

Negative Denominators in Index Variables: The Vulnerability of Return on Equity, Debt to Equity, and Other Ratios

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Abstract: This paper highlights construct validity issues that can occur when researchers utilize index variables (commonly referred to as ratios) in which the denominator can become negative. These indexes are commonly used in management research, and we demonstrate that indexes constructed from data which includes negative values for the denominator lose their ordinal properties and can be difficult, if not impossible, to interpret. Further, we show that common empirical practices to resolve these issues do not solve issues of ordinality and interpretability and may lead to additional validity issues. We recommend the use of alternate measures not affected by the issues described in this article to increase the validity of future organizational research.

Keywords: Indexes, methodological issues, negative denominators, ratios, research methodology.

1. Introduction

For decades, management scholars have criticized their own field for not placing the same importance on the measurement of variables representing constructs as is placed on the theory connecting those constructs (Venkatraman and Grant, 1986, Lubatkin et al., 1993, Hoskisson et al., 1993, Boyd et al., 2005b, Boyd et al., 2005a, Boyd et al., 2013, Ketchen et al., 2013). A lack of confidence that our measures reflect the constructs we intend them to, forces us to question the validity and reliability of our field's findings (Wiseman and Choi, 2011). One place where this occurs is when scholars use index variables (in which one number is divided by another) to operationalize a construct. It is important to ensure that the denominator of the index cannot become negative. If the denominator of an index can become negative, the data requires careful examination because the validity of any statistical analysis is jeopardized if the data includes indexes with negative denominators. The concern here is twofold. First, these indexes will not possess ordinal properties throughout the full range of observations. This limits our ability to compare different values for such indexes. As is shown in this paper, negative denominators can cause two indexes representing the same theoretical construct to have no statistical relationship to one another. Second, it may be difficult, if not impossible, to interpret the meaning of such indexes when the denominator of the index includes negative values. The inclusion of such cases distorts any analyses based on the related index measures. Evidence from contemporary research suggests that management scholars may not be aware of these issues or address them properly, which may have led to the publication of erroneous or misleading results. Further, when the weaknesses of common negative denominator ratios, such as return on equity and debt to equity, are discussed in publications, the issues outlined in this paper are not highlighted (Gallo, 2016, Gallo, 2015).

The purpose of this research paper is fivefold. First, we explain and illustrate why organization scholars should exhibit caution when using indexes in which the denominator can be negative, which we title *negative denominator indexes*. Second, using variables from strategic management as exemplars, we highlight the prevalent use of negative denominator indexes which suggests that scholars are unaware of this problem because most research papers do not mention transformations to negative denominator indexes. Therefore, we review negative denominator indexes used in strategic management, and show the frequency in which these measures are used in major publications. Third, to illustrate the effects on analyses, we replicate relative aspects of a published study and show substantial changes in results when accounting for our concerns. Fourth, we critically review potential remedies of the problems described and find that transformations of negative denominator ratios have potential flaws. Finally, we offer recommendations that improve the interpretability of findings.

2. Literature Review

Before we begin, it is important to define and clarify our terminology. Following established terminology (Stevens, 1951), we refer to single variables such as net income, total assets, total liabilities and total equity as *scales*. Scales can either be nominal, ordinal, interval, or ratio in nature. When one scale is divided by another scale, such as net income divided by total assets to create the measure return on assets, we refer to the quotient as an *index* (following Cohen et al., 2003). Analog to scales, indexes can have nominal, ordinal, interval, or ratio properties.

The appropriate use of indexes has gained more scrutiny in the business literature recently (Faello, 2015). Additionally, indexes are prominently being used in contemporary research in the areas of firm performance (Mubashar and Tariq, 2017), operations (Färe and Karagiannis, 2017), real estate (Mills, 2016) as well as accounting and finance (Kristanti and Herwany, 2017). Indexes serve three roles in data analyses (Bollen and Ward, 1979). The first purpose of an index is to attempt to measure a theoretical concept. This may best be exemplified by the use of administrative ratios in organizational studies which is defined as the ratio of administrative personnel to production personnel (Millan and Daft, 1979). The second purpose of an index is to scale a variable for size effects, for example scaling (also known as deflating) R&D expenditures to some measure of firm size. Finally, indexes can be used in an attempt to correct for heteroscedasticity. In all three roles that indexes serve, their use should be done with caution (see Bollen and Ward, 1979 for a review).

