“A critical analysis of manufacturing capabilities measurement in manufacturing strategy studies”

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**Abstract:** This paper offers a critique of manufacturing performance measurement approaches investigated by previous studies particularly in trade-off modelling studies for manufacturing capabilities. We argue that some studies complete validity analyses of the trade-off model using measures of manufacturing performance that are inconsistent with the trade-off theoretical concept. The paper also seeks to synthesize the relationship between the cumulative capabilities model and the trade-off model within the context of the performance frontiers theory. The results of this analysis seek to advance theory development in this arena, yielding specific and novel research topics and proposals for future studies.

**Keywords:** empirical research methods, literature review, trade-offs model, theory of performance frontiers

1. Introduction

In his seminal article, Skinner (1969) first warns companies that a production system inevitably involves trade-offs and compromises. Within this initial theoretical construct, any production system must be designed to perform well limited operational tasks, with these tasks bounded by corporate strategic objectives. Additionally, a failure to recognise such trade-offs on the part of corporate manufacturing executives may result setbacks to the performance and livelihood of the organization. Skinner further defines aspects directly and indirectly related to a production system that are found in trade-off situations. For example, trade-offs exist between lead-times and inventory levels. Skinner (1974) extends his previous observations and states that manufacturing and operations performance measures such as short delivery cycles, superior product quality and reliability, dependable delivery promises, ability to produce new products quickly, amongst others, also necessitate trade-offs. That is, tradeoffs represent the need for certain tasks and measures to be compromised to meet other tasks and measures. Thus, his conclusion is that organizations must become “focused” to develop strategic edges.

One of the core concepts emerging from Skinners theses is that since no organization can be the best at everything, all the internal aspects of a manufacturing company should be designed and aligned to reflect dimensions which they can be good at, recognizing their limitations. Within this operational strategic construct, an organization has to decide upon areas of emphasis on which they wish to excel. This focus is expected to come at the expense of achieving lower levels of performance on other dimensions. This concept calls for a sound and consistent business and manufacturing strategy, in which the trade-offs and limitations that exist among the different areas of manufacturing are recognised and implemented. Consequently, all operational processes, policies, and priorities, within manufacturing organisations need to be congruent with the decisions that are taken at the top management level, which ideally, would reflect existing trade-offs and limitations.

In the investigation of the trade-off model studies have defined “competitive priorities” and “manufacturing capabilities” as equivalent constructs. This specific equivalency may or may not be technically correct. We believe this definitional construct of equivalency among these terms is an issue in the valid assessment of the applicability of the trade-off model. Thus, provided with this grounding we examine previous investigations in which the trade-off model has been tested.
We will also examine another important aspect related to the issue of trade-offs amongst different manufacturing capabilities. Specifically, studies that aim to analyze the trade-off model should at least include measures of performance (actual or perceptual) which can be compared to those of their direct competitors and/or industry. When analysing trade-offs amongst manufacturing capabilities, the measures to assess the performance of a production system should be aimed towards the “asset frontier” as defined by Schmenner and Swink (1998). We believe that this strategic direction is consistent with the propositions of the trade-off model. Within manufacturing trade-off investigations and specifically regarding the measurement of manufacturing performance, a clear and necessary distinction has to be made between manufacturing internal improvements, Schmenner and Swink’s “operating” frontier, and manufacturing external improvements relative to industry or competitors, Schmenner and Swink’s “asset frontier”. While an organization has the opportunity to achieve internal improvement, it does not necessarily mean that those improvements will be reflected in terms of its external performance relative to its competitors or industry. Since the trade-off model deals with limitations and compromises between manufacturing performance dimensions of any organization relative to its industry or competitors, then researchers investigating the trade-off model should use measures of manufacturing performance that are more consistent with this external focus.

This paper seeks to investigate the following research questions:

1. In terms of the trade-off model of manufacturing performance, should the terms “competitive priorities” and “manufacturing capabilities” be considered as equivalent?

2. In terms of the trade-off model, and based on the “performance frontiers” concept, should measures of “improvement or betterment” and “best-in-industry” be equivalently defined?

3. When assessing the validity of the trade-off model of manufacturing capabilities construct, how should scientists and practitioners measure manufacturing performance variables?

The remainder of the paper is organised as follows: In section 2, we further comment on the differences between competitive priorities and manufacturing capabilities. In section 3, we discuss the issue of the appropriateness of measures of manufacturing capabilities in some studies that examine the “trade-off” model. In section 4 we discuss how our findings from this study set the stage for a specific research agenda for future studies.

