been identified that predicts such a relation.

This article provides a theoretical explanation of *why* relative firm size measures risk. The distinction between the theoretical explanation in this article and all previous work is that our explanation does not rely on a presumed relation between a particular characteristic of the firm and its risk.⁴ Instead we argue that, regardless of what process generates the return of the firm, the empirically demonstrated relation between these variables and expected return should always be observed.

The intuition underlying the above observation can best be illustrated by the following thought experiment. Consider a one-period economy in which all investors trade off risk and return. Assume that all firms in this economy are exactly the same size; that is, assume that the expected value of every firm's end-of-period cashflow is the same. Since the riskiness of each firm's cashflow is different [i.e., the correlation of the cashflows with the underlying risk factor(s) will vary across firms], the market value of each firm must also differ. Given that all firms have the same expected cashflow, riskier firms will have lower market values and so, by definition, will have higher expected returns. Thus, even though all firms are the same size, if market value is used as the measure of size, then it will predict return.

The thought experiment illustrates the main contribution of this article. The reason for the relation between the anomaly variables and the expected return of the firm is not related to the *operating* characteristics these variables measure (e.g., earnings, firm size). Rather, they predict expected return because of the theoretical risk premium contained in the *market* characteristics of these variables. For example, the market value of equity is negatively correlated to average return because it is theoretically inversely related to the risk of the firm. That is, the market value of equity of a firm is affected by (at least) two things. First, relatively bigger firms have relatively higher market values. Second, riskier firms have relatively lower market val-

⁴ For instance, in their theoretical explanations, Ball (1978), Chen (1988), and Jagannathan and Wang (1992) explicitly assume that the operating aspects of their respective explanatory variables are affected by the same risk factors that determine the expected return. Ball assumes that the P/E ratio and risk are related because *earnings* proxies for unmeasured risk. Chen's argument is based on a relation between size (smaller firms are assumed to fluctuate more with business cycles) and risk. Jagannathan and Wang argue that firms that have lost value will have larger systematic risk. Alternatively, Jagannathan and Viswanathan (1988) assume that the systematic risk of firms' cashflows does not vary through time but that the overall expected cashflows (or operating size) of firms do vary through time. They then show that this will induce a negative relation between the systematic risk of a dollar invested in the firm and its relative size.

ues. Therefore, so long as there is no *positive* correlation between the operating size of a firm and its risk, a firm with a low market value is more likely to be riskier than a firm with a high market value.

This article is organized as follows. In the next section we formally derive the theoretical relation between market value and expected return. Next, we provide conditions that imply a similar relation between market value and the part of expected return not explained by an asset pricing model. Finally, we discuss the magnitude of the effect and provide an explanation for the empirical observation that book-to-market equity is a better predictor of return than market value. Section 2 concludes the article.

1. The Predictive Power of Market Value

In this section we formalize the arguments discussed in the introduction. In the context of a one-period model, we show why, even in an economy in which firm size and risk are *unrelated*, the logarithm of a firm's market value always measures the firm's discount rate. The logarithm of market value variable is used because it has received the lion's share of attention in the literature. However, the logic can be applied to explain the predictive power of other anomaly variables such as E/P, dividend yield, book-to-market equity, or simply market value itself. It is also easily extended to a multiperiod framework.

1.1 The relation between market value and return

Consider a one-period economy that consists of a set of firms, I , each of which is a claim to an uncertain end-of-period cashflow, $\tilde{c}_i$, where $i \in I$. The firms are traded on a spot market at the beginning of the period. The value of the i th firm on this spot market is denoted p_i . The continuously compounded return is given by $\tilde{r}_i = \log(\frac{\tilde{c}_i}{p_i})$.⁵ Each firm in this economy is parameterized by the expected value of the logarithm of its cashflow,⁶ $E[\log \tilde{c}_i]$, and its (continuously compounded) expected return, $E[\tilde{r}_i] = E[\log(\frac{\tilde{c}_i}{p_i})]$. The economic interpretation of these two variables is that they separately measure firm size and risk, respectively. We will henceforth define $C_i \equiv E[\log \tilde{c}_i]$ and $R_i \equiv E[\tilde{r}_i]$.

