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Multiplicative Interaction: More Appropriate for Combined Effect than for Moderation Fit

César H. Ortega Jiménez
Universidad Nacional Autónoma de Honduras, IIES; Universidad de Sevilla, Tegucigalpa, Honduras, cortega@unah.edu.hn, cortega@us.es

José A. D. Machuca
Universidad de Sevilla, Sevilla, Spain, jmachuca@cica.es

Pedro Garrido Vega
Universidad de Sevilla, Sevilla, Spain, pagarrido@us.es

Abstract

This paper is the result of a research from the High Performance Manufacturing project (an international empirical study involving 50 researchers (from 14 research groups) from 28 Universities in 14 countries). The main role of this international research is to share its findings with POM researchers in what can be very important in order to improve the POM empirical research. Thus, this paper focuses on the way two interaction forms (moderation and combined-effect) are applied in the literature of Production and Operations Management (POM), highlighting their theoretical dissimilarities and showing that the methodology of multiplicative interaction may be more appropriate for combined-effect than for moderation fit, contrary to its general use in POM. This conclusion is very valuable for POM empirical researchers when dealing with the interaction of two factors in order to improve an outcome (e.g. performance).

Keywords: High Performance Manufacturing (HPM), Fit, Production and Operations Management (POM), Combined Effect, Interaction, Moderation.

1. Introduction

In some POM empirical works, analysing at least two factors (e.g. manufacturing practices and performance), is pretended to study the consistency between such factors to verify if it leads to a better result (e.g. Primrose, 1992; Sakakibara et al., 1993, Gupta and Somers, 1996; Pagell et al., 200; Matsui, 2002; Demeter, 2003). This implies the analysis of what is named Bivariate Fit, which, in simple terms, is no more than measuring the fit or adjustment between two factors. This type of analysis is very important in POM empirical research in order to verify the possible interrelationships between manufacturing practices (MP) and/or the impact of their link on performance.

Fit in POM may be seen as when management tries to control or improve a manufacturing practice (MP1), by regulating or adapting its level of implementation of the manufacturing practice (LIMP1) taking into account the level of another practice (LIMP2) and/or vice versa (Drazin and Van de Ven, 1985). *Interaction fit* between both practices occurs when LIMP1 does not easily adapt to LIMP2 and shows a wider range of adaptation variance with respect to the optimum levels of LIMP2 and/or vice versa (i.e. misfit between both practices). In addition, a specific value of LIMP2 may interact with different values of LIMP1 and/or vice versa leading to performance (P) changes (P_0, P_{-1}, P_{-2}, P_{-3}). When this happens, there is a state of disequilibrium in the plant's performance due to the misfit between MPs. Figure 1 shows different performance values (P_{-1}, P_{-2}, and P_{-3}) associated with different misfit levels between the levels of implementation of both manufacturing practices (MP1 level and MP2 level). The line P_0 shows higher performances associates to the highest fits (lowest misfits).

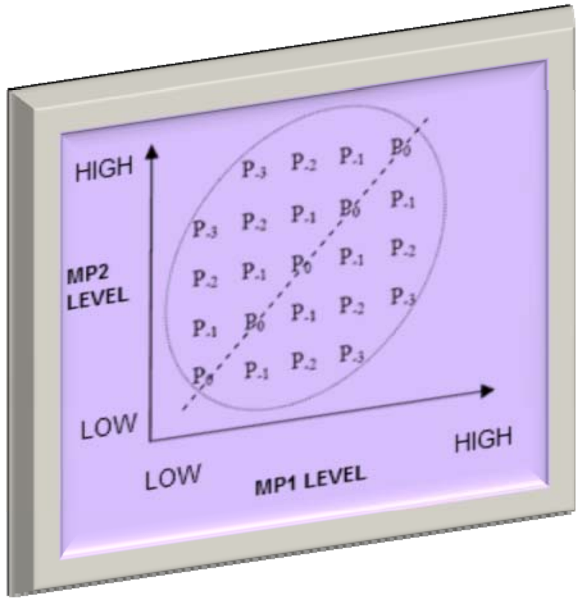

Figure 1. Interaction fit

The notion of "interaction fit", explained above, is used in this paper to evaluate the interconnection between two independent variables (predictors), taking as a starting point an asseveration of contingency scholars (e.g. Schoonhoven, 1981). Fit is thereby explained by variations of adaptation between both predictors, reflecting performance variations (i.e. a misfit between two predictors), where best performances are obtained by organisations with best fits. .