2. Competitive priorities and manufacturing capabilities: Are they equivalent?

In numerous studies “competitive priority” has been used equivalently with “manufacturing capability”. For instance, Avella et all (2001) write that “… the review of various works enable us to state the existence of four key manufacturing competitive priorities (or capabilities): cost or efficiency, flexibility, quality and delivery.” (p. 140). Also, Noble (1995) writes that “… this study will investigate and extensively test the hypothesised cumulative model for the building of manufacturing capabilities (competitive priorities).” (p. 694).
Others have made a clear distinction between those two terms. For example, Safizadeh et al (2000) comment that "by 'manufacturing capabilities', we mean a production system ability to compete on basic dimensions such as quality, cost, flexibility and time. We reserve the term "competitive priorities" to mean the importance attached to these same dimensions" (pp 111-112). Boyer and Lewis (2002) write that “Competitive priorities denote a strategic emphasis on developing certain manufacturing capabilities that may enhance a plant’s position in the marketplace”. A clear distinction between competitive priorities and actual performance is found in Ahmad and Schroeder (2002). They comment that “While competitive priorities are an organisation’s set of goals or strategic preferences chosen to compete in the market place, performance ratings represent achievement along those goals. Two organisations may choose to pursue the same competitive priority yet their performance on that competitive priority may vary widely. For example, an organisation may choose on-time delivery as its competitive priority; however, whether it achieves superior on-time delivery performance or not depends on several factors including allocation of pertinent resources, implementation of appropriate management practices (e.g. JIT), the relationship with the suppliers and so on”. (p. 78).

In studies of production and manufacturing competence others have also distinguished between importance and actual levels of performance along several performance areas (see for example Cleveland et al, 1989; Vickery, 1991; Kim and Arnold, 1992; Vickery et al, 1993). These authors show the actual manufacturing performance levels of a company do not necessarily match the importance placed on them by the firms, hence the need to distinguish between those two concepts.

We argue that “competitive priorities” and “manufacturing capabilities” are different, though closely related, concepts within a manufacturing environment. The trade-off concept clearly makes a distinction between “manufacturing policies” and “production tasks”. Competitive priorities belong in the same category as manufacturing policies, while production tasks belong in the same category as manufacturing capabilities. Based on this categorization, we now critically examine the result of assuming that those two terms are equivalent by analysing studies that report on competitive priorities and how they relate to the validity of the “trade-off” model of manufacturing capabilities. Specifically, we have chosen three studies that are representative of this interpretation.

Kathuria (2000) analyses the competitive priorities and managerial performance in his study of taxonomies amongst small US manufacturers. This study examines how different groups of manufacturing organizations “cluster” together according to organizational emphasis on standard competitive priorities such as cost, delivery, flexibility and quality. The author utilises a set of constructs from which organizations are asked to rate the importance they place on different activities within their plants. Factor and cluster analyses are applied to obtain clusters of competitive priorities amongst the sample of subjects. They identify four organizational clusters: 1) Starters; 2) Efficient conformers; 3) Speedy conformers; and 4) Do all. Starters are characterized by less than average priorities on quality and cost, and average emphasis on the other priorities. Efficient conformers have the smallest averages on flexibility and delivery priorities and above average emphasis on the other two priorities. Speedy conformers emphasize three of the competitive priorities. Do all organizations emphasise all four competitive priorities. Hence, the author concludes that the fact that a group of manufacturers was found to simultaneously emphasise on all four competitive priorities reinforces the cumulative capabilities model (also knows as the “sand cone model”), but this finding contradicts the trade-off model construct.
Li (2000) analyses manufacturing capability development of Chinese manufacturing organizations. An objective of the study examines whether manufacturing capabilities introduced at later stages of development strengthen earlier stage capabilities, as the cumulative capabilities models suggest. Their manufacturing capabilities included cost reduction, quality, delivery, and flexibility. These manufacturing capabilities are measured by the emphasis the sample organizations place on operational practices supporting each manufacturing capability. A path analytic approach is used to analyse the capability building model. The results show that flexibility directly and favourably contributes to other manufacturing capabilities such as cost reduction, delivery and quality. The author argues that this result is consistent with the sequential capability building models reported in the manufacturing strategy literature. The author comments that under intense market competition, Chinese manufacturers have moved to the stage of developing flexibility capability. He finds that the manufacturing capability of flexibility has enhanced the performance of Chinese manufacturers in terms of sales revenue, profit after tax, market share and return on investment.

