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# Do statistical myths and urban legends matter for the sustainability of strategy research? The case of moderation analysis

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## Abstract

Statistical and methodological myths and urban legends (MULs) are perpetuated truisms which in reality are not true. It is widely believed that MULs can perpetuate incorrect methodological decisions, lead to misapplications of analyses, produce inaccurate inferences and provide errant guidelines for reviewers and editors who decide on the merit of manuscripts. However, other than identifying the practices that can lead to MULs and documenting their likely existence, few if any studies have considered their implications for theory development. In the present study, we test whether an MUL associated with using hierarchical linear regression analysis to test moderation can lead to differences in findings and influence conclusions: we address two questions in particular: (1) Did strategy scholars employing hierarchical linear regression interpret and make conclusions regarding main effect coefficients separately from significant interaction terms and (2) would the findings change if such an interpretation would have been made jointly with significant interactions? Based on a content analysis of *SMJ* articles, we find that MULs are present with respect to testing moderation and that they could adversely influence results and proposed implications for theory and knowledge development. We find that MULs matter in strategic management research and could shape the sustainability of its knowledge base.

**Keywords:** statistics, research methods, linear regression, strategic management research

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## Introduction

For over a decade, there has been a crusade within the organizational sciences to educate scholars as to the prevalence of statistical and methodological myths and urban legends (MULs). Vandenberg (2006, pp. 195-196) first defined MULs by characterizing them as follows:

“Doctoral students may be taught or told something to do within the research process as if it were an absolute truth when in reality it is not, and yet, being who they are, they accept that presumed fact as the “truth.” Similarly, authors may accept something from an editor or a reviewer who in turn was told that “this” is the way it must be as well. The unfortunate outcome is that the truism being perpetuated is anything but true. These are aspects of the research process that are, in reality, myths or urban legends. At one point, there may have been a kernel of truth to it, but that kernel has long been forgotten or altered in such a way as to be lost. Rather, unbeknownst to the student, author, reviewer, and editor applying the criterion, it is a criterion of the legendary kind (i.e., “my grandpappy . . .”). There are all kinds of deleterious side effects to this, not the least of which may be the unfair evaluation of a manuscript against criteria that are mythical in nature or the application of the criteria in undertaking some aspect of the research process resulting in a finished study of questionable quality. The overall end result, however, is a degradation of the whole research process.”

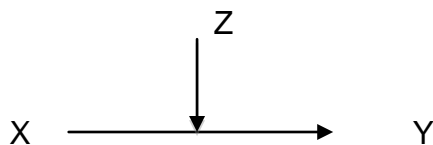
MULs can potentially result in improper methodological choices during study design and execution, and the misapplication of analytical procedures can result in findings and inferences that are wholly or partially inappropriate or outright false (Lance and Vandenberg, 2009; Vandenberg, 2006; Vandenberg, 2011). Scholars are not alone. Editors and reviewers have also developed decision scripts from the MULs against which to judge the publication worthiness of journal submissions. However, those heuristics and criteria are frequently inappropriate.

The present paper examines whether the application of MULs in strategic management research with respect to moderation may have led to problematic interpretations and conclusions that shapes the sustainability of empirical findings and knowledge development. The purpose of our study is to assess a sample of empirical strategy studies that use hierarchical linear regression to test moderation and then document whether the application of a popular MUL may have led scholars to misinterpret their findings. We address two questions in particular: (1) Did strategy scholars employing hierarchical linear regression interpret and make conclusions regarding main effect coefficients separately from significant interaction terms and (2) would the findings change if such an interpretation would have been made jointly with significant interactions?

Our study considers a sample of published articles in the *Strategic Management Journal* from 2000 through 2009. Our purpose in doing so is constructive. Specifically, the results not only tell us how these analytical tools have been historically applied in general, but in cases where there may have been shortcomings (i.e., the myths underlying each have been widely accepted), we can pinpoint where in the analytical process a shortcoming emerged. Per Vandenberg (2011), this information should be used to educate scholars as to what the appropriate course of action should have been and why. The intent is to improve scholarship by highlighting the side of the analytical tools considered to be mythical or urban legend in nature. Strategy scholars need to know what the myths and urban legends are, how MULs can adversely affect results and implications, and what they need to do to improve their studies.