According to Millan and Daft (1979) and Stevens (1951), for a scale or index to have *nominal* properties, we must be able to determine if one value is equal to another. An example of a nominal scale is an indicator variable which denotes gender in a sample. *Ordinal* scales allow a researcher to determine if one point on the scale is greater or less than another point on the scale. Likert scales with 'strongly disagree' to 'strongly agree' are examples of ordinal scales. *Interval* scales have the added property that equal intervals between points on the scale represent equal conceptual distances of the construct the scale is meant to represent. For example, the difference between 80 and 82 degrees Fahrenheit and the difference between 90 and 92 degrees Fahrenheit is the same measurable amount of two degrees. For scales or indexes to have *ratio* properties, they must have all of the above properties as well as an absolute zero point, denoting the absence of the construct being measured. An example of a ratio scale would be the balance in a checking account, which may be zero, reflecting the absence of money.

Indexes have been seen as a cause for concern in management research when used as dependent variables (DVs) (Wiseman and Choi, 2011). Spurious parameter estimates in ordinary least squares regression will most likely occur when independent variables (IVs) and dependent variables (DVs) are both divided by the same variable (such as firm size). Similar spurious results can also occur between completely independent DVs and IVs after the DV becomes a ratio (divided by another variable) (Wiseman and Choi, 2011).

These recent findings prompt us to take a close look at other potential spurious results that may come from commonly used indexes, specifically when an index denominator may be negative. When indexes have negative denominators two major issues occur when attempting to interpret results or data. We will address each issue independently, but both pertain to construct validity. The first issue is that negative denominators make the ratio difficult to interpret as a theoretically coherent continuous variable. The second issue is that negative denominator ratios may not reflect the theoretical construct that we as researchers are interested in.

2.1 Negative Denominator Indexes

Given the critical roles that indexes serve in empirical research, it is important to understand why scholars should be concerned about negative denominator indexes. In the following, we use the term *negative denominator index* to refer to indexes which have the *potential* to be constructed with negative values in their denominator. Negative denominator indexes are important because they influence the validity of how constructs are operationalized in two important ways. *First*, negative denominator indexes may lack ordinal properties, and *second* they may suffer from a lack of interpretability (both issues will be explained later with the use of Figure 1). These issues have been raised in the accounting literature (Trimbath, 2006), but so far have been neglected in the broader organization and management research methods literature. To better demonstrate these issues with negative denominator indexes, we utilize firm equity as a scale commonly used as a denominator in strategic management research. Although negative equity sounds like an oxymoron and is generally considered a rare exception, our analysis, discussed later, shows that it is more common than initially

expected. Negative equity can occur when a firm experiences losses, depreciation of assets without offsetting increases in equity, takes out loans for non-asset expenditures such as payroll or marketing, or through the depreciation of assets. The importance, and prevalence, of firms with negative equity was highlighted in a recent paper. The paper used an indicator variable of negative equity as a dependent variable reflecting a firm's survivability in the context of financial, political and governance factors (Kristanti and Herwany, 2017). As detailed later, approximately 7.95% of COMPUSTAT firms have negative equity, which have empirical effects on data analyses.

2.2 Lack of ordinal properties

Recall that for a scale or index to have ordinal properties, lower or higher values must reflect a lesser or greater amount of a construct, respectively. However, when an index has a denominator that can become negative, and a researcher's sample contains both positive and negative denominator values, the index will not possess ordinal properties.

