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Zero-sum and frontier trade-offs: an investigation on compromises and compatibilities amongst manufacturing capabilities

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Zero-sum and frontier trade-offs: an investigation on compromises and compatibilities amongst manufacturing capabilities

Abstract: This paper examines well-accepted methodologies and rationales used to assert the presence/absence of trade-offs and compatibilities between manufacturing capabilities, and comparisons are made with respect to more recent theoretical developments. By means of a detailed analysis of a representative framework, important limitations and inconsistencies are identified. The proposal for the existence of zero-sum and frontier trade-offs intends to resolve some of those issues. Generally speaking, zero-sum trade-offs are identified by a statistically significant and negative correlation. On the other hand, frontier trade-offs are predicted to be observed after some level of compatibility between different capabilities is achieved. This means that, apart from widely-used probabilistic methodologies such as linear regression/correlation analysis, subsequent deterministic approaches and rationales need to be applied in order to acknowledge the potential existence of frontier trade-offs. These and other implications are discussed in light of previous studies, and suggestions for future research are offered.

Keywords: *trade-off model, compatibilities, cumulative capabilities, zero-sum trade-offs, frontier trade-offs, theory of performance frontiers, probabilistic analyses, deterministic analyses, top performers/extreme cases, thought experiments.*

1 Introduction

The importance that trade-offs amongst an organisation's objectives have on its strategy (and hence its competitiveness) has been commented on and discussed by prominent authors in both the business (e.g.; Porter, 1980, 1985; Mintzberg et al, 2003) and manufacturing (e.g.; Skinner, 1969, 1974; Hayes and Wheelwright, 1984; Hill, 1995) strategy fields. The operations management authors in particular have commented that a successful strategy is one that is built around strategic manufacturing trade-offs. Structural (e.g.; **production capacity and technology, facilities**) and infrastructural (e.g.; **quality management systems, human resources management, information technology systems**) resources have to be deployed and developed accordingly. Moreover, it is argued that the failure to recognise the existence of these trade-offs could result in a loss of competitive power at the industry/marketplace level (Hayes and Wheelwright, 1984).

A salient theme from this line of research is the approaches and rationales by which researchers, especially in manufacturing strategy studies, have examined and come to the conclusion that different capabilities (e.g.; quality, delivery, cost) are traded-off or compatible. This is a particularly important issue in investigations that employ quantitative approaches to the analysis of the information (e.g.; linear regression/correlation analysis).

In this paper, we intend to address some of the limitations that past empirical and theoretical research on trade-offs and compatibilities between manufacturing capabilities has left pending. By means of a detailed analysis of well-accepted methodologies and assumptions, we arrive at the conclusion that, in order to resolve those issues, two types of compromised relationships between different capabilities need to be recognised: "zero-sum" and "frontier" trade-offs. Zero-sum trade-offs are commonly represented by a statistically significant and negative relationship between two capabilities. Generally speaking, this kind of trade-off is one in which a gain in performance in one capability entails a loss in performance in another capability in a more direct/linear manner. On the other hand, the frontier type of trade-off is characterised by a differential in performance between two capabilities after some level of compatibility is achieved, something that is consistent with the concepts and ideas advanced by various authors (e.g.; Skinner, 1992, 1996; Schmenner and Swink, 1998). It is noted that frontier trade-offs are difficult (if not impossible) to identify with probabilistic and overall associative approaches to the analysis of a

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3 sample of subjects (e.g.; linear regression/correlation analysis, path analysis). Thus,
4 it is proposed that additional and more focused and deterministic (i.e.; precise)
5 analyses, including those with a heuristic “benchmark” approach also be employed. It
6 can also be said that zero-sum trade-offs represent a relationship between two
7 capabilities that can be far more “adversarial” than when two capabilities are in a
8 frontier trade-off. As such, the differential in performance caused by a zero-sum
9 compromise is expected to be considerably greater than the one caused by a frontier
10 trade-off.
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18 We discuss the findings of our investigation in light of past theoretical and
19 empirical research. For example, we argue that when some studies have claimed to
20 offer evidence against the existence of trade-offs between different capabilities in
21 their samples, they are really offering evidence only against the existence of zero-
22 sum trade-offs, but not against the potential existence of frontier trade-offs. Zero-
23 sum compromises might be contingent upon various circumstances and conditions
24 (e.g.; Safizadeh et al, 2000; Flynn and Flynn, 2004). Also, when authors have
25 acknowledged and/or provided evidence that some trade-offs can be improved but
26 not eliminated (e.g.; New, 1992; Skinner, 1992, 1996; da Silveira and Slack, 2001),
27 they have arguably made an implicit reference to a frontier trade-off that governs the
28 relationships between different criteria. The potential presence of frontier trade-offs
29 implies a change in the way compromises and compatibilities amongst manufacturing
30 capabilities are understood. This means that, as opposed to what current rationales
31 propose, compatibilities (e.g.; cumulative capabilities) and (frontier) trade-offs can co-
32 exist within the same sample of subjects. To the best of our knowledge, this is the
33 first investigation that examines the issues outlined above. The consequences of
34 these and other results are discussed, and proposals for future research are offered.
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47 The rest of the paper is organised as follows: section 2 deals with the
48 definitions and background of our investigation. Specific research questions are laid
49 out. Section 3 presents an analysis on well-accepted approaches and rationales, and
50 compares them with more recent theoretical developments. Inconsistencies and
51 limitations are highlighted, and the existence of zero-sum and frontier trade-offs is
52 advanced in order to resolve some of those issues. Section 4 compares the findings
53 of our investigation with those of previous research, and section 5 offers conclusions
54 and suggestions for future studies.
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2 Trade-offs and compatibilities amongst manufacturing capabilities: definitions and background

2.1 Definitions

In order to achieve clarity, several concepts and definitions need to be established. Therefore, a trade-off situation is defined as one in which a firm achieves high levels of performance in one manufacturing capability at the expense of lower levels of performance in one or more capabilities (i.e.; a gap in performance that represents a differential in competitive power). This definition is consistent with the trade-off model's original tenets: "... no technologically-based system can perform equally well on every performance criterion" (Skinner, 1996, p. 8). In this context, a "high" level of performance is defined as an "... outstanding enough to create competitive advantage" (Skinner, 1996, p. 6) level of achievement in one or more capabilities. The preceding statements imply that, at the very least, different capabilities that are traded-off will not attain an "outstanding enough to create competitive advantage" type of performance at the same time and under the same circumstances. This definition includes the meaning of the "frontier" and "zero-sum" trade-offs introduced in section 1.