Boyer and Lewis (2002) investigate the need for trade-offs in operations strategy and explore whether US manufacturing plants view competitive priorities as trade-offs. In order to measure the competitive priorities of cost, quality, flexibility, and delivery, they utilise scales to rate the importance placed on those four competitive priorities. Their results show that some pairs of competitive priorities are in a trade-off situation with negative and significant correlations. Yet, their study manufacturing plants consider all four manufacturing capabilities vital for their success. Their conclusion is that these findings are consistent with the cumulative capabilities model. However, they add that distinctions amongst priorities signify that decision-makers still perceive a need for trade-offs. They do make a clear distinction between competitive priorities and manufacturing capabilities: "Competitive priorities denote a strategic emphasis on developing certain manufacturing capabilities that may enhance a plant's position in the market place. Such emphasis may guide decisions regarding the production process, capacity, technology, planning and control" (p. 9). They observe that a critical element of operations strategy involves translating competitive priorities into both structural and infrastructural operational capabilities (a congruence theoretic proposal).

Altogether, these papers exemplify an issue of whether it is adequate to consider the term “competitive priorities” as being equivalent to “manufacturing capabilities”. We believe that this equivalency is not adequate. Many of the studies that have examined the validity of the trade-off model utilising measures of “competitive priorities” and not of real manufacturing capabilities and performance are inaccurately deriving conclusions and recommendations regarding the real capabilities that manufacturing companies can develop. Several studies have clearly distinguished capabilities from priorities (e.g. Cleveland et al., 1989; Vickery, 1991; Kim and Arnold, 1992; Vickery et al., 1993) also illustrating that manufacturing organizations differentiate between what they consider important (priorities) and what they are capable of achieving (capabilities).

Since one of the most important issues in the manufacturing strategy/operations management field is the study of how manufacturing capabilities can be developed inside manufacturing organizations, measures of real manufacturing performance should be utilised. The three studies exemplified above arrive at various conclusions regarding the validity of the trade-off model in their respective samples. Since these papers utilise measures of competitive priorities instead of measures of real manufacturing capabilities and performance, we believe that their conclusions
regarding the trade-off model are questionable. We return to this issue in section 4. We first introduce the relationship between the trade-offs construct and the theory of performance frontiers.

3. Trade-offs and performance frontiers

The trade-off construct refers to the limitations and compromises that exist amongst manufacturing performance measures. A seemingly rival concept known as the cumulative capabilities models has been proposed by several authors (Nakane, 1986; Ferdows et al, 1986; De Meyer et al, 1989, Ferdows and De Meyer, 1990). Schmenner and Swink (1998) give useful definitions of both the trade-off and cumulative capabilities concepts.

“Law of trade-offs: A manufacturing plant cannot provide the highest levels amongst all competitors of product quality, flexibility, and delivery, at the lowest manufactured cost”. (pp. 106-107).

“Law of cumulative capabilities: Improvements in certain manufacturing capabilities (e.g., quality) are basic and enable improvements to be made more easily in other manufacturing capabilities (e.g., flexibility)”. (p. 107).

Schmenner and Swink (1998) define performance frontiers as “…the maximum performance that can be achieved by a manufacturing unit given a set of operating choices” (p. 108). They distinguish the operating frontier from the “asset” frontier in the following way: “The asset frontier is altered by the kinds of investments that would typically show up on the fixed asset portion of the balance sheet, whereas the operating frontier is altered by changes in the choices that can be made, given the set of assets that the plant management is dealt” (p.108). Thus we argue that the operating frontier focuses on internal improvements and betterments of performance in a manufacturing organization, while the asset frontier focuses on the best in industry type of performance. This is illustrated in figure 1.

![Figure 1. Operating and asset frontiers. Firm A is likely to operate under the laws of cumulative capabilities while firm B, due to diminishing returns on improvement is more likely to be subject to the law of trade-offs. (adapted from Schmenner and Swink, 1998).](image-url)
Thus, we can argue that any study that aims at analysing the trade-off model of manufacturing capabilities should take into consideration this difference between asset and operating frontiers, especially in how manufacturing capabilities are measured for the analysis.