This can be demonstrated using a common measure of firm performance: return on equity (ROE). If ROE is calculated for a firm which has negative equity, ROE takes on the inverse ordinal properties that we would wish for it to display. Figure 1 illustrates in a hypothetical example how ROE changes for a firm with 10 million in net income and 30 million in assets *as liabilities are increased*. At point A, the firm has 31 million in liabilities, resulting in -1 million in equity. Thus, the ROE value is -10 (e.g., $10/-1$). At this point, a firm with low levels of negative equity seems to have an extremely low performance when an ROE index is calculated. At point B, the firm has 60 million in liabilities, resulting in -30 million in equity. When ROE is calculated, it is -.33 (e., $10/-30$). Per this situation, the firm has more debt at point B and should be in a worse financial position than at point A. However, when using ROE as a measure, at point B the firm would be *incorrectly* interpreted as having better ROE performance than a firm at point A. Therefore, if a scholar uses ROE as a measure of firm performance with firms in their dataset with negative equity, ROE will not have ordinal properties and will not be a useful measure of firm performance.

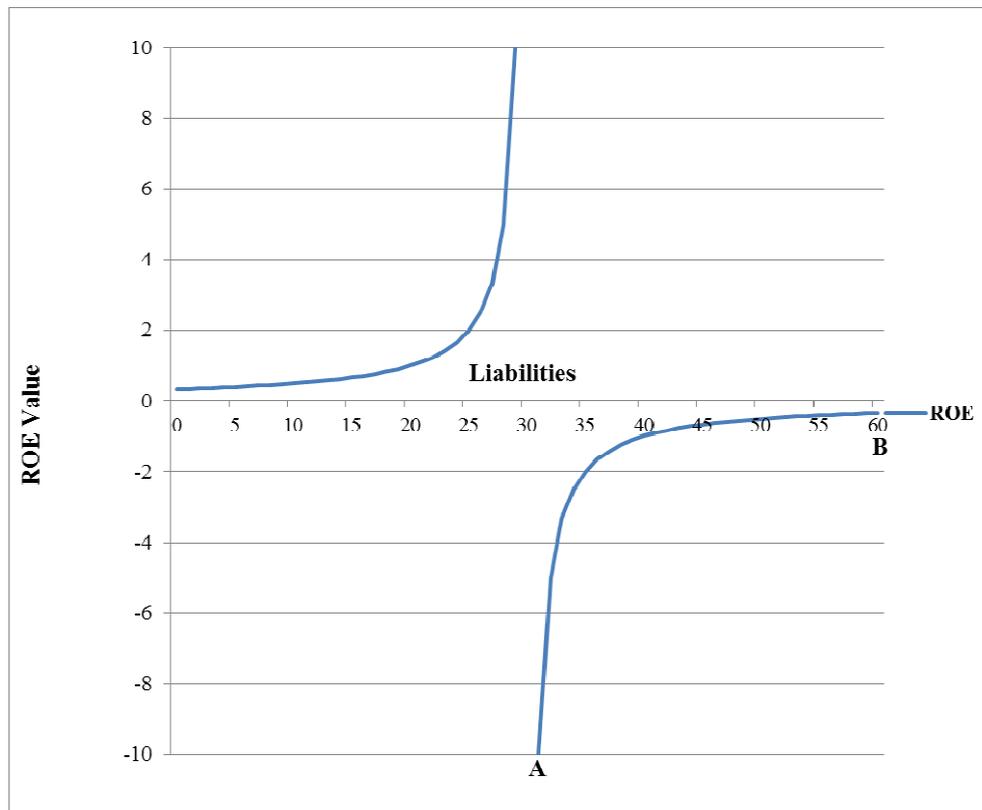


Figure 1: Return on equity as liabilities increase

2.3 Loss of interpretability

When the firm's equity is negative, the ROE of the firm is negative when net income is positive. In this situation, a common perception of negative ROE would suggest the firm is unprofitable and unsuccessful, which is incorrect since in reality the firm is profitable. Practitioners are aware of this misinterpretation issue and generally omit negative ROE values from their analyses (Jensen Investment Management, 2011). The question becomes: why do we as scientists not take the same precautions in statistical analyses? After all, it is simply the division by a negative equity value that causes the aforementioned firm to appear unprofitable. If a researcher's sample has profitable firms with negative equity in it, these profitable firms would seem to be unprofitable according to the ROE index.