## Moderation

Moderation occurs when one variable (the moderator) influences the relationship between two other variables and produces an interaction effect. Typically viewed in terms of contingency models, moderation has long played a key role in theory development and empirical testing in the strategic management literature (cf. Venkatraman, 1989; Venkatraman and Prescott, 1990). For example, moderation is often considered as whether environmental conditions modify the strength of the relationship between strategy variables and subsequent performance (Prescott, 1986) and if CEO power shapes the relationship between board composition and performance (Combs et al., 2007). In its simplest form, a moderating effect is depicted as follows:



In the absence of a moderator,  $X$  is expected to predict  $Y$ . The moderator term,  $Z$ , however denotes that the strength of the  $XY$  relationship will vary depending on the level of  $Z$ . Indeed,  $Z$  could theoretically amplify, dampen, or reverse the effect of  $X$  on  $Y$ .

Although there are exceptions, moderation is most frequently operationalized in a multiple regression framework by introducing the product of the independent variable and the moderator variable ( $XZ$ ) into the regression. Boyd et al. (2012: 288) note that this approach is now widely adopted in strategic management research, as scholars in this field 'frequently test moderation using interactions of predictor variables (e.g., cross-product multiplicative terms), which are added to a regression model'.

Edwards (2009) notes that while an important tool in the organizational sciences, there is still a great deal of confusion in conducting moderation tests. An unfortunate side effect to this confusion is the development of certain myths that have crept into published studies and are now being adopted by others as truth. Edwards (2009)

identifies seven myths with regard to moderation tests which often “lead researchers to make unwise choices, waste time and effort, and draw conclusions that are misleading or incorrect” (p. 143). The seven myths are Myth 1: Product terms create multicollinearity problems; Myth 2: Coefficients on first-order terms are meaningless; Myth 3: Measurement error poses little concern when first-order terms are reliable; Myth 4: Product terms should be tested hierarchically; Myth 5: Curvilinearity can be disregarded when testing moderation; Myth 6: Product terms can be treated as causal variables, and Myth 7: Testing moderation in structural equation modeling is impractical.

Although each myth has potential implications for findings and interpretations, we focus on Myth 4, as its application can be empirically identified and its effects directly assessed. More specifically, according to Myth 4, conventional wisdom indicates that moderation variables should be tested in a two-stage hierarchical manner, where  $X$  and  $Z$  are included in a base model (first-stage) and then the  $XZ$  product term is added in a second stage. A statistically significant coefficient and  $F$ -ratio associated with adding the product term in the second model provides evidence of the moderation effect.

However, this procedure is subject to two drawbacks. ‘First, when a moderating effect is captured by a single product term, such as  $XZ$ ... hierarchical analysis is unnecessary because the  $F$ -ratio... will give the same result as the  $t$ -test of the coefficient on  $XZ$  (Cohen, 1978; Jaccard et al., 1990; McClelland & Judd, 1993). A second drawback... is that it can generate interpretations of the coefficients on  $X$  and  $Z$  that are misleading’ (Edwards, 2009: 150-151). This latter outcome is due to the fact that the  $X$  and  $Z$  terms are typically entered first followed by their product term.

More specifically, the MUL occurs when researchers (1) interpret the first-order coefficients in the first-step, before adding the product term,  $XZ$ , and (2) then interpret the product term in the second step. Edwards argues that such a process invites errors. He demonstrates that the first-step interpretations are ‘unconditional, such that the effect of  $X$  on  $Y$  is viewed as a constant across levels of  $Z$ , and likewise, the effect of  $Z$  on  $Y$  is viewed as a constant across levels of  $X$ . However, if the coefficient of  $XZ$  is significant in the second step, then the effects of  $X$  and  $Z$  are both conditional, such that the effect of each variable depends on the level of the other variable’ (page 151). Thus, scholars that apply the hierarchical approach to testing first-order effects unnecessarily invite the unconditional interpretation of direct effect coefficients in the base model. In sum,

‘when the second step indicates that moderation exists, *the coefficients on  $X$  and  $Z$  in the first step should be disregarded* because, by definition, moderation means that the effects of  $X$  and  $Z$  on  $Y$  are not each represented by a single value, but by a range of values that vary across levels of the other variable. This variation is not captured by the coefficients on  $X$  and  $Z$  from the first step, and reporting these coefficients invites their interpretation, which is unwarranted when the second step gives support for moderation’ (Edwards, 2009, p. 151, italics added).