Unfortunately, as many affirm (Schoonhoven, 1981; Hartmann and Moers, 1999, 2003; Meilich, 2006), most theoretical researchers on contingency have *used the interaction form of fit loosely*. Furthermore, as Venkatraman (1989) declares, it is common to postulate relationships using phrases such as "contingent on" and "moderated by ", but precise guidelines are rarely provided as to how to transfer these statements to the analytical and statistical level. As a result, these works have been attacked for *being vague in their predictions, operationalisations and subsequent statistical analyses* (Schoonhoven, 1981; Van de Ven and Drazin, 1985). Regardless of this, in specialised literature (e.g., Brownell, 1983; Dunk, 1993; Lee, Miranda and Kim, 2004) there exists a *tendency to relate interaction almost exclusively to the use of moderation*, even to the point of identifying the contingency perspective (which is very important in the HPM empirical project) with only this view (Chenhall, 2003; Lee et al., 2004).

This situation often leads to conclusions based on wrong models, as many POM researchers are not aware of the problem discussed in this paper. Therefore, to build theory based on wrong models in POM empirical papers is a danger, which this work would like to help to prevent. A failure to distinguish the issues discussed here when using the moderating model in empirical POM research may lead to misleading conclusions.

In the following sections, procedures for the mentioned problem, more precise conceptually and statistically, are provided.

2. COMBINED-EFFECT VS. MODERATING INTERACTION MODELS: A CONCEPTUAL PERSPECTIVE

Conceptually, in moderating interaction (Figure 2), a moderating variable affects the relationship between a predictor (independent variable) and an outcome (usually performance), but this moderator is not related to either (e.g. Arnold, 1982, 1984). In other words, the moderator does not have influence on the dependent variable in the absence of the predictor, as well as having no influence on the predictor: its influence only operates to change the effect of the predictor on performance (Sharma, Durand and Gur-Arei, 1981; Luft and Shields, 2003). However, the matter of which of two independent variables is labelled as moderator and which as predictor is not only a theoretical but also a statistical question.

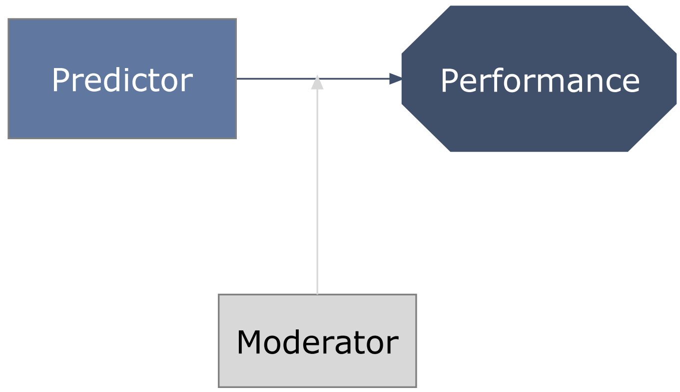

Figure 2. Moderating Interaction

Propositions based on the contingency perspective are tested by evaluating the presence of the effects of moderation. However, as seen below, this entails certain problems, especially statistical ones. In fact, as seen later, these statistical discrepancies are one of the reasons that the moderation model cannot be tested by a multiplicative interaction methodology, MIM (e.g. moderated regression). Instead, the MIM can make another type of fit model operational, which specialised literature (Luft and Shields, 2003; Roca and Bou, 2006) calls the "independent-variable" or "combined-effect" interaction (Figure 3). This model does not have a moderator since it consists of examining the connections between several dimensions of two independent variables (predictors) and an outcome (e.g. performance). The manner in which one of the predictors affects performance depends on the value of the other predictor and vice versa (Southwood, 1978; Roca and Bou, 2006).