A compatibility situation implies that there is evidence of an overall and similar degree of performance achievement up to a determined level between different capabilities. This definition of "compatibility" covers the characterisation of "cumulative capabilities" that has been used by previous authors (e.g.; Ferdows and de Meyer, 1990; Noble, 1995; Flynn and Flynn, 2004). Nonetheless, contrary to the definition of "cumulative capabilities", "compatibility" does not necessarily imply, for example, that just because different capabilities observe a generally compatible situation (e.g.; a positive and significant correlation/regression coefficient), such a scenario indicates that the analysed criteria have achieved, or will eventually achieve, an "outstanding enough to create competitive advantage" level of performance at the same time and under the same circumstances. Put differently, our definition of compatibility allows for the presence of both "cumulative capabilities" (e.g.; mutual progression) and (frontier) trade-offs (i.e.; a differential in performance with respect to higher levels of achievement) in a relationship between different capabilities.

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3 We also advance a heuristic and deterministic (i.e.; precise) approach to analyse
4 compromises and compatibilities between competitive criteria. The firms are first
5 identified according to the levels of performance they achieve across the different
6 capabilities included in the analysis. Then, for each individual firm, we make
7 assessments of performance between different pairs of manufacturing capabilities in
8 terms of the mutual levels of achievements and also the shortfalls/differentials in
9 performance with respect to higher levels of achievement. This, in turn, will allow us
10 to focus on the “top performers” (i.e.; a benchmark approach) in order to understand
11 more fully the trade-offs and/or compatibilities that might exist between different pairs
12 of capabilities. The “top performer (s)” is defined as the firm (s) that observes the
13 highest levels of achievement across multiple capabilities in a sample. This would
14 mean that, for instance, the ideal top performer (s) would be the firm (s) that achieves
15 an outstanding enough to create competitive advantage type of performance across
16 all manufacturing capabilities at the same time. Section 3 explains this approach in
17 more detail.
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29 Schmenner and Swink (1998, p. 108) affirm that an asset frontier is defined by
30 and dependent upon the kinds of investments that appear on the fixed asset portion
31 of the balance sheet. Furthermore, they assert that, as firms approach their asset
32 frontier, trade-offs between different capabilities will become more evident. These
33 relationships are characterised by the laws of diminishing returns and synergy¹.
34 Figure 1 illustrates these concepts:
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Take in figure 1

2.2 Theoretical background

51 There has been much interest in examining whether manufacturing firms can
52 become industrial/marketplace leaders across several or all manufacturing
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55 ¹ The law of diminishing returns entails a proportional (e.g.; linear) relationship between two
56 variables that becomes a disproportional (e.g.; nonlinear) one after a certain point in the
57 relationship is reached. Thus, when Schmenner and Swink (1998) state that their framework
58 rests on this premise, it can be derived plausibly that the “cumulative capabilities” they speak of
59 in their framework are represented by the proportional aspect of the relationship, whereas
60 “trade-offs” are exemplified by the non-proportional aspect of it (see for example the discussion
in page 110 of Schmenner and Swink, 1998).

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3 capabilities. The underlying idea, evidently, is to achieve excellence in performance
4 that in turn will provide firms with a competitive advantage. Let us consider Skinner's
5 actual words: "one system cannot be outstanding enough at meeting all criteria to
6 create competitive advantage" (Skinner, 1996, p. 6). Also: "... no technologically-
7 based system can perform equally well on every performance criterion" (Skinner,
8 1996, p. 8). Putting those two statements together, the conclusion is that the trade-off
9 model actually predicts that no manufacturing system can perform equally well and
10 outstandingly enough across every performance criterion at the same time.
11 Therefore, it is recommended that companies should adopt a "focused factory"
12 approach to the design, development, and implementation of the strategy and
13 operations of a production unit. Echoing Skinner's arguments, Hayes and
14 Wheelwright (1984, p. 41) also warn against trying to compete by offering superior
15 performance in all manufacturing capabilities, since any attempt to do so would likely
16 result in firms achieving only a second-best type of performance in all of them,
17 something that in turn would make them lose competitiveness. It follows from the
18 preceding discussion that in order to conclusively assert that no trade-off is present in
19 a relationship between any pair of capabilities, a firm or firms would have to attain an
20 "outstanding enough to create competitive advantage" type of performance across
21 those capabilities at the marketplace/industrial level of analysis and under the same
22 circumstances.
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38 On the other hand, various authors have proposed what they consider to be
39 competing, more complete and comprehensive models and theories. For example,
40 the cumulative capabilities models (e.g.; Ferdows and de Meyer, 1990) and rigid-
41 flexibility models (e.g.; Collins et al, 1998) offer alternative views on the development
42 of strong capabilities. The basic idea behind these models is that some (or all) trade-
43 offs can be overcome, particularly if continuous improvement programs such as
44 TQM, JIT, TPM, etc., are successfully implemented. It is also worth noting that it is
45 not clear whether the proponents of the cumulative capabilities and rigid-flexibility
46 models affirm that *all* trade-offs can be overcome or simply that a production unit can
47 be "outstanding enough to create competitive advantage" on more than one or two
48 capabilities. A literature review identifies a number of studies that deal with diverse
49 aspects of the trade-off model and/or its competing concepts, with varying results
50 and conclusions (Ferdows and de Meyer, 1990; Roth and Miller, 1990, 1992; Noble,
51 1995; Schroeder et al, 1996; Mapes et al, 1997; Morita and Flynn, 1997;
52 Szejczewski et al, 1997; Fillipini et al, 1998; Collins et al, 1998; Flynn et al, 1999;
53 Fynes et al, 2000; Mapes et al, 2000; Safizadeh et al, 2000; Dostaler, 2000, 2001; da
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3 Silveira and Slack, 2001; Corbett and Whybark, 2001; Corbett and Claridge, 2002;
4 Stratton and Warburton, 2003; Lapre and Scudder, 2004; Rosenzweig and Roth,
5 2004; Flynn and Flynn, 2004; Narasimhan et al, 2005; Fynes et al, 2005; da Silveira,
6 2005; da Silveira, 2006; Grobler and Grubner, 2006; Squire et al, 2006; Swink et al,
7 2006; Stratton and Warburton, 2006; Sarmiento et al, 2007; Antonio et al, 2007;
8 Sarmiento et al, 2009).