We shall now examine how studies that deal with the trade-off model are presented in terms of the way that manufacturing capabilities are measured. While the literature on manufacturing trade-offs is extensive, we have selected four published studies that are representative and exemplify our arguments and ideas. Included are studies by Ferdows and De Meyer (1990) and Noble (1995) which are frequently cited as evidence supporting the cumulative capabilities models.

Ferdows and De Meyer (1990) propose that for a company to achieve lasting improvements in manufacturing performance, a preferred sequence in the development should be followed. Quality is at the base of their model (referred to as the sand cone model), followed by capabilities such as dependability, speed and then cost efficiency. In their study organizations are asked to rate the perceived change in eight performance measures (including quality, delivery speed, and cost) over a period of two years (1985-1987). Their conclusion is that organizations achieving improved performance on more than one measure are paying for it elsewhere (and the effect was not captured by the study), or the trade-off construct itself has to be modified. They make the assumption that most respondents had no operating slacks in their production systems in 1985 due to the large, well performing manufacturing units bias in their sample. They argue, if the assumption is valid and using the sequential development of their sand cone model, organizations will achieve lasting improvements of performance across several manufacturing capabilities.

Noble (1995) uses a multiple country sample that includes manufacturing companies from Korea, North America and Europe to examine the validity of the cumulative capabilities model. The manufacturing capabilities included quality, dependability, delivery, cost, flexibility and innovation. Composite measures are used for each capability. For instance, quality includes items that measure whether companies have recently accomplished productivity regarding rework, yields and machine up time. The subjects are asked to rate the degree to which the quality control staff is a source of productivity ideas. The strength of the quality control/assurance function within the plant is also assessed by the respondents. Similar approaches are used to measure the other manufacturing capabilities. The author argues that results obtained in the study yield some evidence for the cumulative capabilities model, particularly in the Korean sample and that better performing firms generally compete on the basis of multiple capabilities.

Szwejczewski et al (1997) study whether the trade-off between lead-times and delivery reliability still applies using a sample of UK manufacturing organizations. The authors conclude that the trade-off between shorter lead-times and high levels of delivery performance no longer holds true.

Filippini et al (1998) provide definitions and empirical evidence to the study of trade-offs and compatibility between manufacturing performance measures. They analyse whether several manufacturing performance measures are in a trade-off or compatibility situation in their study of cross-industry Italian manufacturing organizations. The performance measures analysed in the study are return on sales, invested capital turnover, quality consistency, quality capability, punctuality, and
delivery time. Their results offer evidence about the circumstances in which some performance measures face trade-off situations. This study also offers evidence that tends to support the cumulative capabilities models.

While the four studies analysed here concentrate on the trade-off concept, only those by Szwejczewski et al (1997) and Filippini et al (1998) use measures of manufacturing performance that we feel are more consistent with the trade-off concept. Studies by Ferdows and De Meyer (1990) and Noble (1995), while useful and important, are not using measures of manufacturing performance consistent with the trade-off model. For example, Ferdows and De Meyer (1990) and Noble (1995) use, in some instances, measures of internal improvement and betterment operating frontier as the resultant variable, while the Szwejczewski et al (1997) and Filippini et al (1998) studies utilise measures of manufacturing performance compared to industry/competitors (asset frontier) as the resultant variable. Figure 2 illustrates this point.

![Diagram](image)

**Figure 2.** Classification of four studies in terms of the manufacturing performance measures used to analyse the trade-off model. 1) Ferdows and De Meyer (1990); 2) Noble (1995); 3) Szwejczewski et al (1997); 4) Filippini et al (1998)

Once again, these arguments are based on the theory of performance frontiers. The distinction between the operating and asset frontier advanced by this theory has encouraged us to re-evaluate some of the studies that focus on the issue of manufacturing trade-offs. Part of our conclusions based on these observations is that studies should use consistent measures of manufacturing performance, especially with respect to the trade-off construct. The rationale here is that more accurate results and analyses for the trade-off construct can be obtained if more consistent measures of manufacturing performance (asset frontier measures not operational frontier measures) are utilised. This issue is further discussed in the following section.
4. Discussion and conclusions

This literature overview reveals a number of important issues worthy of research and discussion. However, we concentrate our comments and conclusions on the issue of the equivalence of competitive priorities and manufacturing capabilities, and also on the topic of performance frontiers, cumulative capabilities and trade-offs models.