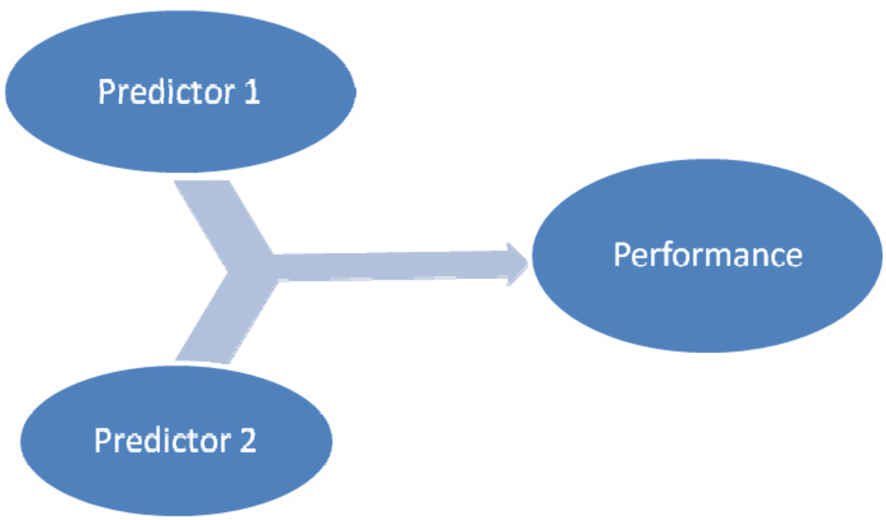

Figure 3. Combined-Effect Interaction

Although moderating and combined-effect interaction models theoretically represent different causal relationships, there is no difference between the methodological analysis of one and the methodological analysis of the other (the same one is used in both cases: multiplicative interaction). However, the latter is the only one which conceptually fulfils the requirements of the use of MIM (the one most commonly used in literature), where a better understanding of the impact of the interaction of the two predictors on performance is achieved. Therefore, the combined-effect model should be the one, which uses multiplicative interaction methodology. The next section statistically stresses this point.

3. COMBINED-EFFECT VS. MODERATING INTERACTION MODELS: A STATISTICAL PERSPECTIVE

In POM literature, a common way to conceptualise and test the existence of moderation fit is the use of moderated regression analysis (MRA). In MRA, the regression equation not only contains a multiplicative interaction term, but also includes main effect coefficients ($\beta_1 P$ & $\beta_2 M$). However, the moderating interaction model does not contemplate the moderator's main effect ($\beta_2 M$) (e.g. Hartmann and Moers, 1999; Luft & Shields, 2003). A typical way of operationalising moderation (Figure 2 above) is set out in equation (1):

$$\mathbf{P = \beta_0 + \beta_1 Pr + \beta_2 M + \beta_3 Pr \times M + \varepsilon} \qquad \mathbf{(1)}$$

where P is the outcome, Pr is the predictor, M is the moderator, Pr × M is the interaction effect (i.e.: the effect that M has on the relationship between Pr and P) and ε is the error variable. Fit is prevalent when the interaction coefficient β_3 differs significantly from zero. That is, the impact of Pr on P varies across different levels of M (Hartmann and Moers, 1999; Schoonhoven, 1981; Venkatraman, 1989).

The moderation interaction model leaves out the alternative theoretical interpretation of the interaction multiplicative term (Pr × M) from equation (1): (M × Pr)[1], since a non-significant amplifying effect of Pr on the effect of M on P is postulated in the model. Besides, as opposed to the theoretical moderation model where a non-significant relationship between M and P is postulated, equation (1) permits not only the amplifying effect of Pr on P, but also of M on P, since, even if Pr is nonexistent, M would still have an impact on P due to term $\beta_2 M$,.

Thus, the use of equation (1) above represents a problem for the theoretical "moderating interaction" model, since the widespread multiplicative method will not only statistically measure the effect that the variable (defined theoretically as "moderator") has on the relationship of the predictor and performance (Figure 1 above). In addition, it will also measure the effect (not defined conceptually in the model) of the predictor on the relationship of the moderator with performance (which is not defined in the theoretical model, either) as shown in Figure 4 (see Jaccard, Turrisi and Wan, 1990; Roca and Bou, 2006). This may be statistically derived from the literature (Hartmann and Moers, 1999, 2003; Jaccard and Turrisi, 2003; Luft and Shields, 2003).