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15 An analysis of the aforementioned studies shows some evidence that firms are
16 capable of achieving synergies, mutual progression, and in some cases, what could
17 be considered as high levels of performance on a number of capabilities.
18 Nonetheless, it can also be concluded that the main tenets of the trade-off model
19 have not been refuted. In other words, the reviewed investigations do not offer
20 evidence supporting the existence of a firm or firms that have actually achieved an
21 “outstanding enough to create competitive advantage” level of performance across *all*
22 manufacturing capabilities.
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29 A key topic in this area of research concerns the way in which authors have
30 determined that two or more capabilities are traded-off or compatible. The reviewed
31 studies show a favoured approach to the examination of these themes: researchers
32 obtain from firms cross-sectional data (perceptual and/or objective) representing
33 manufacturing performance metrics (e.g.; cost, delivery). The data is then analysed
34 using quantitative and probabilistic approaches (e.g.; linear regression/correlation
35 analysis and related methodologies). Generally, analysts have come to the
36 conclusion that different capabilities are in a trade-off or in a compatibility (e.g.;
37 “cumulative capability”) situation if they observe significant negative or positive
38 correlation coefficients, respectively. For example, Safizadeh et al (2000, p. 117)
39 write: “.. a positive correlation means parallel developments of two capabilities. A
40 negative correlation implies trading-off one capability for another”. Such definitions
41 imply that, since the trade-off model and its seemingly competing theories have been
42 depicted as mutually exclusive concepts, previous authors have chosen to assert the
43 presence of two competing concepts (e.g.; trade-offs or cumulative capabilities)
44 based on mutually exclusive types of evidence (i.e.; significant negative or positive
45 correlations) that describe overall associations amongst variables within a sample of
46 subjects. The type of compromised relationship described in those studies is
47 consistent with the zero-sum trade-off introduced in section 1.
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As previously mentioned, the above methodologies and rationales have been widely accepted and used in past research. Nevertheless, we think that more recent theoretical developments have important repercussions on those approaches. For example, various authors in the operations and strategic management areas (e.g.; New, 1992; Skinner, 1992, 1996; Schmenner and Swink, 1998; Porter, 1996) have suggested that while there may be instances in which different criteria can observe mutual improvements and parallel trajectories along their development, strategic trade-offs and compromises are still existent, relevant, and should not be overlooked. Thus, if compatibilities and compromises can be observed along the development of two capabilities, it follows that approaches capable of identifying both trade-offs *and* compatibilities in a relationship are necessary. Such approaches should be consistent when the unit of analysis is a group of firms or individual firms. These premises suggest a reassessment and re-evaluation of current methodologies and rationales used in these types of studies in order to determine whether they are consistent with newer theoretical developments. Consequently, when contradictions or inconsistencies are found, they need to be resolved.

The re-evaluation of well-accepted methodologies and rationales raises a number of important questions. For example, are regression/correlation analyses capable of identifying the potential trade-offs *and* compatibilities that can exist between a pair of competitive criteria as implied by more recent theoretical investigations? If not, what types of approaches are needed? If new approaches are needed, how can they be reconciled and made consistent with past methods and rationales? The rest of the paper will attempt to answer these questions.

3 An investigation on trade-offs and compatibilities

Consistent with Schmenner and Swink (1998), we utilise “thought experiments” to illustrate and support our arguments. The use of thought experiments is a well-accepted approach in areas such as physics (Popper, 2002). Nevertheless, some researchers (e.g.; Folger and Turillo, 1999) have also discussed the usefulness of such an approach in business management studies. Therefore, our use of this type of experiment is justified. By means of a detailed analysis of a framework that is representative of more recent theoretical developments, we explore the potential advantages and limitations of widely accepted methodologies and rationales. To resolve some of the issues that past investigations did not identify and

thus left unresolved, we formally acknowledge the existence of zero-sum and frontier trade-offs.

3.1 Rationale for the existence of frontier trade-offs

To support our arguments for the existence of frontier trade-offs, we use the illustration advanced by Schmenner and Swink (1998, figure 1 in this paper). However, one addition is made in order to highlight some issues within that framework. Figure 2 shows this:

Take in figure 2

We have added a positive regression/correlation line to Schmenner and Swink's (1998) original framework to represent the "cumulative capabilities" they say are present in their illustration. As was discussed in section 2, a positive and significant linear regression/correlation coefficient is a widely used and well-accepted means to depict "cumulative capabilities". Furthermore, figure 2 suggests a positive and significant trajectory, as the firms included in it are portrayed to move upwards and to the right along the development of their capabilities. Therefore, we think that our inclusion of the regression/correlation line in figure 1 is valid. Having said this, we also identify a particular issue: Schmenner and Swink (1998) argue for the existence of both "cumulative capabilities" and "trade-offs" in their framework. They also comment that such compromises are observed after cumulative capabilities are attained, and that those trade-offs become more evident the closer a firm gets to its asset frontier. Thus, it can be said within reason that the trade-off implied by the theory of performance frontiers cannot be one that is consistent with an overall linear and negative regression/correlation analysis. As was discussed in section 2, such a coefficient is also a well-accepted means to assert the presence of a compromised relationship. To sum up, figure 2 implies a scenario in which both compatibilities and a trade-off that is not representative of a negative and significant regression/correlation line have to be fitted into one single framework.

To understand better and to attempt to resolve the above issues, we propose to extend the framework presented in figures 1 and 2 to include several firms at

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3 different stages in the development of their capabilities. Consistent with the
4 assumptions made by Schmenner and Swink (1998), we also assume that the firms
5 included in the study have similar asset frontiers and are comparable to each other.
6 Since the study is illustrative in principle, the firms are modelled to have only two
7 manufacturing capabilities (e.g.; quality, cost). We call these variables “MC1” and
8 “MC2”. The different performance levels in the firms are represented by a likert-type
9 scale. These types of scales are a widely-used means to perceptually assess the
10 relative performance of a firm compared to its industry/competitors². This approach
11 makes it consistent with the main tenets of the trade-off model that were discussed in
12 section 2. The scale includes varying levels of performance: 5, 4, 3, 2, 1. In order to
13 maintain consistency with Skinner (1996), a “5” represents an “outstanding enough to
14 create competitive advantage” level of performance, while the rest of the scales
15 represent lesser levels of achievement.
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26 Figure 3³ illustrates the “cumulative capabilities” and (frontier) “trade-off”
27 predicted by the theory of performance frontiers in an ideal form. It also includes
28 different ways in which the sample of firms can be analysed.
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Take in figure 3