⁵ The empirical studies that have documented the size anomaly have generally used the one-month return. However, as a consequence of the fact that we take the logarithm of market value, continuously compounded returns are positionally simpler to handle and are theoretically more appealing. The difference between the monthly and continuously compounded return is very small: If $\tilde{r}_{m,m}$ and $\tilde{r}_{c,c}$ is the return expressed on a monthly and continuously compounded basis, respectively, then a second-order Taylor expansion gives $E[\tilde{r}_{m,m} - \tilde{r}_{c,c}] \approx \frac{1}{2} E[\tilde{r}_{m,m}^2] = 0.2$ percent for the market portfolio. Using continuously compounded returns greatly simplifies the article without affecting the inferences.

⁶ We again take logs to maintain consistency.

The (cross-sectional) distribution of firms in this economy is given by $L : \mathfrak{R}^2 \rightarrow [0, 1]$, a function of the firms' parameters (i.e., expected log cashflow, C , and expected return, R).⁷ Therefore, $L(c, r)$ is the probability that any randomly selected stock will have an expected log cashflow of c or less and an expected return of r or less. We will assume that the cross-sectional distribution of expected log cashflow in the economy is independent of the cross-sectional distribution of expected return. The economic interpretation of this assumption is that the size of the firm is unrelated to its riskiness. Formally then,

$$L(C, R) = G(C)H(R), \quad (1)$$

where $G : \mathfrak{R}_+ \rightarrow [0, 1]$ and $H : \mathfrak{R} \rightarrow [0, 1]$ are the cross-sectional distribution functions of C and R , respectively.⁸

With no further assumptions, it is possible to show that the logarithm of market value is, by itself, a predictor of expected return. To see this, consider a cross-sectional regression of the expected return of each stock onto the logarithm of its beginning of period market value:

$$R_i = \alpha + \theta \log p_i + \epsilon_i. \quad (2)$$

From the definition of R_i we have that,

$$\log p_i = C_i - R_i. \quad (3)$$

The coefficient θ (i.e., the value if the regression is "run" in the population) is

$$\begin{aligned} \theta &= \frac{\text{cov}(\log p, R)}{\text{var}(\log p)} \\ &\equiv \frac{\int_{\mathfrak{R}^2} (c - r) r dL(c, r) - \int_{\mathfrak{R}^2} (c - r) dL(c, r) \int_{\mathfrak{R}} r dH(r)}{\int_{\mathfrak{R}^2} (c - r)^2 dL(c, r) - (\int_{\mathfrak{R}^2} (c - r) dL(c, r))^2}. \end{aligned} \quad (4)$$

The denominator of θ is strictly positive; hence, we investigate the

⁷ In the cross-section, C and R are random variables (since they differ from firm to firm). We adopt the convention that without a subscript (e.g., R) denotes the random variable, while with the subscript (e.g., R_i) denotes a realization of the random variable (i.e., the expected return of the i th firm).

⁸ We assume independence for expositional simplicity. All that is actually required is that the expected log cashflow of a firm not be too positively related to its expected return, this is, $\text{cov}(C, R) \leq \text{var}(R)$.

sign of the numerator:

$$\begin{aligned}\text{cov}(\log p, R) &= \text{cov}(C - R, R) \\ &= \text{cov}(C, R) - \text{cov}(R, R) \\ &= -\text{var}(R) < 0.\end{aligned}\tag{5}$$

Since $\theta < 0$, any cross-sectional regression of average return onto the logarithm of market value should produce a negative coefficient. The empirical result that average return and the logarithm of market value are negatively correlated is therefore no more anomalous than the observation that risk and return are related. Even when firm size (as measured by expected cashflow) is assumed to be unrelated to riskiness (as measured by expected return), market value will be theoretically inversely correlated with realized return.