Additionally concerning, firms with negative equity *and* negative profits would have a positive ROE. This positive ROE would make the firms appear to be profitable, when in fact the firm is in a dire situation (unprofitable and negative equity due to more liabilities than assets). In our research of the prevalence of negative equity ratios (next section) we found one study that seems to have firms exhibiting this exact issue (Kulich et al., 2011). The study reports that firms in their sample have a mean ROA (net income divided by assets) of -1.96. Since a firm cannot have negative assets (the denominator), this negative value suggests that net income (the numerator) *must* be negative. A negative ROA would not normally be of concern, but the authors also report a ROE of 6.25. Since we deduce that the firm's sample of firms have a negative net income, in order to get a positive ROE, equity (the denominator) must be negative as well. Therefore, we have found evidence that the results of this study may be flawed due to the presence of negative equity.

In both of the situations outlined above, interpreting the results from statistical analyses becomes difficult when ROE is used as an independent or dependent variable. The issue will also occur with other negative denominator indexes, such as debt to equity (DTE). Next, we explore the relevance of these aspects within strategic management research as an exemplar.

3. Methodology

We elected to examine the use of negative denominator indexes in strategic management because the field's constructs, particularly in the area of firm performance as well as the use of archival data, have been gaining increased attention in the field of research methods (Boyd et al., 2013, Hamann et al., 2013, Mubashar and Tariq, 2017). We raise four sequential questions regarding the relevance of our study. First, to what extent do strategic management scholars use negative denominator indexes, such as ROE and DTE, in their research? Second, do a meaningful number of firms in these analyses have negative equity? Third, do negative denominators influence the relationship between conceptually similar variables? And fourth, do negative denominator ratios influence the results of strategic management studies?

To answer the first question, we examined the use of negative denominator indexes in two top management journals: The Academy of Management Journal and the Strategic Management Journal. Second, we then examined how many firms have negative equity by looking at financial data on major firms for the last thirty years using COMPUSTAT. Next, to determine if negative equity ratios influence financial ratios, we selected a conservative sample of firms with negative equity and examined whether or not conceptually similar variables, such as ROA and ROE, had high correlations which would suggest that negative equity had no effect on results in the literature. Lastly, to determine if current studies succumb to issues outlined in this paper, we replicated a study and examined how some of the final results of the paper may have been influenced by negative equity.

4. Results

Strategy scholars are primarily concerned with understanding the sources of firm performance (Penrose, 1959, Wernerfelt, 1984, Barney, 1991). When the construct of firm performance is operationalized through an empirical measure, it typically involves assessing a firm's profitability. To compare firms of different sizes, a firm's profitability is often deflated (i.e., divided) by the firm's sales, assets, or equity. Our specific concern here is with equity-based deflation because equity, unlike sales and assets, can be negative. Such a deflation leads to a common measure of firm performance: ROE (net income divided by total equity). ROE has been described as the "ultimate measure of the strength of any financial institution" (Richard, 2000 p.60 citing Earle & Mendelson, 1991). ROE is most commonly used as a measure of firm performance (Ming-Jer et al., 2010, Tian et al., 2011, Tuggle et al., 2010, Ortiz-De-Mandojana and Bansal, 2016, Kim et al., 2015) and a measure of profitability (Lee and Makhija, 2009, Cho et al., 2016, Vedd and Yassinski, 2015). In a review of the *Academy of*

Management Journal (AMJ) and the *Strategic Management Journal* (SMJ) from 2000 to 2011, as shown in Table 1A ROE was used in approximately 20% of studies that utilized either ROA or ROE. This suggests that ROE is a commonly used measure of firm performance in the field of strategy.