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40 **The preceding figure represents the proportional and disproportional**
41 **aspects of a relationship between two variables as suggested by Schmenner**
42 **and Swink’s (1998) framework.** Therefore, if a researcher were to investigate the
43 relationship between MC1 and MC2 by means of current rationales and approaches,
44 he/she would very likely conclude that “cumulative capabilities” exist between the two
45 variables in the study, and that there is no evidence of any trade-offs. This would be
46 based on the positive and significant regression/correlation line and coefficient
47 obtained. Nevertheless, it is clear that such a conclusion would be incomplete. While
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55 ² **Although using perceptual measures of performance is consistent with the trade-off model’s**
56 **aims and goals, it could also be possible to utilise objective measures of achievement (e.g.;**
57 **“98% on-time delivery rates, “30% of defective product”), as long as the sample includes firms**
58 **from the same industry and similar context, or comparable competitors so that reasonable**
59 **comparisons with respect to the marketplace-leading performers can be made.**

60 ³ Figure 3 can also be understood as an ideal “picture” of a single firm as it advances in the
development of two capabilities that observe both “cumulative capabilities” and (frontier) “trade-offs”, as
implied by several authors.

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it is true that the positive and significant regression/correlation line would be an acceptable and overall indicator of the “cumulative capabilities” that exist in the framework (e.g.; a 1/1 ratio between MC2 and MC1 as shown by firms A, B, C and D), this method would not be able to identify the existing differential in performance between MC1 and MC2 (i.e.; a frontier trade-off) as observed in firm “E” (e.g.; a 4/5 ratio between MC2 and MC1). Such a compromise would be the result of the presence of the asset frontier as proposed by Schmenner and Swink (1998), which in turn would mean that only one capability would attain a level 5 in performance, while the other one would achieve only a lesser level of performance (e.g.; level “4”). This differential in achievement clearly would be in accord with the definition of trade-offs advanced by Skinner (1992, 1996). The problem, nevertheless, resides in the fact that an overall methodology such as linear regression/correlation analysis would “mask” or “hide” the (frontier) trade-off caused by the asset frontier and that is expected to take place at the higher levels of performance. Arguably, methodologies based on the central tendency behaviour of the observations, such as linear regression/correlation analysis and related methodologies, would be incapable of detecting and distinguishing the differential in performance that is predicted to occur at the highest levels of the performance continuum and the closer a firm gets to its asset frontier.

Given these limitations, we think that a more correct and holistic analysis of the sample, as well as of individual observations, needs to include but also go beyond regression/correlation analysis. We propose a deterministic and heuristic approach to analyse each individual firm. Assessments with respect to both commonalities in performance achievements (e.g.; cumulative capabilities) and also shortfalls and differentials in performance (e.g.; trade-offs) amongst the criteria in discussion can be made. For example, let us re-examine figure 3, assuming that the researcher is not aware of the presence of a (frontier) trade-off. By analysing the firms individually, it could be said within reason that there is evidence of mutual progression and compatibilities in achievement between MC1 and MC2 up to the “4” level of performance, and that this trend is supported by an overall positive and significant regression/correlation coefficient. Nonetheless, by means of a deterministic “benchmark” analysis of the sample that focuses on the top performers (firms “D” and “E”), it can also be affirmed that the similar level of mutual progression, achievements, and compatibilities was not replicated at the level “5” of performance (i.e.; there is a differential in performance between MC1 and MC2, as seen in firm E), which in turn could be indicative of the presence of a (frontier) trade-off between MC1

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3 *and MC2*. Arguably, focusing on the “best performers” (e.g.; firms that achieve “high
4 levels of performance” in one or more capabilities) gives the researcher the best
5 chance at analysing whether such high levels of performance could have come at the
6 expense of lower levels of achievement in one or more different capabilities. Ideally,
7 more focused and corroborative case studies (including longitudinal ones) would also
8 be performed.
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15 We think that our proposed heuristic approach and rationale to the analysis of
16 the results is more complete than the way in which previous authors have examined
17 the evidence and derived their conclusions in studies using a quantitative approach
18 with cross-sectional data. For instance, various studies claim to present no results
19 that support the existence of trade-offs in their samples⁴ (e.g.; Ferdows and de
20 Meyer, 1990; Noble, 1995; Flynn and Flynn, 2004). However, such a rationale is
21 limited, because, while the lack of a significant and negative relationship might
22 indicate the absence of a (zero-sum) trade-off, it is possible that a frontier trade-off
23 could still be present, as our analyses have shown. To sum up, achievements in
24 performance should be interpreted both in terms of the mutual levels of progression
25 and compatibilities that the criteria under study observe, and also in terms of the
26 performance shortfalls identified with respect to higher levels of achievement, which
27 in turn could be indicative of the presence of a frontier trade-off.
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37 We now proceed to justify the existence of zero-sum trade-offs.
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41 **3.2 Rationale for the existence of zero-sum trade-offs**

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45 It could be said that trade-offs of the zero-sum type, while not identified and
46 labelled as such, is the most widely accepted form in which a compromised
47 relationship between variables has been portrayed and understood. Our analyses of
48 the trade-off model literature reveal that such an assumption is commonly used by
49 previous investigations when assessing whether trade-offs between two different
50 criteria exist, particularly in quantitative studies (e.g.; Ferdows and de Meyer, 1990;
51 Safizadeh et al, 2000; Flynn and Flynn, 2004). Generally, a significant and negative
52 regression/correlation coefficient has been taken as an indication of this type of
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59 ⁴ One way in which past studies assert the absence of a negative and significant relationship (and
60 hence the absence of a (zero-sum) trade-off) is by means of a positive and significant coefficient
between two capabilities. Another way is by means of a non-significant coefficient.