1.2 The relation between market value and the unexplained part of return

In this section we will show why market value can add additional explanatory power in any test of an asset pricing model that does not completely explain expected return. The Intuition behind this result is straightforward. In an economy in which the operating size of the firm is unrelated to its riskiness, market value is negatively correlated with all risk factors. Therefore, so long as an omitted risk factor is unrelated to the firm's operating size, market value will also be negatively correlated with the omitted risk factor. Consequently, market value will always provide additional explanatory power in any test of an asset pricing model that omits relevant risk factors that are uncorrelated with operating size. We will use the same economy as in the previous section to show this formally.

Let $\hat{R}$ be the continuously compounded expected return predicted by the asset pricing model that is being tested. In addition to the assumptions made in the previous section, we assume that $\hat{R}$ and C are distributed independently.⁹ That is, like the actual expected return, we assume that the expected return predicted by the asset pricing model is not related to the operating size of the firm. Of course, if $\hat{R}$ and C were related to each other, then, because we have assumed that R and C are unrelated, this relation alone would be evidence that the asset pricing model being tested was misspecified.¹⁰ Formally, then, the

⁹ Again, independence is assumed for expositional simplicity. Assuming $\text{cov}(C, R) \leq 0$ and $\text{cov}(\hat{R}, C) = 0$ will provide the same result.

¹⁰ One way to "fix" this misspecification would be to project $\hat{R}$ onto C to get the part of $\hat{R}$ orthogonal to C . If this is then used as the prediction of the asset pricing model, the model would no longer

asset pricing model assigns a (continuously compounded) expected return $\hat{R}_i$ to the i^{th} firm and this determines $M : \mathfrak{R} \rightarrow [0, 1]$, the cross-sectional distribution of $\hat{R}$ in the economy. The joint distribution function of C and $\hat{R}$ is then given by $M(\hat{R})G(C)$.

Consider a cross-sectional regression test of the asset pricing model in the economy:

$$R_i = \omega + \beta \hat{R}_i + \epsilon_i. \quad (6)$$

The part of expected return not explained by the model (the abnormal return) is the part of R orthogonal to $\hat{R}$. Therefore, ϵ_i is the part of firm i 's expected return not explained by the model. Since this regression is "run" in the population, if the asset pricing model explains expected returns exactly, then $\epsilon_i = 0, \forall i \in I$. If, on the other hand, the asset pricing model only partially explains expected returns, then ϵ will be different from zero. It turns out that whenever ϵ is different from zero, market value will be inversely related to it and must provide additional explanatory power over and above the asset pricing model. To see this, consider cross-sectionally regressing ϵ (i.e., the residuals of the above regression) onto the logarithm of market value:

$$\epsilon_i = \eta + \gamma \log p_i + \zeta_i. \quad (7)$$

The theoretical value of the regression coefficient γ is

$$\gamma = \frac{\text{cov}(\log p, \epsilon)}{\text{var}(\log p)}.$$

As before, the denominator of γ is strictly positive; hence, we investigate the sign of the numerator:

$$\begin{aligned} \text{cov}(\log p, \epsilon) &= \text{cov}(C - R, \epsilon) \\ &= \text{cov}(C, R - \omega - \beta \hat{R}) - \text{cov}(R, \epsilon) \\ &= -\text{cov}(R, \epsilon) \\ &= -\text{cov}(\omega + \beta \hat{R} + \epsilon, \epsilon) \\ &= -\text{var}(\epsilon) < 0. \end{aligned}$$

Thus, whenever $\epsilon \neq 0$, the logarithm of market value is always negatively correlated to it. In an economy in which operating size is unrelated to both expected return and the prediction of the model being tested, the logarithm of market value will always provide additional explanatory power in any test in which the expected return predicted by the model differs from the actual expected return.

be misspecified, a priori, and the results in this section could be applied.

There are, of course, many reasons why the expected return predicted by an asset pricing model might differ from the actual expected return. The obvious reason is that the asset pricing model is misspecified and therefore does not correctly price all relevant factors. It is important to appreciate that this is not the only possible explanation. The asset pricing model might well price risk correctly, but the empirical specification may be incorrect or inappropriate. For example, the CAPM (or single beta model) might in reality hold perfectly, but the test may be conducted using a proxy portfolio that is not mean-variance efficient. The expected return calculated using this proxy would then differ from the actual expected return and so, by the above logic, market value will have additional explanatory power. Similarly, even if the proxy portfolio is mean-variance efficient, the beta of each stock may be estimated with error. Any error in the beta estimate must induce an error in the expected return predicted by the model, and so market value will provide additional explanatory power. Thus, the observation that market value explains the part of return not explained by the CAPM, by itself, is not necessarily evidence that the CAPM is misspecified.

