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Complementing View of Interaction Fit for Production and Operations Management

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ABSTRACT

Studies of interaction fit have been used in Production and Operations Management for a lot of time. The purpose of this paper is to propose the complete view of interaction fit to evaluate the effect of possible interrelation between two Manufacturing Practices (MP's). Two interaction forms may be used for a complete view of this kind of fit: 1) that of difference (supplementary) to measure fit line and 2) multiplicative (complementary) to measure the impact on performance of a MP when another MP changes (Schoonhoven, 1981). Each form demands specific technical analysis because they have specific theoretical suppositions and imply different research tasks. Although both forms test independent variables through interaction effects, they differ in their theoretical suppositions about interaction. This has implications in the performance functions (fit lines) and impacts assumed. However, researchers many times don't acknowledge interaction form, and are not clear about their theoretical position, exchanging between both models. Hence, this paper highlights theoretical differences between these two interaction forms, thus avoiding potential problems that could arise if such conflicts were not taken in consideration. Nevertheless, the intention of this paper is not to contrast both interaction forms to verify a possible opposition; on the contrary, both forms may complement thus evaluating the interrelation studied from dual perspectives, like in the duality of the faces of a coin.

Keywords: Interaction fit, Difference form, Multiplicative form.

1. INTRODUCTION

One possible scenario for interaction fit may be drawn from Drazin and Van de Ven (1985), where for management to control or improve a manufacturing practice (MP), it needs to regulate or adapt the practice's dimensions taking into consideration the dimensions of another practice and vice versa. Interaction fit may occur when management tries to control or improve a production practice (e.g. Just in Time, JIT) by regulating or adapting the implementation level from some of its dimensions (LIJIT), taking into consideration some dimensions from another practice (e.g. Total Quality Management, TQM), by means of their implementation level (LITQM) and/or vice versa (Drazin and Van de Ven, 1985; Van de Ven and Drazin, 1985). Let TQM be a univariate variable ranging from a low implementation TQM (L) to a high implementation TQM (H). JIT design may also be measured with respect to ''implementation level'' ranging from low to high. For interaction theory to hold (i.e. high And low levels of TQM benefit from high Andlow levels of JIT, respectively), high performers are expected to be found along a diagonal from bottom-left to upper-right in Figure 1, Table A. In other words, interaction fit between both practices may be seen when LIJIT dimensions does not easily adapt to LITQM dimensions and shows a wider range of adaptation variance with respect to the optimum levels of implementation from LITQM dimension and/or vice versa (i.e. misfit between both practices). In addition, a specific value of implementation from LITQM dimensions may interact with different values of implementation from LIJIT dimensions, and/or vice versa, leading to performance (P) changes (P_0, P_{-1}, P_{-2}, and P_{-3}). When this happens, there is a state of disequilibrium in the plant's performance due to the misfit between both MP's. Table A from Figure 1 shows different performance values (P_{-1}, P_{-2}, and P_{-3}) associated with different degrees of misfit between the levels of implementation of both MP's (JIT level and TQM level). Line P_0 shows higher performances are linked with the highest fits (lowest misfits). Departures from the optimal designs would result in lower performance (the indices denote the level of performance, where the zero number represents high performance, and the other indices denote the opposite) (Gerdin, 2006). Furthermore, Tables B and C illustrate the expected relationship between JIT levels and performance for TQM low and high levels, respectively. An Interaction form of fit is seen because the relationship between JIT level and performance differs between both levels of TQM.