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3 trade-off. As footnote 4 explains, the absence of such a coefficient has been
4 explained as the lack of evidence of a compromised relationship between two
5 variables. Figure 4 illustrates an ideal version of this type of trade-off:
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Take in figure 4

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16 As can be seen, the relationship shown above reflects a trade-off situation, a
17 differential in performance between **MC3 and MC4 (e.g.; fast delivery and market-**
18 **based quality, as in Flynn and Flynn, 2004)** observed particularly at the highest
19 levels of performance. This is also consistent with the definition of a compromised
20 relationship as proposed by Skinner (1992, 1996). It is also evident that, as opposed
21 to the case in which frontier trade-offs are present, linear regression/correlation
22 analyses would be a fairly adequate tool to identify this latent trade-off.
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29 The previous paragraphs have dealt with various issues that our research into
30 the trade-off model and related concepts has raised. The acknowledgement of the
31 existence of both zero-sum and frontier trade-offs reconciles some of those
32 difficulties. This implies a change and re-evaluation of the rationales used to assert
33 that two variables are in a compatible and/or compromised situation. Moreover,
34 figures 3 and 4 show that the compromises in performance that zero-sum and frontier
35 trade-offs represent are considerably different (e.g.; under a zero-sum trade-off, firm
36 "E" would attain a "5" along MC3, but only a "1" in MC4; under a frontier trade-off,
37 firm "E" achieves a "5" along MC1, but only a "4" in MC2). Also, it bears repeating
38 that the presence of the asset frontier implies that both compatibilities (e.g.;
39 cumulative capabilities) and (frontier) trade-offs between two criteria can exist in the
40 same sample of subjects, and that it is important to extend current methodologies
41 and rationales used in these types of studies in order to acknowledge such a
42 situation.
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4 Discussion

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55 Previous investigations offer some evidence of the several situations
56 described and discussed in section 3. For example, two studies (Safizadeh et al,
57 2000; Flynn and Flynn, 2004) have shown evidence of zero-sum trade-offs between
58 different capabilities. These trade-offs seem to be contingent upon various situations
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3 and scenarios (e.g.; production technology). Frontier trade-offs, on the other hand,
4 have not been explicitly identified and discussed as such. Nevertheless, da Silveira
5 and Slack (2001) write that managers view trade-offs differently from academics, and
6 that while some trade-offs can be improved, they cannot be eliminated. Their results
7 arguably could be indicative of the frontier trade-offs that we have identified. The
8 consensus amongst researchers that have studied manufacturing trade-offs seems
9 to be that evidence of a compromised relationship can only be asserted by means of
10 a significant and negative correlation coefficient. Nevertheless, as our investigation
11 has shown, a frontier type of trade-off is also a latent possibility that can explain why
12 different capabilities, while observing mutual progression and compatibilities up to a
13 certain level of performance, will not attain the same compatibility at higher levels of
14 achievement.
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24 We think that frontier trade-offs have a plausible theoretical basis. For
25 example, Skinner (1992, 1996) and New (1992) acknowledge the possibility that
26 some trade-offs could be improved, but not eliminated, by the adoption of more
27 advanced manufacturing technologies. Skinner (1992) in particular goes on to
28 explain that two capabilities that are traded-off may run in parallel or counter to each
29 other at different levels or amplitudes, but in the end, one will attain a higher level of
30 performance than the other one. Thus, a pair of variables under the effect of a
31 frontier trade-off could be indicative of Skinner's words: while they might be
32 compatible even at the higher levels of performance, in the end, only one of them will
33 attain an "outstanding enough to create competitive advantage" type of performance.
34 Schmenner and Swink (1998) and their research into the asset frontier also offer
35 strong support for the frontier trade-off concept identified in our investigation.
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45 Another important issue concerns the potential causes of both zero-sum and
46 frontier trade-offs. Various authors (e.g.; Schonberger, 1986, 1990; Ferdows and de
47 Meyer, 1990; Noble, 1995) imply that the absence of high implementation levels of
48 JIT, TQM and related practices might cause a zero-sum trade-off between different
49 criteria. Nevertheless, from the studies that present evidence of such trade-offs
50 (Safizadeh et al, 2000; Flynn and Flynn, 2004), it can not be concluded that the
51 negative and significant relationships observed are due to a lack of implementation of
52 those practices. On the other hand, Safizadeh et al (2000) present an interesting
53 result: zero-sum trade-offs seem to be dependent upon the production technology
54 utilised. For example, "cost" and "delivery" observe a significant and negative
55 relationship in batch shop processes, but no similar situation is reported for other
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3 types of production technologies. A similar scenario occurs between “quality” and
4 “customisation”, which has a zero-sum relationship in continuous flow shops, but no
5 significant relationship in other types of production technologies. With regards to the
6 causes of frontier trade-offs, from Schmenner and Swink (1998), we can derive that
7 these compromises are caused by the asset frontier. Adding to the potential causes
8 of competitive advantage, Vastag (2000), in his comments on the theory of
9 performance frontiers, argues that, excluding some special circumstances, the
10 sources of sustained competitive advantage are more likely to come from
11 infrastructural factors within firms (i.e. operating frontier) than from structural ones
12 (i.e.; asset frontier). Also, Skinner (1992, 1996) suggests that structural and/or
13 infrastructural factors might be at the root of trade-offs.
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23 In terms of the compatibility situations depicted in our study (e.g.; significant
24 and positive associations between two or more capabilities), these relationships are
25 commonly found in previous studies (e.g.; Collins et al; 1998; Fynes et al; 2000;
26 Rosenzweig and Roth, 2004; Flynn and Flynn, 2004). These and similar
27 investigations show a number of relationships in which different capabilities observe
28 a positive and significant regression/correlation coefficient. Oftentimes, these
29 compatibilities are associated with higher implementation levels of practices such as
30 TQM, TPM and related programs (e.g.; Morita and Flynn, 1997; Collins et al, 1998,
31 Fynes et al, 2000).
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39 With regards to the more holistic approach discussed in sections 2 and 3,
40 only two studies (Filippini et al, 1998; Corbett and Claridge, 2002) were found to
41 utilise a methodology similar to it. In those investigations, the authors group the
42 subjects based on the levels of performance achieved along several capabilities and
43 classify the firms in terms of the number of manufacturing capabilities in which they
44 actually achieve what could be considered as a “high level of performance”.
45 Interestingly, the results in both studies show that, generally, achieving high
46 performance along multiple capabilities is difficult, a result that arguably is consistent
47 with Skinner’s trade-off and focused factory concepts (e.g.; 1969, 1974).
48 Furthermore, Filippini et al (1998), by means of a new methodology, establish the
49 presence of trade-offs and compatibilities between some pairs of manufacturing
50 capabilities, even when there is no significant correlation between them. For
51 example, Filippini et al (1998) arrive at the conclusion that there are strong
52 compatibilities between “delivery time” and “quality consistency”, in spite of the
53 absence of a significant and positive correlation between those capabilities. Like
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3 ours, their investigation also extends the definition of compatibilities and trade-offs
4 beyond the obtention of significant positive and negative correlations.
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8 The preceding discussions have important implications. The use of
9 probabilistic and linear regression/correlation analyses and related methods (e.g.;
10 path analysis) to determine the existence of trade-offs and compatibilities in a sample
11 of subjects is a limited approach. A negative and significant regression/correlation
12 coefficient might be a good indicator of the latent existence of a differential in
13 performance between two variables, something that is consistent with the definition
14 of a trade-off relationship. Nonetheless, as our investigation shows, in the case of
15 significant and positive overall patterns, exclusive regression/correlation analyses are
16 incapable of identifying the potential presence of a frontier trade-off. Such evidence
17 between two capabilities might indicate a general level of compatibility. However,
18 care should be exercised when interpreting such results, as a positive and significant
19 regression/correlation line tends to “mask” or “hide” a frontier trade-off. Thus, a more
20 holistic and deterministic analysis should acknowledge both the levels of
21 compatibilities observed, and also the performance shortfalls with respect to higher
22 levels of achievement, leaving open the possible presence of a frontier trade-off that
23 would explain such shortfalls. Extra analyses focusing on the best performers (e.g.; a
24 benchmark approach) are needed in order to identify the shortfalls in performance
25 with respect to the highest levels of achievement.
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39 It can also be concluded that, when past investigations (e.g.; Fynes et al;
40 2000; Flynn and Flynn, 2004) have claimed to find evidence that does not support
41 the existence of trade-offs amongst the variables under study, in reality they have
42 found evidence only against the zero-sum type of trade-off. The absence of a
43 negative and significant relationship between two capabilities would seem to indicate
44 that a gain in one would not necessarily mean a more direct, linear-type of loss in the
45 other one. This would give basis to assert the absence of trade-offs of the zero-sum
46 type. However, as we have shown, the absence of a zero-sum trade-off between two
47 capabilities does not necessarily mean the absence of a frontier trade-off. Although
48 these two trade-offs entail a differential in performance between two capabilities, they
49 are considerably different, and require separate types of analyses in order to
50 conclusively assert that they are not present within a sample. Consequently, future
51 studies, while commenting on the absence of a significant and negative relationship
52 between two criteria, could also make a distinction and conclude that evidence does
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3 not support the presence of trade-offs, but only of the zero-sum type, and that frontier
4 trade-offs could still be present.
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8 **5 Conclusions and suggestions for future research**