Have strategy researchers applied the MULs regarding interpreting main effect coefficients separately from significant interaction terms? Do these practices potentially result in misleading inferences and thereby threaten the sustainability of research findings and interpretations?

## **Method**

The population of papers studied was moderation articles published in the *Strategic Management Journal* between 2000 and 2009. We chose this journal because it publishes only strategic management research and using it as our source of articles reduces guesswork as to whether a particular article can be considered within the strategic management research domain. A manual examination of each of the published articles during this period resulted in the identification of 242 moderation articles which tested moderation by product terms. We randomly selected 20 percent of the moderation ( $n = 57$ ). Some of these articles did not provide sufficient data for further analysis. The final sample was 48 moderation articles.

Next, we developed coding schemes to operationalize the MULs. We deconstructed Myth 4 into its detailed components and then: created variables for each, developed questions for each variable in an explicit and clear manner, and captured additional textual-related details associated with Myth 4 through open-ended questions. Two coders developed a detailed rubric for guiding the data collection process (the rubrics are available upon request). The rubric was first applied to two randomly selected papers with each coded independently by the two coders. Comparisons of the coders' application of the rubric produced an 88% agreement rate. Differences were discussed, the rubric was revised, and the coding was redone until 100% agreement was reached. This process was repeated for three additional papers in the sample. Afterwards, the remaining articles were divided between the coders for independent classification. At the end of the process, the two coders independently coded and compared two more articles. In addition, to test for generalizability, four additional articles were randomly selected from the population of moderation papers and coded. Reliability tests revealed no differences between the coders.

## **Findings and Implications**

In considering whether MULs matter for strategic management research and the possible sustainability of findings and theory, we address two questions: (1) Did strategy scholars employing hierarchical linear regression interpret and make conclusions regarding main effect coefficients separately from significant interaction terms and (2) would the findings change if such an interpretation would have been made jointly with significant interactions? Findings indicate that strategy scholars have applied Myth 4 in their tests and interpretations of moderation. More specifically, we find that over 80 percent of the studies that tested moderation used hierarchical regression analysis, the two-stage approach, where a base model of results and then the second model are presented. Our assessment of the conclusions from these studies reveals that nearly half of the coefficients of the first-order terms either gained or lost significance in the full

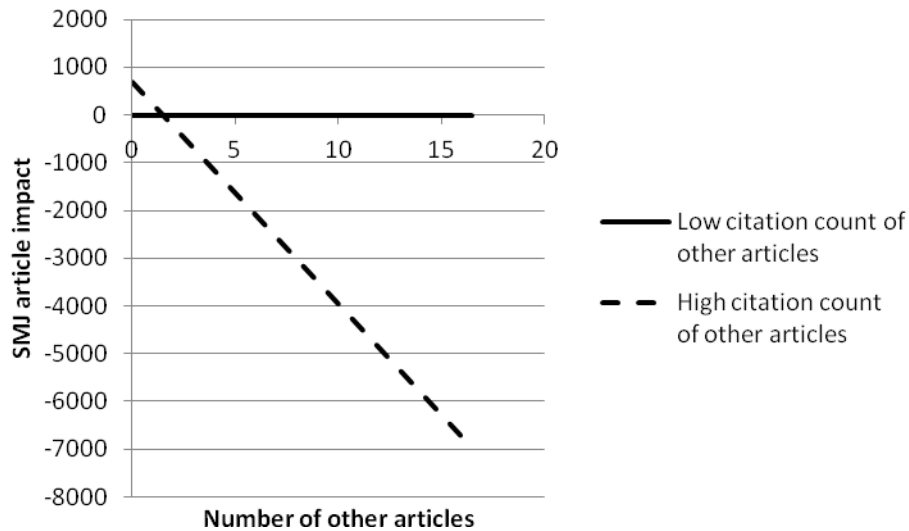
moderated model (the second stage) compared to the base model which did not include the product variable. In these cases, the conclusions reached about the direct effect of the first-order variables would depend on which model the author chose to use as the basis for their interpretation. The most common choice was to interpret the direct effect coefficients from the base model but not the moderated model. To put it another way, many strategists report results that had direct effects which were significant (insignificant) in the base model but became insignificant (significant) in the moderated model, even though the authors interpreted direct effect coefficients only in the base model. Thus, the MUL is not only practiced in strategic management, many scholars have likely misinterpreted their study's findings. Applying MULs appears to have implications for results and potentially shape the sustainability of theory development.