Table A. All plants | **Table B. Low level TQM** | **Table C. High level TQM**

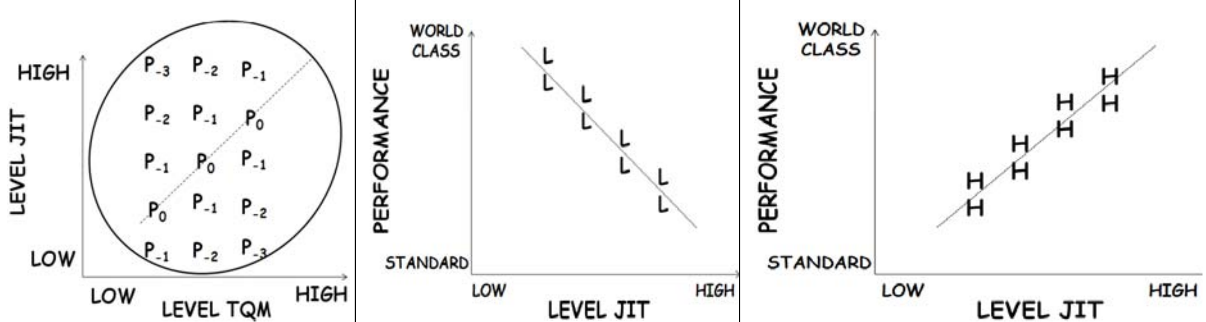

Figure 1: Interaction fit: TQM and JIT implementation levels (Adapted from Gerdin and Greve, 2004)

In the specialised literature (e.g. Brownell, 1983), there exists a tendency to relate interaction almost exclusively to the use of moderation (Figure 2), even to the point of identifying the contingency perspective only with this perspective (Chenhall, 2003). Moderation simultaneously examines the link amongst three variables: when the impact that an independent variable (predictor, e.g. JIT) has on the dependent variable (outcome, e.g. performance) is influenced by the level of a third, independent variable, it is said that this last variable is the moderator (e.g. TQM) of the relationship between the other two variables. However, this moderator is not related to either JIT or performance (e.g. Allison, 1977; Arnold, 1982, 1984; Stone and Hollenbeck, 1989). In other words, the moderator (TQM) does not have influence on the dependent variable (performance) in the absence of the predictor (JIT), as well as having no influence on the predictor: its influence only operates to change the effect of the predictor on the dependent variable (Sharma et al., 1981; Luft and Shields, 2003). Furthermore, the matter of which of two independent variables is labelled as moderator and which as predictor is more of a theoretical than a statistical question (Ortega et al., 2008).

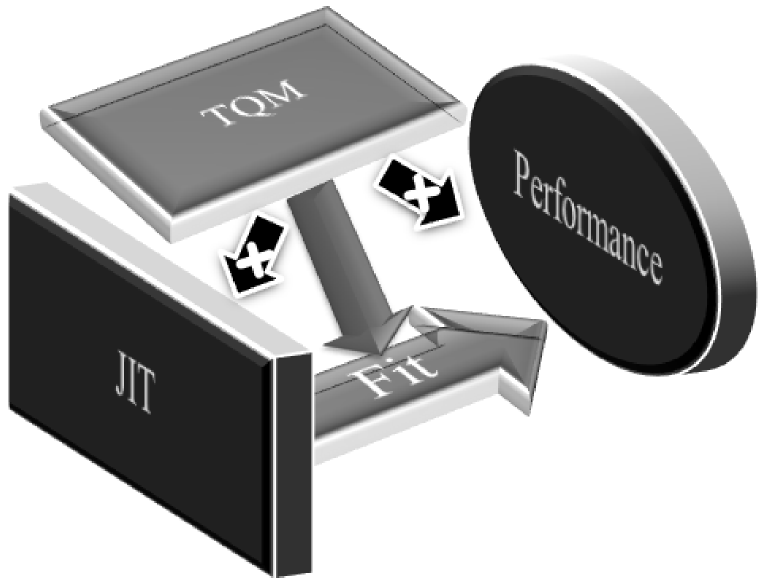

Figure 2: Moderation fit

Thus, moderation fit involves certain problems, especially statistical ones. In fact, these statistical discrepancies are one of the reasons why the moderation model will not be used here. Instead, to make interaction fit operational, the model used here is what the literature (Luft and Shields, 2003; Roca and Bou 2006) calls "independent variable" or "combined effect" (Figure 3) interaction. With this type of fit, a moderator does not exist; instead there are two independent variables (e.g. JIT and TQM), each one having a causal influence on the dependent variable (e.g. performance). The form in which and the extent to which one of the independent variables affects the outcome depends on the value of the other independent variable and vice versa (Roca and Bou, 2006). Although these two interaction models theoretically represent different causal relationships, there is no difference between the statistical analysis of one and the statistical analysis of the other in the literature (they both use the same one: combined effect interaction), thus presenting a problem for the moderation fit (Ortega et al., 2008).