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11 This investigation argues for the existence of two types of compromised
12 relationships: Zero-sum and frontier trade-offs. These phenomena have been
13 empirically and/or theoretically discussed and found in previous research, particularly
14 in the operations management literature. Our proposal addresses some of the
15 problems that past research has left unattended and that were discussed in section
16 3. Zero-sum trade-offs are characterised by a negative and significant relationship
17 between different variables representing manufacturing capabilities. On the other
18 hand, frontier trade-offs are hypothesised to be observed in a relationship in which
19 different criteria can observe some degree of compatibility, a level after which a
20 differential in performance will be observed. This is consistent with the performance
21 frontier concept advanced by Schmenner and Swink (1998) and also with the
22 research by other authors (e.g.; Skinner 1992, 1996; Porter, 1996). Furthermore,
23 both zero-sum and frontier trade-offs indicate that, generally speaking, different
24 capabilities affected by either trade-off will not achieve an “outstanding enough to
25 create competitive advantage” level of performance at the same time and under the
26 same circumstances, something that is consistent with the foundational principles of
27 the trade-off model. To the best of our knowledge, our study is the first one that
28 formally establishes and recognises these different types of trade-offs and that also
29 reconciles the differences between previous approaches and rationales and more
30 recent theoretical advancements.
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46 Frontier trade-offs imply a change in the way that compromised relationships
47 are established in quantitative studies. It is important not only to analyse a sample
48 with linear regression/correlation analyses. The possible presence of frontier trade-
49 offs also entails a need to rank the observations (e.g.; manufacturing firms) in terms
50 of their actual performance achieved. This will allow the analyst to observe whether
51 an “outstanding enough to create advantage” level of performance has been
52 achieved along multiple capabilities by one or more firms, and also to determine if
53 this phenomenon is consistent with overall trends within the sample as represented
54 by significant correlation coefficients. Moreover, the absence of a negative and
55 significant correlation coefficient between two variables has been interpreted as the
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3 absence of a compromised relationship. While this rationale can still be used to
4 assert the absence of a zero-sum trade-off, unless there is conclusive evidence to
5 the contrary, the *potential* existence of a frontier trade-off should be recognised. For
6 example, when analysing multiple manufacturing capabilities, and in the presence of
7 significant and positive correlations, it should be acknowledged that while there
8 seems to be no evidence of zero-sum trade-offs, frontier trade-offs could still be
9 present. Put differently, since the absence of zero-sum and frontier trade-offs can
10 only be unmistakably established if, and only if, different capabilities observe an
11 “outstanding enough to create competitive advantage” level of performance at the
12 same time, relationships in which at least one capability attains a lesser level of
13 performance should be assessed considering the compatibilities and also the
14 shortfalls in achievement observed, leaving the potential existence of frontier trade-
15 offs as a possible explanatory variable for the performance shortfalls.
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26 The heuristic approach and rationale to the analysis of trade-offs and
27 compatibilities that we are proposing can also be extended to research that includes
28 more than two capabilities, both at the individual firm and at the group level. For
29 example, let us suppose that a manufacturing firm observes 5, 5, 3, and 4 levels of
30 achievement along “cost”, “delivery”, “quality” and “flexibility”. Based on our rationale,
31 it could be concluded that compatibilities amongst these capabilities are observed up
32 to the “3” level of performance, a level after which varying performance achievements
33 are observed, something that could be indicative of the existence of a frontier trade-
34 off amongst this group of capabilities. Frontier trade-offs can also be studied by
35 means of longitudinal case studies with individual firms. As figure 3 and footnote 1
36 imply, a firm could observe a “5” and a “4” levels of achievement in various criteria.
37 Researchers could then investigate whether that gap in performance widens,
38 disappears or stays unchanged over time, and the causes behind it.
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49 Studies with real firms can not be expected to match the ideal conditions of
50 our analytical investigation in section 3. From this premise, it follows that the issues
51 raised by our research can become even more difficult in real-life studies. Therefore,
52 we believe that our comments and proposals are even more relevant and valid when
53 real-firms are included in an investigation. For example, the analyses and
54 discussions in section 3 are based on the assumption of similar asset frontiers in all
55 the participants. While this is useful to illustrate the nature of frontier trade-offs and its
56 implications, it is possible that, in real-life investigations, a sample of subjects can
57 include firms that have different asset frontiers, even when they belong to the same
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3 industry and context and/or are direct competitors. In other words, different asset
4 frontiers could result in frontier trade-offs between different pairs of criteria in different
5 individual firms. In such situations, our recommendation is to include as many
6 manufacturing capabilities as possible in the analysis so that the shortfalls in
7 performance with respect to higher levels of achievement can be identified. Since
8 trade-offs are real and exist in all manufacturing firms, differentials in performance
9 between pairs of competitive criteria should be expected and observed, either by
10 means of regression/correlation analyses and/or other methodologies such as the
11 benchmark approach we advance.
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20 Although the questions posed at the end of section 2 have been answered
21 already, we are laying them out again: linear regression/correlation analyses and
22 related approaches are sufficient to identify overall compatibilities, but insufficient
23 with regards to (frontier) trade-offs that can exist at the same time in a relationship
24 between different criteria. New approaches need to be added to the analysis,
25 including those with a “benchmark” focus as proposed in section 3. Past rationales
26 and assumptions can be reconciled with more recent theoretical developments by
27 acknowledging the existence of both zero-sum and frontier trade-offs.
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34 Recently, Schonberger (2007) wrote that “... two decades later, trade-off
35 viewpoints seem much suppressed. As Boyer and Lewis (2002) suggest, trade-offs
36 may be irrelevant in this hypercompetitive global economy that presses for
37 improvement in multiple dimensions. Academic interest has shifted largely to the
38 nature and subtleties of multiple or cumulative capabilities (e.g., Flynn and Flynn,
39 2004)”. We are modestly proposing that finer phenomena such as frontier trade-offs
40 might be getting overlooked amongst overall positive and significant linear
41 regression/correlation coefficients. While improvements and compatibilities might be
42 achieved simultaneously along different criteria, we believe that trade-offs amongst
43 them are still existent, relevant, and thus important for a long-lasting competitive
44 advantage. We are inviting our colleagues to think of compromised relationships not
45 only as those consistent with a zero-sum trade-off, but also to consider that frontier
46 trade-offs are a real possibility. We hope that future researchers will take this up as a
47 topic for their investigations.
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For Peer Review Only