1.3 Magnitude of the effect

The previous subsections demonstrate that market value is theoretically negatively correlated to both expected return and the part of expected return that is not explained by the asset pricing model being tested. Yet neither section addresses how much of the cross-sectional variation in expected return will be explained by market value. It turns out that the fraction of the cross-sectional variation in expected return that is explained by market value depends on how the cross-sectional variation of C compares to the cross-sectional variation of R . The most effective way to demonstrate this is to calculate explicitly the theoretical value of the R -squared statistic (R^2) for the regression in Section 1.1:

$$\begin{aligned} R^2 &= \frac{\text{var}(\theta \log p)}{\text{var}(R)} = \theta^2 \frac{\text{var}(\log p)}{\text{var}(R)} \\ &= |\theta| = \frac{\text{var}(R)}{\text{var}(C - R)} = \frac{\text{var}(R)}{\text{var}(C) + \text{var}(R)}, \end{aligned}$$

where we have used Equations (4) and (5). If the cross-sectional variation in C is small, then R^2 is close to 1 and market value will explain most of the cross-sectional variation in R . On the other hand, if the cross-sectional variation in C is large, then R^2 is close to 0 and market

value will explain only a small fraction of the cross-sectional variation in R .¹¹

Unfortunately, C is difficult to observe empirically, so that actual differences in the cross-sectional variation in C and R are not easily observable. There is, however, some evidence that the relative cross-sectional variation in R is large enough so that the effect identified in this article could completely account for the observed relation between market value and return. Specifically, the only way the existing empirical evidence on the size effect could be consistent with a relatively small cross-sectional variance in R is if C is cross-sectionally negatively correlated with R . That is, the observed inverse relation between market value and return is due primarily to a relation between operating size and risk. However, a follow-up paper [Berk (1994)] finds no evidence of such a relation. Therefore, the empirically observed relation between market value and return must be explained solely by the effect identified in this article.

Perhaps a more sensible approach is to avoid this problem by simply adjusting the market value measure so that it is insensitive to the variation in C . Since we have assumed that C and R are unrelated, one way to do this without affecting the theoretical results derived in the previous section is to normalize market value by expected cashflow. For example, define a new measure: $Q \equiv E[\log \frac{\tilde{C}}{p}] = C - \log p$. It should be clear that results similar to those in Sections 1.1 and 1.2 can be derived for this variable. Yet, unlike the variable $\log p$, the fraction of the cross-sectional variation in R that is explained by Q is independent of the cross-sectional variation in C . That is, if $\Delta \equiv \frac{\text{cov}(Q, R)}{\text{var}(Q)}$ is the coefficient of a cross-sectional regression of R on Q , then

$$R^2 = \frac{\text{var}(\Delta Q)}{\text{var}(R)} = \Delta^2 \frac{\text{var}(C - \log p)}{\text{var}(R)} = 1.$$

Thus, Q explains all of the cross-sectional variation in expected returns. Unfortunately, the expected cashflow is not readily observable and so no researcher has undertaken such an empirical study. However, something quite similar has been done.

Like the expected cashflow, the book value of equity is a measure of the size of the firm that does not theoretically contain a risk premium. As such, one would expect these two measures to be correlated. So long as there is some correlation between the expected cashflow and book value of equity, book equity can be used as a

¹¹ Similar results can be obtained for the regression in Section 1.2; that is, $R^2 = \frac{\gamma^2 \text{var}(\log p)}{\text{var}(e)} = |\gamma| = \frac{\text{var}(e)}{\text{var}(C-R)} = \frac{\text{var}(e)}{\text{var}(C)+\text{var}(R)} = \frac{\text{var}(R)}{\text{var}(C)+\text{var}(R)} - \beta^2 \frac{\text{var}(R)}{\text{var}(C)+\text{var}(R)}$.

control for the cross-sectional variation in expected cashflows. Therefore, the logarithm of the ratio of book equity to market equity is, in principle, a better 'measure of the continuously compounded expected return than is the logarithm of market equity alone. In light of the above argument, it is not surprising that Fama and French (1992, Table III) find that the logarithm of book-to-market equity is a much better predictor of return than the logarithm of market equity alone.