We have shown that in some studies, competitive priorities and manufacturing capabilities have been inappropriately defined as equivalents. The assumption that these two concepts are indeed equivalent is examined in the light of the study of the trade-off model of manufacturing capabilities.

In the three studies reviewed here on the validity of the trade-off model, the relationships amongst performance dimensions such as costs, flexibility, quality and others are examined. These studies measure the dimensions on perceived emphasis or priority and not actual performance. Using on the relationships amongst those measures, these studies arrive at varying conclusions about the applicability of the trade-off model. They consider that the emphasis or importance that organizations place on different manufacturing dimensions is a good estimator of their actual performance. Thus, these studies make the cognitive leap that priority or emphasis is indeed equivalent to actual capability or performance at least in terms of manufacturing performance.

Simply put, organizations with high priorities on certain dimensions do not necessarily mean that it will achieve (or is already achieving) high performance levels on those particular dimensions. As Ahmad and Schroeder (2002) comment, other factors (aside from the importance put on a manufacturing dimension) such as the adoption of adequate management practices may determine whether an organization achieves a high level of performance on a particular manufacturing dimension. However, as others have argued, even if companies try to do all they can (such as adopting adequate management practices) to achieve high levels of performance, it could be that factors outside their control might influence the outcome of their efforts (Wacker, 1996; Droge and Germain, 1998 discuss the potential effect of contextual variables on manufacturing performance).

Equating competitive priorities to manufacturing capabilities could become an issue if the actual performance of a manufacturing company is assessed by the priority or emphasis that is being placed on the various manufacturing capabilities. There is still value and importance in studying competitive priorities that companies have, we only argue that emphasis on competitive priorities only reveals the way in which an organization intends to compete. If an organization reveals that it simultaneously places a high priority on a number of manufacturing capabilities, it does not mean that trade-off construct is rejected. Nonetheless, if an organization achieves high levels of performance across a number of manufacturing dimensions (capabilities), this would make a more convincing argument against the trade-off construct. But, the caveat here is our second argument, that these capabilities should not be based on internal capabilities without reference and explicit consideration to overall industry capabilities when evaluating the trade-off construct.

The trade-off model proposes the existence of limitations and compromises amongst high levels of manufacturing performance measures. Schmenner and Swink (1998) explain this issue in more detail. Some authors present alternative views to the development of manufacturing capabilities. For instance, Ferdows and De Meyer (1990) propose that in order to obtain lasting improvements in manufacturing performance, a sequential development should be followed. We assume that the
underlying idea behind the cumulative capabilities models is that of incremental improvements, in a certain order, which ultimately will result in lasting, high levels of performance across a number of manufacturing capabilities. If this assumption is true, it could be said that both the trade-off and cumulative capabilities models aim at analysing how manufacturing performance measures behave at, or near the performance frontier ("asset frontier", as in Schmenner and Swink, 1998). Hence, we feel that if these models are to be studied, it would be preferable to include performance measures that could relate the manufacturing capabilities to the asset frontier (relative capability measures based on external comparisons).

Since the trade-off construct addresses trade-offs between high levels of manufacturing performance measures, consistent indices of performance should be utilised in order to assess the existence of such trade-offs. Ferdows and De Meyer (1990) and Noble (1995) have used items regarding the improvement achieved in some areas of manufacturing. These are important measures as they show how capabilities may be improved and developed. However, it would be preferable if these improvement indexes were accompanied by other measures with which assessments regarding the position of an organization relative to the performance asset frontier. Organizations can achieve improvements or betterment within their own performance (operating) frontiers by increasing utilisation, efficiency or altering manufacturing operating policies. Nonetheless, these indices alone do not give an accurate measure of how an organization (regarding manufacturing capabilities) is situated in respect to its industry and competitors (the asset frontier).