Figure 1

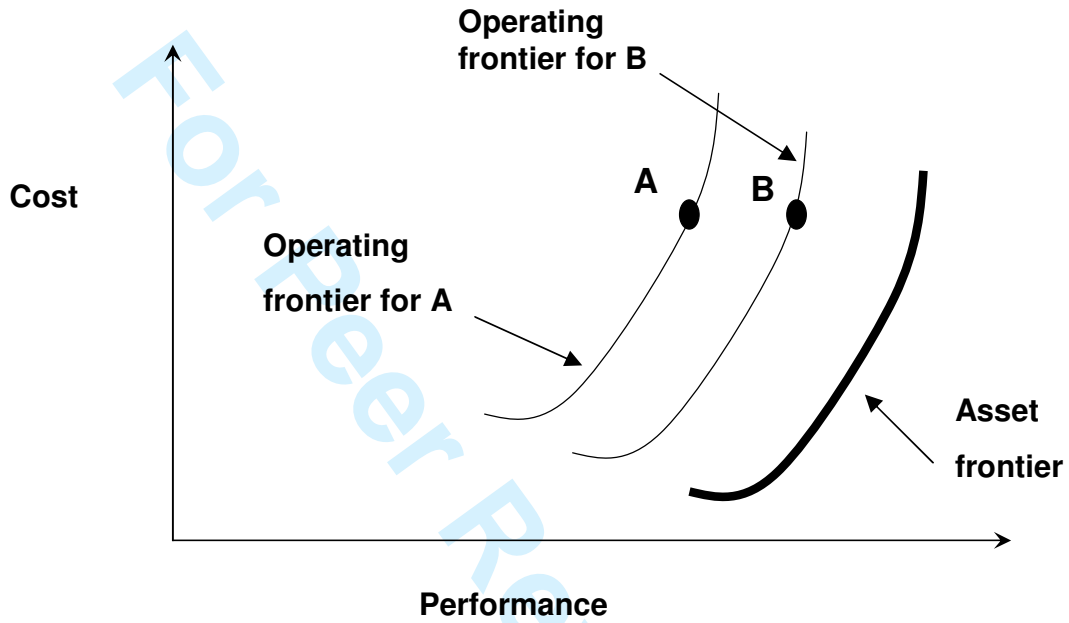


Figure 1. Operating and asset frontiers. Firm A is likely to operate under the laws of cumulative capabilities while firm B, due to diminishing returns on improvement is more likely to be subject to the law of trade-offs. (adapted from Schmenner and Swink, 1998).

Figure 2

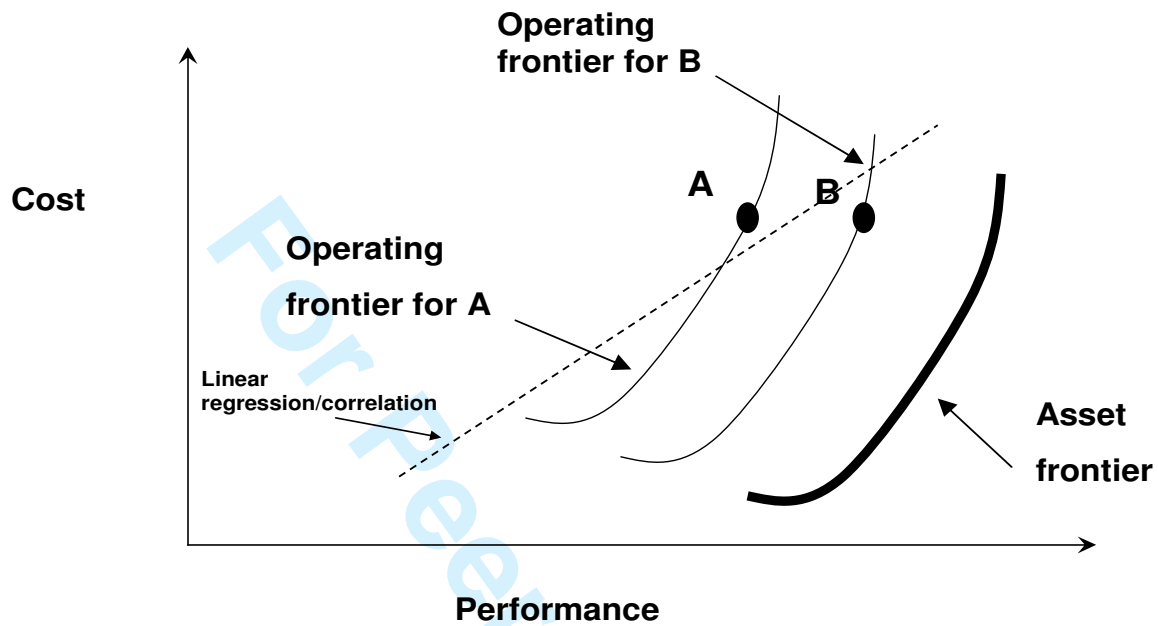


Figure 2. Original theory of performance frontiers illustration with the addition of a regression/correlation line that represents the “cumulative capabilities” implied by the framework.