2. Conclusion

Banz's original paper (1981) and the subsequent literature on the size anomaly documented two important empirical regularities. First, it showed that the logarithm of a stock's market value is an inverse predictor of its return. Second, when risk is controlled for by using an asset pricing model like the CAPM, it demonstrated that market value has explanatory power over the part of return not explained by the model (the abnormal return). We have shown that, even in an economy in which firm size and risk are unrelated, the logarithm of market value will be inversely related to expected return. Consequently, market value and expected returns will be negatively correlated in the cross-section. Furthermore, if either the asset pricing model is misspecified or the empirical specification is incorrect, we demonstrate that, so long as this misspecification does not imply a positive relation between operating size and the return predicted by the model, the logarithm of market value will be inversely correlated with the part of return not explained by the model. Our results therefore provide a theoretical explanation of the size effect within the current asset pricing paradigm.

An "empirical anomaly" is, by definition, an empirical fact that cannot be supported by the prevailing theory. As such, an important implication of this article is that it is misleading to refer to the size effect as an "anomaly." The fact that return and market value have been found to be inversely related certainly cannot be regarded as evidence against any asset pricing theory. Similarly, since empiricists usually do not expect the asset pricing models they test to hold exactly,¹² the fact that they do not and that market value is left with additional explanatory power should not surprise anyone. The empirical findings therefore provide no theoretical justification for researchers to look for, in Schwert's words, "the 'missing factor' for which size is a

¹² For instance, the fact that it is empirically obvious that all agents do not hold the market portfolio has not stopped researchers from attempting to test the CAPM. Generally, researchers themselves explicitly recognize the existence of measurement error in their tests [e.g., Fama and French (1992, pp. 431 and 439-440)].

proxy.” There is no one factor that market value “proxies” for. Market value is inversely correlated with unmeasured risk, so the type of risk it will “proxy” for is entirely determined by the asset pricing model that is being tested. If two different asset pricing models miss different factors in the risk premium, then size will “proxy” for different factors in the two tests.

The empirically observed size effect is not, by itself, evidence of a relation between firm size and risk. Nevertheless, based on the empirical evidence, we certainly cannot rule out the possibility of such a relation. This question can only be resolved empirically, and it is therefore the focus of a follow-up paper, Berk (1994). In this paper we find no evidence of such a relation. That is, using four measures of size that do not contain adjustments for risk,¹³ we find no evidence that the size of the firm is in any way correlated to either return or the part of return not explained by the CAPM.

Though our results show that there is no reason to regard the size effect as an asset pricing anomaly, they do provide a sound theoretical justification for using market value related measures to increase the power of an empirical test. For instance, the portfolios used in asset pricing tests can be assured to exhibit substantial cross-sectional variation in their expected returns if market value is used to construct these portfolios. Although previous empirical studies have used market value in this way, Lo and MacKinlay (1990) have pointed out that the authors of these studies provide no theoretical basis for their methodology. Consequently, Lo and MacKinlay (1990) have questioned the conclusions of these empirical studies. Our arguments imply that the results in these empirical studies are indeed valid.

The theoretical arguments in this article demonstrate that variables such as market value have an important role to play in future empirical tests. Since these variables always explain any unmeasured risk, they can be used as a measure of how much of the risk premium remains unexplained by the model being tested. In particular, if a specific asset pricing model claims to explain all relevant risk factors, then, at a minimum, it must leave any market value related measure with no residual explanatory power. As such, the market value related variables loom as natural yardsticks by which all asset pricing models could potentially be measured. Although the econometric work remains to be done, developing the statistical foundations of such a testing procedure is an important task for future researchers.

¹³ Book value of assets; book value of property, plant, and equipment; number of employees; and total value of annual sales.

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