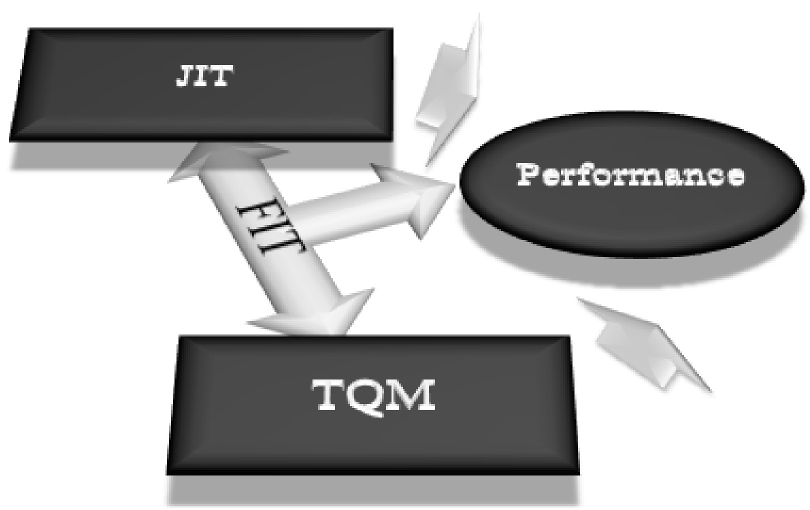

Figure 3: Interaction Fit

Thus, the interconnections here are evaluated using the notion of fit as interaction, starting from an asseveration of contingency scholars (e.g. Schoonhoven, 1981): when a relationship between two initially independent variables exists that predicts a third variable (e.g. operational performance), then there must be interaction between the first two variables. In fact, taking the typology of Schoonhoven (1981), two forms of interaction, which seem to dominate the contingency literature (Venkatraman, 1989; Pennings, 1992), are derived in the following section: 1) difference, also known as matching (residual analysis or deviation score),; and 2) multiplicative form. Section 3 will focus on the two fundamentals differences (fit line for difference and impact for multiplicative form) which complement the view of interaction fit. Section 4 gives a discussion and implication from proposing both forms to have a complete view of interaction. Finally Section 5 gives conclusions of this paper.

2. INTERACTION FIT: DIFFERENCE AND MULTIPLICATIVE FORMS

The forms of difference and multiplicative explained in the following are used separately in Production and Operations Management (POM) empirical research adducing that they are mutually incompatible when in reality they can be used to complement each other, as will be shown in Section 3 and 4.

2.1. DIFFERENCE FORM

The interaction of difference may be measured by seeing how close equivalent values of both independent variables/predictors are in organizations (Chan and Hu, 1993). Together these optimal combinations form a fit line, where outcome is assumed to be maximized when both predictors fit each other, and thus the fit line should coincide with an outcome line denoting maximal outcome at each level of the predictors. Hence the causal relationship is between such fit and outcome. For illustrative purposes, the two Manufacturing Practices (MP's) from Figure 1 will be used for the rest of the paper -Just in Time (JIT) and Total Quality Management (TQM). Thus, performance is assumed to be maximized when JIT fits with TQM, and thus the fit line (see Figure 1, Table A) should coincide with a performance line denoting maximal performance at each level of either MP's (Donaldson 2003). As an example, it may be assumed iso-performance, where all fits on the fit line yield about the same performance. When iso-performance is assumed, incremental changes in JIT/TQM do not necessarily affect a firm's performance negatively, provided that measures are taken by the firm in adjusting the corresponding MP (TQM/JIT) accordingly.