Another important factor to consider when explaining the determinants of firm performance is the amount of debt a firm carries. A heavily indebted firm may have large debt payment obligations that reduce the amount of cash the firm has to invest in future projects. Further, a heavily indebted firm may be unable to borrow additional funds at reasonable interest rates. This may make it difficult for a firm to obtain capital that will allow it to grow or survive a downward trend in the business cycle. On the other hand, a very low debt level suggests that a firm's resources are underutilized and opens the door for hostile takeovers. A medium debt level is thus generally preferred (van Binsbergen et al., 2011). Therefore, strategic management scholars often control for the amount of debt a firm has when conducting statistical analyses. A common measure of a firm's indebtedness is DTE (total liabilities divided by total equity). DTE has been used as a measure of slack or potential slack (Greve, 2011, Desai, 2016), leverage (Ho et al., 2011, Muller and Kräussl, 2011, Xia and Li, 2013, Pathak et al., 2014, Ma and Khanna, 2016) and solvency (Hermelo and Vassolo, 2010, Nadolska and Barkema, 2014). In our review of *Academy of Management Journal* and *Strategic Management Journal* articles from 2000 to 2016, as shown in Table 1B we found that DTE was used 83 times (approximately 75% of studies) as a measure of debt. In contrast, debt to assets (DTA), an alternative to DTE was only used 28 times (25%) in our review. This suggests that DTE is a *preferred* measure of a firm's relative debt level. Therefore, we conclude that equity based measures of firm performance and debt are commonly used in management research and, in light of our discussion above, may be a source of serious concern. However, these variables are only two examples of negative denominator ratios and the implications of indexes with denominators that can become negative go beyond ROE and DTE.

A methodologically troubling observation in our review of AMJ and SMJ papers is that we find scant information regarding whether or how authors transform equity-based measures to avoid loss of ordinal properties or loss of interpretability. We do find that some scholars have commented on the issues with equity indexes (Greve, 2003, Iyer and Miller, 2008) which suggest some awareness of the issue. But as shown, scholars continue to use equity based measures without describing their transformations to avoid the issues outlined in this paper.

4.1 Prevalence of negative equity and its effects

Even though management scholars use equity based measures of firm performance and debt, two important questions to answer are whether or not negative equity is prevalent in a large number of firms and does negative equity influence the relationship between conceptually similar variables? To answer these questions we examined the population of COMPUSTAT firms from the last thirty years which data was available: 1986 to 2015. We find that on average 7.95 percent of firms had negative equity. The minimum and maximum were 5.3 percent in 1994 and 11.69 percent in 2002. As explained earlier, the ROE values of those firms will reflect the opposite of their actual performance. Since this paper uses equity indexes as an exemplar of negative denominator indexes, and we are concerned with their effects on the validity of statistical analyses, we ran correlations between conceptually similar variables. Because our data had shown that 1994 had the smallest percentage of firms with negative equity, we employed this year's data to ensure a conservative comparison. When we examine the zero order correlation between DTE and DTA— both measures of firm indebtedness—the correlation for the 1994 sample is 0.0001. The correlation between ROE and return on assets—both measures of firm financial performance—is 0.0007. These findings suggest that even a small percentage of firms with negative equity in a sample can cause the relationship between two conceptually related variables to become statistically non-existent [We ran several alterations to the data to determine whether that the lack of correlation can be alleviated through adjustments to the negative equity values. We address those adjustments in our discussion]. This is a major concern from a construct validity standpoint because we would expect measures the same construct to be highly correlated (Cronbach and Meehl, 1955). Given these analyses we conclude that a large enough percentage of public firms have negative equity, thus scholars should be concerned with the results of studies using equity-based indexes.

4.2 Do negative denominator ratios influence findings?

Alarmed by these findings we wanted to know if management scholars are using negative denominator indexes in their publications without addressing the statistical issues inherent in them. In our literature review of AMJ and SMJ we found several studies which reported DTE variables with low means and standard deviations over ten times the size of the mean (McDonald et al., 2008, Chakrabarti et al., 2007, McNamara et al., 2008). Because the DTE index cannot be negative unless the firm has negative equity (since a firm cannot have negative debt), the high standard deviations suggest that these studies may have observations with negative equity. This suggests that these studies may suffer from the issues of negative denominator indexes we address in this paper. However, this may also be caused by severe skewness in the data underlying those variables. To investigate this further, we set out to replicate published findings to further check the legitimacy of our concern.