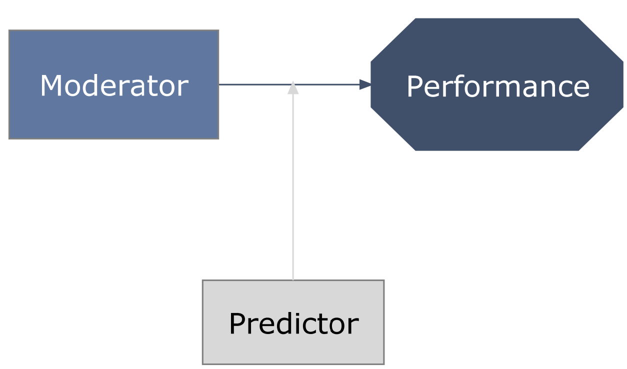

Figure 4. Missing conceptual part of moderation

However, the combined-effect model, as indicated in the previous section, may be that which best describes the whole view of interaction from the equation (1), which for practical as well as conceptual reasons may better be expressed as in equation (2)

[1] The interaction effect is not affected by which variable is termed as moderator or predictor.

$$P = \beta_0 + \beta_1 Pr_1 + \beta_2 Pr_2 + \beta_3 Pr_1 \times Pr_2 + \varepsilon \qquad (2)$$

where P is the dependent variable, Pr_1 is predictor 1, Pr_2 is predictor 2, $Pr_1 \times Pr_2$ is the interaction effect (i.e.: the effect that Pr_2 has on the relationship between Pr_1 and P and/or the effect that Pr_1 has on the relationship between Pr_2 and P) and ε is the error variable. Fit is prevalent when the interaction coefficient β_3 differs significantly from zero. That is, the impact of Pr_1 on P varies across different levels of Pr_2 and/or the impact of Pr_2 on P varies across different levels of Pr_1 (Hartmann and Moers, 1999; Schoonhoven, 1981; Venkatraman, 1989).

4. CONCLUSIONS

This paper is beneficial for POM empirical researchers, since it intents to help improving the operationalisation and modelling of POM empirical research. Researchers in the POM field, who can sometimes use models and statistical techniques incorrectly, leading to results based on wrong or partially wrong models and statistical methods.

On the one hand, this work argues that the specific form of interaction is not always acknowledged by POM empirical researchers. Quite a few studies are unclear about theoretical position and switch between moderation and combined-effect interaction as if the two forms were conceptualisations of the same underlying methodology. The combined-effect interaction model represents two predictors interacting between each other on performance, whereas the moderation interaction model partly represents this interaction view, since in the latter model there is only one predictor with a moderator affecting exclusively the predictor-performance relationship. Therefore, since each model represents different theoretical causal relationships, each should be clearly described in the narrative of qualitative studies, since it would be theoretically more beneficial to make assumptions about the interaction form and choose a model and a statistical method that corresponds with theoretical assumptions.

On the other hand, since in POM empirical research quantitative studies of moderation, some statistical tests (e.g. moderated regression) may be used—and in fact are used—it is necessary to take care not to be tempted to make generalisations on the basis of the hypotheses of these quantitative studies. For instance, the fact that one of the independent variables has an influence on performance or that it only moderates the effect of the other independent variable on performance, is not only an important theoretical question, but also a practical one. Thus, a failure to distinguish the issues discussed in this paper when using the moderating model may lead to misleading conclusions.

Furthermore, the two models address different tasks. Different theoretical assumptions and different tasks call for different models and analysis techniques. Therefore, the use of equation (1) as a convenient statistical method of interaction to make the moderating model operative should be abandoned since research results may be sensitive to this selection. Moderation should not be used with the multiplicative interaction method unless its limitations are explicitly commented on. However, this paper leans towards recommending to POM empirical researchers the multiplicative interaction method for the combined-effect model rather than the moderating model.

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