Proponents of the difference model would probably admit that there are some causal relationships between both MP's, although these relationships are usually omitted from the model. Fit is preferred to be understood as some kind of interdependence between two MP's. Focus is on the assumed unidirectional causal relationship between fit and performance. To make this model operative, analysis of deviation score, residual analysis and subgroup analysis (based on performance) may be used. Describing these methods is beyond the scope of this paper.

From the equation 1, the suppositions of the functional form of difference are: a) that curve-linear correspondence exists between the deviation score and the outcome variable; b) that the value of JIT at which higher performance occurs depends on TQM and/or vice-versa; and c) that there is a detectable level of selection forces (a high degree of congruency) between TQM and JIT.

$$\mathbf{P = \beta_0 + \beta_1 JIT + \beta_2 TQM + \beta_3 \left| TQM - JIT \right| + \varepsilon} \qquad \textbf{(1)}$$

where P is the outcome performance, TQM is predictor 1, JIT is predictor 2, $\left| TQM - JIT \right|$ is the difference interaction effect (i.e.: effects of JIT (an independent variable) on a performance (dependent variable) at given values of TQM (the other independent effects), β_0, β_1, β_2, β_3 are the coefficients, and ε is the error variable. Fit is prevalent when the interaction coefficient β_3 differs significantly from zero. In other words, the impact of JIT on P varies across different levels of TQM (Schoonhoven, 1981; Venkatraman, 1989; Hartmann and Moers, 1999). The other scenario may be possible: the impact of TQM on P varies across different levels of JIT.

2.2. MULTIPLICATIVE FORM

Multiplicative interaction may exist when the impact on an outcome of the first and/or of the second independent variable differs for different values of the other independent variable. Unlike the difference model, multiplicative form always produces changes in the outcome, although the relative effectiveness of either independent variable does not necessarily change. The multiplicative model with its focus on incremental effects obviously belongs to the category of single degree-of-freedom interaction contrasts, which formally compares the effect of an independent variable (JIT) on a dependent variable (performance) at one level of a second independent variable (TQM) with that at another level of TQM (Jaccard and Turissi 2003, p 7). Therefore, if it is assumed that maximal performance would vary in the multiplicative model, there may be evidence of hetero-performance.

This paper chooses the multiplicative interaction method for the combined-effect model (Figure 3) rather than the moderating model (Figure 2) in the following way):

$$\mathbf{P = \beta_0 + \beta_1 JIT + \beta_2 TQM + \beta_3 (JIT \times TQM) + \varepsilon} \qquad \mathbf{(2)}$$

as in equation 1 above, JIT × TQM is the combined- effect interaction (i.e. the effect that TQM has on the relationship between JIT and P and/or the effect that JIT has on the relationship between TQM and P). Fit is prevalent when the interaction coefficient β_3 differs significantly from zero. That is, the impact of JIT on P varies across different levels of TQM and/or the impact of TQM on P varies across different levels of JIT (Hartmann and Moers, 1999; Schoonhoven, 1981; Venkatraman, 1989).

In order to make this model operative, regression analysis, ANOVA, and subgroup analysis (based on either predictor) may be used. These methods' descriptions are not part of this paper.

3. COMPLEMENTING VIEW OF INTERACTION FIT

Both forms of interaction may be used to make a more complete analysis of interaction fit, mindful from the start that both forms represent different theoretical positions on interaction. However, the intention here is not to contrast both forms in order to verify a possible dichotomy that is manifested in an opposition between them; on the contrary, it is expected that both forms may complement the interaction view in organisations, as a duality of two sides of the same coin.

Thus, this paper takes two fundamental differences between the two forms of interaction, the fit line and impact (the effect of a predictor on another predictor's impact on outcome), and highlights them as methods of exploring different parts of the interaction view.