4.3 Replication of prior work

We attempted to replicate one study that used ROE as the main variable of interest (Henkel, 2009) in order to provide empirical evidence of the problem we are investigating. This study contributed to the literature on the risk-return paradox. It suggests that skewness in measures of firm performance, by looking at the means and standard deviations of ROE in the sample, may have caused spurious outcomes in previous studies. We decided to replicate this paper because the author should have been intimately familiar with the mean and standard deviations of the ROE variable of their dataset, yet used negative ROE values in their analysis. Further, this study’s methodology did not require any proprietary data in order to replicate. While our purpose here is in no way to contend the arguments put forth in this paper, through our replication we are able to show that (1) the author did include firms with negative equity in the analysis and (2) our removal of these observations caused substantial changes in the results.

When we attempted to replicate the Henkel’s study, we were unable to obtain the same results in terms of number of observations and correlations between means and variance for some SIC codes. Table 1 offers a comparison of Henkel’s (2009) results and our replication for the eight industries which we were able to *replicate without error*. The table displays the correlations between the mean and variance for an industry’s ROE for a ten year period from 1970–1979. Of those eight industries, three had at least one firm with a year of negative equity. We eliminated these firms from the dataset and recalculated the correlations. The results are remarkable; the elimination of a single or two firms with negative equity dramatically changes the correlations for each industry. Notably, it not only leads to substantial changes in magnitude but all three industries show a reversal of the relationship. For example, the correlation for SIC 26 changes from -0.19 to 0.76. It should be noted that we are not able to state that these reversals of correlations affect the author’s findings, because we were unable to replicate the entire dataset. However, these results support our contention that negative denominator indexes can create for extreme outliers in a dataset, which have the ability to severely influence the empirical findings of a study. Further, it suggests that outliers are not always eliminated from a published study’s dataset, even when an author’s study is intimately concerned with the mean and standard deviation of a negative denominator index, such as ROE.

Table 1: Partial replication of Henkel (2009)—selected industries

SIC	Henkel (2009)		Replication post removal of negative equity firms		
	# Firms	r	# Firms	r	Difference
23	13	-0.63	13	-0.63	0.00
25	12	-0.10	12	-0.10	0.00
26	18	-0.19	17	0.76	0.95
27	22	-0.30	22	-0.30	0.00
49	108	0.55	108	0.55	0.00
51	16	-0.51	15	0.07	0.58
53	11	0.57	11	0.57	0.00
60	29	-0.16	27	0.54	0.70

5. Discussion & Recommendations

Without the confidence that our measures reflect the constructs we wish for them to reflect, the validity and reliability of a history of findings in the field of management may need to be questioned (Wiseman and Choi,

2011). As such, management scholars should be concerned with the ordinal nature and interpretability of negative denominator indexes. We agree with Wiseman and Choi when they state:

“we may have to reexamine what we know about the determinants of firm performance if the results from prior research have been the product of spurious or misinterpreted findings due to the use of ratio [i.e., index] measures” (2011, p.3)

It is important to note that ROE and DTE are simply exemplars of index variables displaying issues regarding ordinality and interpretability. Any index in which the denominator can become negative may not possess ordinal properties or be interpretable at all possible values. For example, when scholars take the z-score of a variable, or mean center a variable, half of the values in the sample for the variable is positive and the other half is negative. If the variable's values were to be used as a denominator in an index, the issues described in this paper will occur.

It has been suggested to the authors that researchers are aware of these potential construct validity issues and that researchers transform their data to avoid the issues. There are indications of such adjustments in the data of some studies, as we see a variety of different correlations within sets of COMPUSTAT data referenced in some studies, but no explicit mentioning of it. Therefore, as noted before, there is a lack of information regarding the transformations researchers make to their data, and if any transformations are made at all. More importantly, even if transformations are being made without noting them in research papers, no empirical transformation is known to the authors to solve the issues of ordinality, interpretability, and construct validity that does not create further empirical issues (Trimbath, 2006). We illustrate this argument with our prior COMPUSTAT data.