Specifically, our criticism centres on the use of internal improvements and betterments on performance achieved as the resultant (dependent) variable in a relationship in which clearly this type of measures should be treated as the explanatory variable. The cumulative capabilities models posits that incremental and sequential improvements in some areas of manufacturing will lead to higher manufacturing performance levels in which some or all existing trade-offs will be overcome. As an example a model proposed by Ferdows and De Meyer (1990) is as follows:

\[ \text{High Manufacturing Dependability performance (f) = improvements on manufacturing dependability performance + improvements on manufacturing quality performance.} \]

A central proposition advanced by the cumulative capabilities model establishes that higher performance levels within a particular area of manufacturing depend upon internal improvements on that particular area plus the cumulative and sequential effects of the improvements achieved on manufacturing areas that precede it in the sequence. We do not believe that these relationships are being properly modelled and analysed by studies such as those by Ferdows and De Meyer (1990) and Noble (1995). In some instances, they are using measures of internal improvements as the resultant (dependent) variable, an inconsistency with the models they are studying. Ferdows and De Meyer (1990), do recognise and understand this issue, as they wrote that “Since, as mentioned previously, our sample is biased towards large, well performing manufacturing units, we have assumed that most of them were not operating with slacks in their production systems in 1985” (p. 171). We also agree that in some contexts or situations, internal improvements could be directly translated into higher manufacturing performance relative to competitors/industry (for instance, in markets/products where a firm is already located at the highest level on the asset frontier). Nonetheless, this observation reinforces our arguments regarding the importance of distinguishing between the operating and asset frontiers when studying the issue of manufacturing trade-offs.
Schmenner and Swink (1998) argue that the trade-off and cumulative capabilities models may not be rival concepts. They argue these two constructs are complements that are subsumed by the broader theory of performance frontiers. Nonetheless, the original proponents of the cumulative capabilities constructs thought of these models as being a way to explain how sequential, incremental improvements can lead to the achievement of lasting, high levels of manufacturing performance in all dimensions such as quality, flexibility, costs, and delivery. If true, this would place the cumulative capabilities constructs in the same category as the trade-off construct and hence would make them comparable. The question of whether these constructs are competing only increases the importance of adequately assessing not only the improvements or betterments that are achieved internally by companies, but also the situation of the companies with respect to their performance (asset) frontier. At the very least, we feel that studies that aim at analysing the trade-off model should consider measures (raw indexes or perceptual measures) of actual performance that are indicative of the position of a company with respect to the asset frontier (as illustrated in Szwejczewski et al, 1997; or Filippini et al 1998).

In summary, based on our arguments, these are the responses to our original research questions:

1. When studying the trade-off model, “competitive priorities” and “manufacturing capabilities” should not be considered as equivalent terms.

2. When assessing manufacturing performance measures, and in terms of the trade-off model, the resultant variables should be aimed at the “asset” frontier, and not the “operating” frontier. Analyses based on these two different types of performance frontiers could lead to different conclusions regarding the trade-off model. In fact, a preliminary analysis of a sample of firms (from the global manufacturing research group (GMRG)) that reported their performance in relation to both their operating and asset frontiers initially support our proposition. Specifically, the variables “manufacturing throughput time” and “product design time” observe a significant and positive relationship when the measures relate to the asset frontier. Interestingly, when measured towards the operating frontier, those variables do not observe a significant relationship.

3. When analysing the trade-off model, we propose that researchers and practitioners should least apply measures of real manufacturing performance that reveal the status of the manufacturing performance variables in relation to its “asset” frontier.

Figure 3 shows our findings and proposals graphically:
We have contributed to the body of knowledge in this field by examining in detail the concept of performance frontiers and some of its relationships with the trade-off model and cumulative capabilities models. Our findings and observations should help in designing and implementing future studies that seek to address this important area of operations strategy and strategic improvements. Alternatively, we also believe that our findings outline specific issues for future research. In particular, we think that future studies could include an analysis of the relationship (trade-offs and/or compatibility) between manufacturing performance areas and the difference and/or similarity when those analyses are done with measures related to the operating and asset frontiers. Preliminary analyses taking this approach show that the results are indeed different. Replicating previous studies of the cumulative capabilities model as proposed by their original authors, given the observations made in this paper are also avenues of future research. For example, we recommend that these additional follow-up studies be completed in the form of a regression analysis models where measures of manufacturing performance related to the asset frontier act as the dependent, resultant variable, and measures of internal improvements on manufacturing performance (operating frontier) act as the explanatory variables as described by the following functional form:

\[
\text{Asset frontier in manufacturing performance} \quad "X" = \text{improvements (operating frontier) in manufacturing performance} \quad "X" + \text{improvements (operating frontier) in preceding manufacturing areas in the sequence proposed by the cumulative capabilities models}
\]

These studies would further advance the understanding of the linkages and relationships among concepts such as manufacturing trade-offs, cumulative capabilities and performance frontiers.
References