3.1. FIT LINE: MORE FITTING FOR DIFFERENCE FORM

As seen in section 2.1 above, fit lines are better suited for the difference form of interaction fit. In a multiplicative form, the extreme values are assumed to be optimal. It is assumed that performance is improved in a high-high-combination. Hence, if using the same two MP's as example, it will be maximized when JIT and TQM both adopt their maximum values. However, due to symmetry, there must be at least two maxima if either MP is to be regarded as an interactive factor. Symmetry is required since interaction theory aims to explain why firms with very different MP implantation level still may perform equally well. Thus an assumption is added that performance should be maximized also in a low-low situation (Schoonhoven, 1981). Assumptions about multiplicative interaction effects combined with the assumption about symmetry result in the characteristic "saddle form" with tops at high-high and low-low and with bottoms at high-low and low-high (Southwood 1978). For instance, the positive effect on performance of high values on JIT diminishes gradually as TQM decreases. At some inflection point, the positive effect levels away and all designs of JIT display the same impact on performance. Further decreases in TQM affect performance negatively, provided that JIT is unchanged. If, however, the design of JIT is reversed, impact on performance will be slightly positive, and the positive impact will increase progressively as TQM maintains to diminish.

Therefore, when multiplicative form (section 2.2) is compared with the difference model (section 2.1), it may well be said that both models acknowledge that TQM may influence the impact JIT has on performance. They also make assumptions about symmetric behavior. One JIT solution is effective at a high value of TQM while the opposite solution is effective at a low value of TQM. Hence, the situation is identical at the ends of TQM. The crucial difference between the two models lies in what happens with performance between those endpoints. In a multiplicative model it is assumed that performance is maximized at the endpoints (high-high and low-low) and any move from these positions reduces performance. In a difference model, it is assumed that reduced performance, due to an incremental change in TQM, can always be offset by appropriate adjustments of JIT. The reverse is also possible: if there is an incremental change in JIT reducing performance, such performance reduction may be offset by appropriate adjustments of TQM.

To conclude, they both have points in common, but the multiplicative model only implicitly understands different performance patterns. Thus, although the two assumptions may allow two different outcome patterns to be tested, the best option here is for the difference model to test a fit line between two predictors (see Figure 1, Table A): each value of JIT is assumed to be optimal at a certain value of TQM (Figure 4).

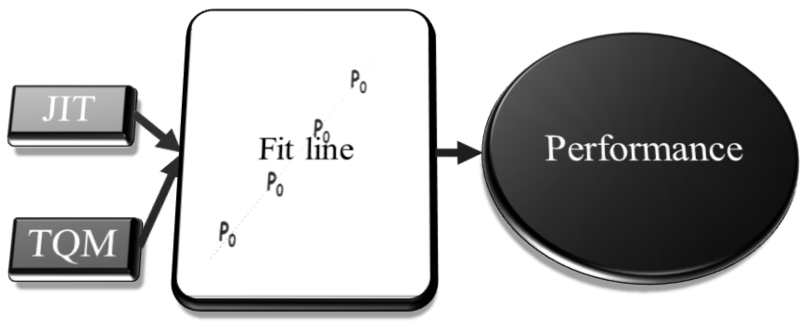

Figure 4: Fit line in difference form

3.2. IMPACT: MORE FITTING FOR MULTIPLICATIVE FORM

Assumptions about interaction also have implications for the way in which impact is treated in the two models of interaction discussed here. The difference model does not make explicit assumptions about impact when proving its case, since they rely on a linear relationship between the distances from the fit line to the outcome.

The difference model analyzes effects of interaction using simple main effects by concentrating on the effects of an independent variable on a dependent variable at given values of the other independent effects (Jaccard and Turissi, 2003). In practical terms, the difference model estimates the fit line simply by the accomplishment of a number of bivariate analyses between JIT and performance – one analysis for each level of TQM.

Therefore the multiplicative model remains, in which both independent variables are understood as interactive if either predictor has an impact on performance on the presence of the other predictor. Thus, it is possible to test when incremental changes in one predictor will affect the other predictor's impact on outcome (Jaccard and Turissi, 2003). The approach is illustrated with the same two MP's, by displaying the marginal performance at incremental increases in JIT within each level of TQM (Figure 5). The other way is also possible: to test the marginal performance at incremental increases in TQM within each level of JIT (Figure 6).