Figure 3

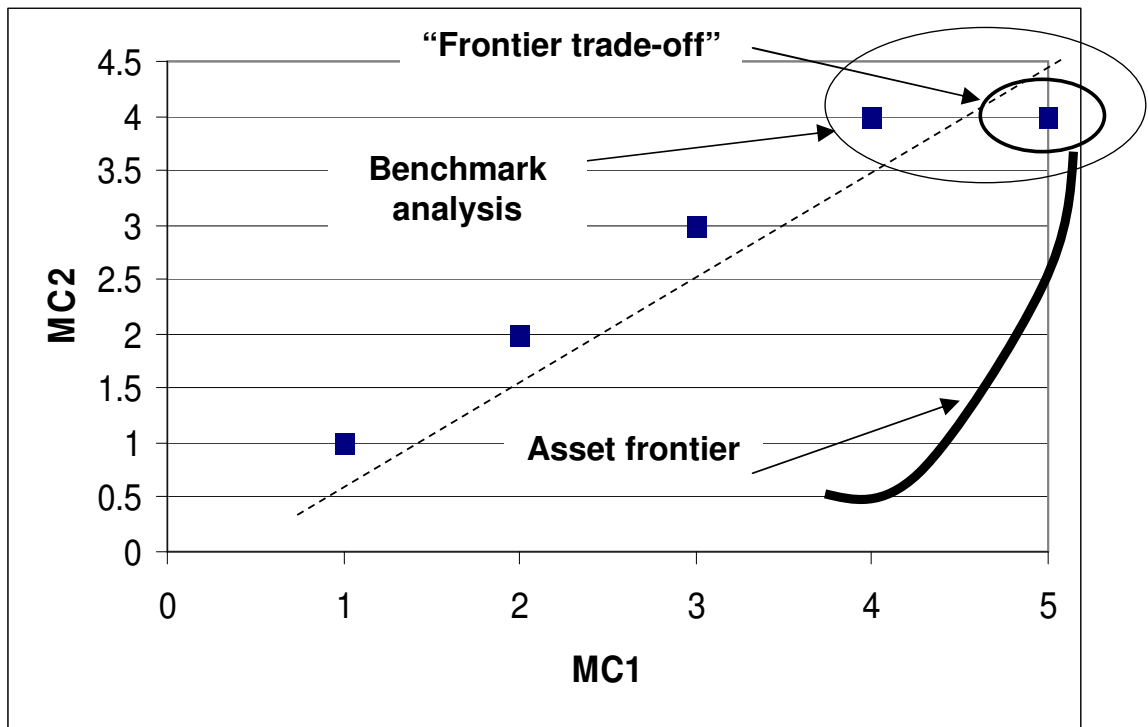
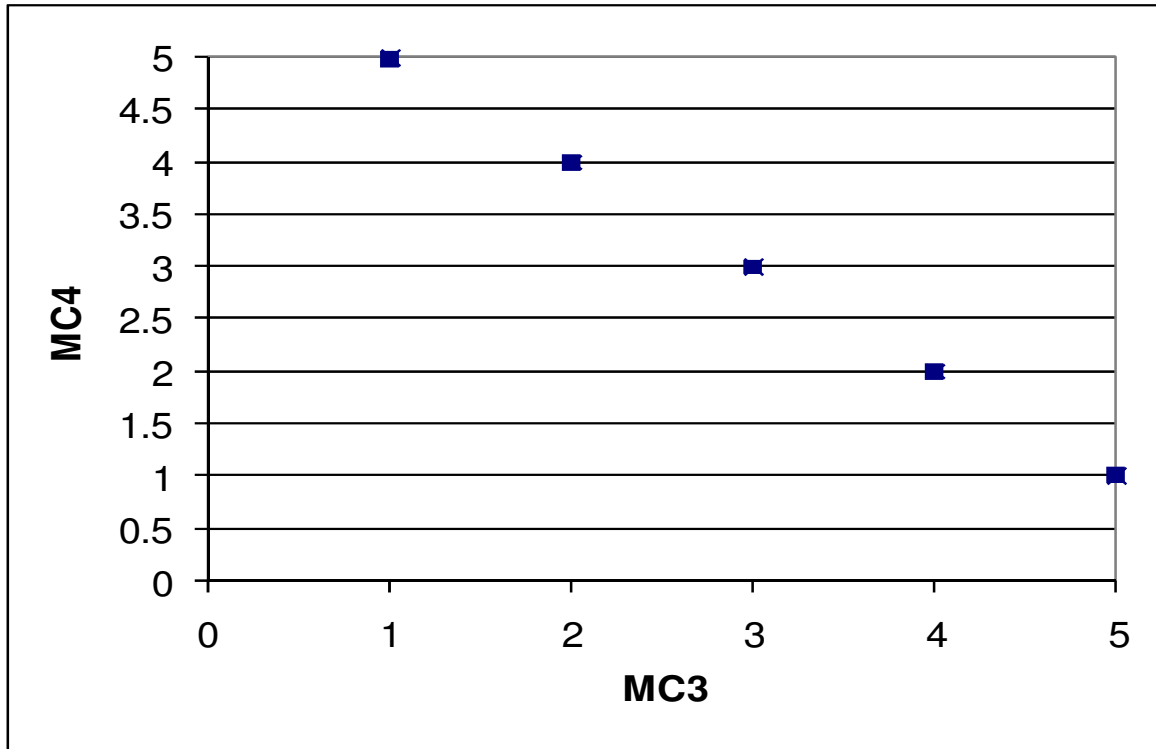


Figure 3. Frontier trade-off and cumulative capabilities between MC1 and MC2

■ = Manufacturing Firms A, B, C, D, E, from left to right.

----- = Linear regression/correlation analysis

Figure 4**Figure 4. Zero-sum trade-off between MC3 and MC4.**

■ = Manufacturing Firms A, B, C, D, E, from left to right.