In the worst case scenario, adherence to methodological myths can lead to conclusions which are unintentionally mistaken, and possibly misleading to future researchers. As Edwards (2008) points out in his discussion of Myth 4, when the underlying theoretical model being tested has a moderated form, the effects that the independent variables and the moderators have on the dependent variable can only be described as being conditional. In other words, when the theoretical model itself suggests that the effect of *X* on *Y* depends on the value of *Z*, it is inappropriate and potentially misleading to make any binary statements based on a point estimate of a direct effect coefficient. We can see a clear example of the risk that exposes us to in Bergh, Perry, and Hanke (2006). In describing the factors that affect how influential a particular *SMJ* article is likely to be, they use an insignificant coefficient in the full model to conclude that the number of other articles an author has published 'is no longer a salient factor once the interactive effect with the corresponding citation counts is brought into the equation' (Pg. 91). This suggests that the number of other articles previously published is not predictive of how influential a focal article is likely to be.

If we examine their results more closely, taking into account the joint conditional effect of the variables theorized to be involved in the moderation, a more detailed and nuanced picture emerges. As illustrated in Figure 1, which was created based on the coefficients reported in Bergh, Perry, and Hanke's (2006) full model, the number of other articles published by a particular author does not have any effect on the impact of their next paper when those previous papers were not highly cited. However when their body of previous work was highly cited, the number of other articles published becomes highly significant to the question of how influential their next paper is likely to be. Drawing a binary conclusion like 'no longer salient' based on the isolated interpretation of a direct effect coefficient, when the true interactive effect does in fact make a particular variable salient under certain conditions, creates a risk that future work will be based on the mistaken rejection or support of foundational theories.

Figure 1: Joint effect of the number of previous articles published and the citations of those previous articles on the impact of future work, from Bergh, Perry, and Hanke (2006)





For these single-product moderation tests, future research only needs to test  $X$ ,  $Z$ , and  $XZ$  in one equation and interpret all three coefficients with respect to one another. Strategy researchers who succumb to moderation Myth 4 interpret the first-order direct effects in a base model, which does not include the product term. This can lead to problems in two ways. First, if there is solid theoretical logic leading to the prediction of a moderated model, then a ‘base’ model which excludes the interaction term is statistically misspecified and thus the coefficients potentially biased. Second, the nature of a significant moderation effect dictates that there can be no meaningful point estimate of the relationship between the independent variable and the dependent variable. By definition, the slope of the line relating  $X$  and  $Y$  (the direct effect) will depend on the level of  $Z$ . Conversely, the slope of the line relating  $Z$  and  $Y$  will depend on the level of  $X$ . The coefficients on the direct effect of both the independent variable and the moderator on the dependent variable are essentially meaningless in isolation. Interpreting the significance of direct effect coefficients leads one to make binary statements that  $X$  either does or does not significantly affect  $Y$ , when the correct approach is to explicate how  $Y$  responds to a range of values for both  $X$  and  $Z$ .

In conclusion, some strategy researchers have used practices that reflect statistical and methodological myths and urban legends when they test moderation models. The adoption of such applications is not surprising, as knowledge creation in social sciences tends to be constructed and replicated over time (Mizuchi and Fein, 1999), meaning that practices become standards and serve as precedent for subsequent scholars. Our findings suggest the need to reconsider how moderation testing using hierarchical regression analysis is conducted in strategic management research. Ultimately, the confidence we place in research findings and the sustainability of knowledge and theoretical explanations depends on the practices and standards in the field. MULs matter, not just for increasing statistical rigor but also for raising the quality of the evidence and interpretations for knowledge development.

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