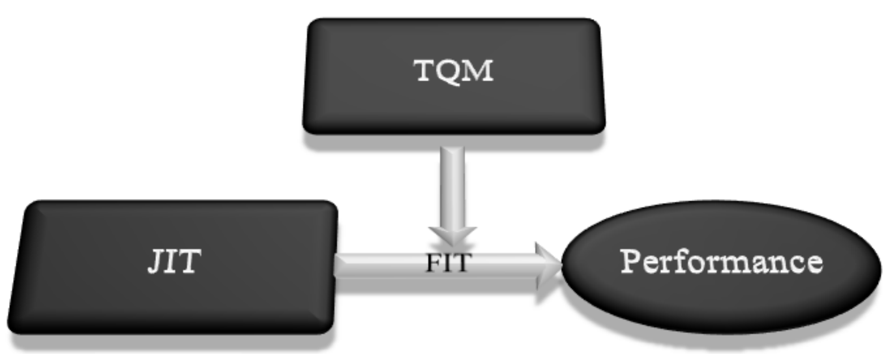

Figure 5: JIT impacts performance by changes of TQM

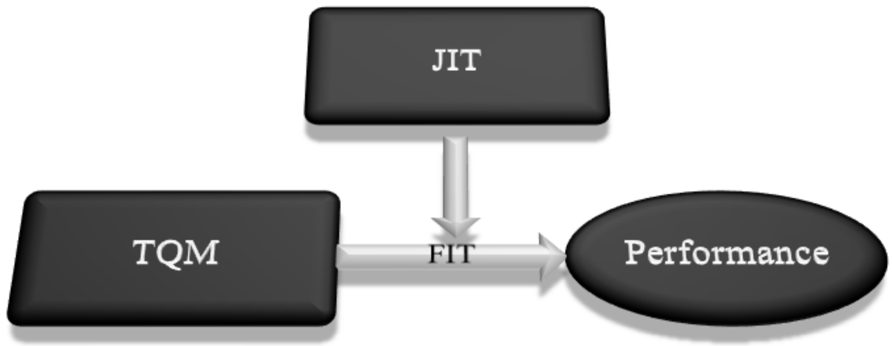

Figure 6: JIT impacts performance by changes of TQM

4. Discussion and Implications

This paper shows a fundamental way by which both interaction forms complement the interaction view: interaction effect with implications on performance (fit line) and impact. Hence, the two forms of interaction address different research tasks: 1) a difference model aims to identify a fit line and to verify it by testing against performance; and 2) a multiplicative model aims to measure how structures impact on performance changes as an effect of contextual changes.

Using the same two MP's, in a difference form, each JIT is assumed to be optimal in a certain TQM level. In a multiplicative form, only two JIT (the extreme values) are assumed ever to be optimal. The two assumptions result in different performance patterns (iso and hetero-performance). This performance pattern is highlighted in the difference model, where identification of a fit line is the main task and performance pattern variances are only implicitly understood. However, although matching models test for fit lines, it cannot be taken for granted that verified hypotheses refute a multiplicative performance pattern. Performance patterns do have points in common in spite of having different interaction views. Hence, empirical support to a difference hypothesis does not automatically exclude the possibility of a multiplicative fit line.

Assumptions about interaction also have implications on the way impact is treated in the models. In a multiplicative model, a variable is understood as an interactive variable if it has impact (e.g. incremental changes in TQM affect JIT's effect on performance and/or vice versa). Furthermore, assumption of symmetry implies that there must be some inflection point where impact is zero. The difference model does not make explicit assumptions about impact. This implicit assumption about impact (or rather absence of impact) becomes clear when taking two of the validation methods into consideration. These two techniques (deviation score analysis or residual analysis) rely on a linear relationship between distance from fit line and performance (deviance from fit is proportional to performance).