Recall that our initial correlation for the 1994 COMPUSTAT sample between DTE and DTA, measures for the same theoretical construct, was 0.0001. Several methodologies were used to find an inferentially valid transformation to increase this correlation. First, when we eliminate all negative DTE values caused by negative equity, the correlation between DTA and DTE was .02 suggesting no relationship. In addition, this transformation non-randomly eliminates potentially important data points. Second, when we transformed all negative DTE values cause by negative equity to the maximum positive DTE value in the sample to more accurately represent heavily indebted firms, the correlation was 0.05. Third, in our research we noted a recent article transformed DTE by taking of log DTE (Judge et al., 2015). We replicated this transformation in our sample and the correlation with DTA is at the 0.96 level. On the surface this seems to solve our stated problem. However, taking the base 10 log of DTE eliminates all negative DTE values, a non-random elimination of data. This elimination may be acceptable for debt measures since it is difficult to conceptualize negative debt. However, this transformation is not acceptable for profitability measures, such as ROE, because firms can be unprofitable.

Finally, it has been proposed that ranking measures in a sample, such as ranking firms on performance from the most successful firm to the least successful firm, may be useful to strategic management scholars (Powell and Reinhardt, 2010). However, to rank firms requires that the measures possess ordinal properties which may not occur with negative denominator indexes. Therefore, it is the opinion of the authors that transformations of indexes with negative denominators have little chance of solving the issues of ordinality and interpretability while achieving construct validity.

To remedy these issues we recommend that researchers do one of the following. First, rather than deflating (dividing) a scale for a measure of firm size, use the numerator of an index as a scale variable. For example, use net income as a measure of firm performance without dividing it by another scale. Researchers can control for the size of an organization by introducing measures of firm size into their models as control variables. Second, if deflating a scale is necessary, deflate the numerator by a variable which cannot become negative. As an alternative to ROE, we suggest management scholars use ROA because assets cannot be negative. An analog substitute for DTE would be DTA. Third, scholars can examine subsets of their data to determine if observations with negative denominators provide different results than other observations. If a difference is detected and cannot be resolved, the difference should be noted in the scholar's methodology. If these three suggestions are not suitable, we refer scholars to recent work regarding best practices for the treatment of outliers (Aguinis et al., 2013).

Even though we are not able to find a transformation that resolves the issues of ordinality, interpretability, and construct validity we encourage other scholars to pursue the issue. While we found accounting and financial literature that has mentioned these issues (Trimbath, 2006), to our knowledge these fields do not have solutions to the issues. Perhaps collaboration among research methodologists from multiple areas, as well as researching new techniques from the fields of mathematics, will provide novel solutions.

We believe the issue of negative denominator indexes is of deep concern, yet the larger field of management is most likely unaware of the issue. More publications on the topic may help close this knowledge gap, and we believe one of the best ways to do so is through replication of prior work. If prior studies can be replicated, and negative denominator indexes can be shown to have an effect on the results of the study, then the field may question some of the field's major findings. Not only would this help to promote understanding of negative denominator indexes, it would help the field by shining light on erroneous empirical findings that other scholars may be basing their work off of.

6. Conclusion

We believe that achieving construct validity is quintessential to any empirical study. In this paper we have shown how indexes will not portray ordinal properties if the sample includes denominators with negative values. We have also shown that these indexes may not be interpretable. In addition, we have shown that datasets with a small amount of negative denominators can make two theoretically similar variables become statistically unrelated. Finally, we provide alternatives to negative denominator indexes as well as recommendations to scholars using indexes with similar characteristics. These issues are of serious concern to the validity of published results, due to the prevalent use of negative denominator indexes, such as DTE and ROE, in strategic management research. As we cannot undo the past, we hope that raising our concerns will aid in increasing the validity in future studies. As such, it is our hope that this research note informs future empirical research and adds to our field's knowledge of methods and measurement.

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