Furthermore, the multiplicative model and the difference model do not only expose different aspects of interaction (simple effects and contrast effects). They also make different assumptions about the interaction effect. If a contingency variable is assumed to operate in the way predicted by the difference model, interaction effects cannot be examined by the simple multiplicative model. This is because the multiplicative model requires linear by linear interactions while a matching model implicitly assumes non-linearity. In addition, some of the statistical methods used differ because they aim to solve different problems - difference methods test for fit lines (deviation score analysis or residual analysis) while multiplicative models test for interaction effects (Moderated Regression Analysis).

Regardless of this, they may find a common ground for testing and complementing both views (i.e., one method as confirmatory of the other) by using sub group analysis – difference method based on performance and multiplicative method based on either predictor. Measuring with metric scales and later arranged into groups, where group belonging is determined by values on two Manufacturing Practices (MP's), enables the utilization of ANOVA and Correlation when testing hypotheses. Since these sub group analytical techniques are being proposed as confirmatory to others previously done (e.g. regression), problems due to the grouping such as throwing away valuable information about incremental changes, or having results with less statistical power or even false should not be the main concern, but whether sub group analysis complement the former analysis. In a case where two different models (each with many methods) support a proposition, it may be that the main effect is no longer a general effect but a conditional one. Besides, if results converge through multiple statistical tests of fit, an evidence of robustness may be provided.

5. CONCLUSIONS

The use of a confirmatory model not only corroborates results of previous model, but it may also throw light about details the other model cannot show. Thus, it would be possible to make a more complete evaluation of the link between any two manufacturing practices. If only one of either model was applied, we may simply get a partial view of the interaction. Hence, the main purpose of this research was to share this sort of methodology with POM researchers in what could be an important finding for obtaining a more complete view of the interaction between any two manufacturing practices by reconciling two different perspectives of interaction fit.
Thus, this paper determined that it is possible for difference and multiplicative perspectives to complement each other, by proposing multiple tests of fit within the same data set, where each technique has an implicit bias. The starting point is the literature showing that it is both critically important and profitable to study the interrelationship between different predictors (e.g. MP's) using multiple perspectives (e.g. Venkatraman, 1989; Gerdin and Greve, 2004; Gerdin, 2006). In addition, comparative evaluation of different models to test fit and the relationship between results and characteristics of the same sample may help to develop medium range theories about which approach to take.

This paper therefore considered two opposing models to investigate whether difference and multiplicative fits may complement each other, especially where research in this area has not yet conclusively rejected said models. Hence, this paper sought to examine complementarities between bivariate fit relationships in two ways: 1) two concepts (difference and multiplicative forms); and 2) multiple statistical tests from each concept within the same data set, taking as a common ground the sub group analysis.

From Section 3, it can therefore be concluded that difference form may be complemented by multiplicative methods in order to detect possible impacts of one MP on another MP-performance, which cannot be found by the former. Likewise, multiplicative form may be complemented by difference methods in order to test for fit lines, which cannot be detected when testing for multiplicative interaction between two manufacturing practices.

In more detail, this research proposes that these two approaches may complement each other in a single study, by assuming that one (multiplicative and difference interaction, alternatively) has been tested positively using two predictors such as MP's (as the two used throughout this paper, TQM And JIT), and complementing the result (and therefore its view) by using and discussing a statistical technique (sub group analysis) from the other approach. Each individual statistical technique proposed here partially tests assumptions of fit (e.g. a different fit perspective). Thus, when testing with more than one technique, a more complete view of interaction between any two manufacturing practices is obtained.

Finally, regardless of this type of methodology, when dealing with the actual data, caution should be taken since multiple models may lead to a triangulation trap, where results may be ambiguous. If results of multiple tests converge, the evidence will carry much weight, but if multiple tests give divergent results, the evidence will not be so robust and this may indicate two entirely different things: 1) differential support for opposing theoretical views; or 2) perspectives may not be evaluated by multiple tests such as this within the same sample.

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