Technical Note

The theory of performance frontiers

Gyula Vastag *

Department of Marketing and Supply Chain Management, The Eli Broad Graduate School of Management, N361 NBC, Michigan State University, East Lansing, MI 48824, USA

Abstract

This paper seeks to illustrate how the basic theory of performance frontiers proposed by Schmenner and Swink [Schmenner, R.L., and Swink, M.L., 1998. On theory in operations management. Journal of Operations Management, 17, 97–113] can be extended to apply to a broader range of operations management issues. It extends the scope of the proposed theory to include a ‘‘between-firm’’ level analysis which can be useful in assessing a firm’s competitive position and for strategic decision making. In addition, this paper provides a link between the resource-based view of organizations that has gained some prominence in the strategy literature and the proposed theory of performance frontiers. This paper argues that the operating frontiers of organizations represent unique resources and they are more important than the asset frontiers in achieving a competitive advantage because these unique resources are valuable, rare and specific to a given firm, and they are difficult to replicate. Future research directions and research methods focusing on the internal resources of competitive advantage are also discussed. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Theory of performance frontiers; Capacity management; Resource-based view of organizations; Operations strategy

I found the paper ‘‘On Theory in Operations Management’’ by Schmenner and Swink (1998) to be very interesting, refreshing and thought-provoking. In my reading, their paper is much more than just an intelligent collection of arguments about the finer points of theory development; the paper is about the direction of a profession that, to a varying degree, we all shape and control. I agree with the authors on the dangers of being inflicted with ‘‘theory envy’’. The picture they paint, quoting Kaplan (p. 100), seems to be valid for operations management researchers as well: ‘‘There are…scientists who, in desperate search for scientific status, give the impression that they don’t much care what they do if only they do it right: substance gives way to form. The work of the…scientist might well become methodologically sounder if only he did not try so hard to be so scientific’. I share their fear that operations management driven by ‘‘theory envy’’ will be more and more fixated on methodology and on attempting to be scientific and not on adding to the improvement and betterment (using the term coined by Schmenner and Swink) of the profession.

Schmenner and Swink finish the article with an encouragement and a call for further debates (p. 112): ‘‘We encourage others in the field to examine operations phenomena, to propose theories to explain them, and to probe their implications. When our discipline can routinely assault proposed theories, refine them when needed, and abandon them when warranted, then we will shed any legacy of theory envy’’. With this encouragement, I would like to rise
to the challenge and discuss the proposed Theory of Performance Frontiers. Although the Theory of Performance Frontiers is intuitively appealing, further explanations of the inputs and outputs of the theory are required. Specifically, I will discuss the make-up of the performance frontiers and how they relate to well-known capacity management terms (Section One). While Schmenner and Swink focused on within-firm issues, this paper extends the coverage of the theory to between-firm issues that are especially relevant in addressing competition among firms (Section Two). Section Three links this new theory to the resource-based view of organizations. This paper shows that the resource-based view can be refined to deal with special operations management circumstances and the proposed theory of performance frontiers. The paper ends with some suggestions for future research. However, there is no doubt that there are other issues to be addressed and further refinements as debate on this theory continues.

1. The make-up of performance frontiers

In Schmenner and Swink (1998) the production frontier is defined as (p. 108) "the maximum performance that can be achieved by a manufacturing unit given a set of operating choices". In spirit, it is very similar to a manufacturing performance index or a manufacturing performance score (Voss et al., 1995; Vastag and Narasimhan, 1998). Schmenner and Swink go through the operations management literature (p. 108) and summarize the "make-up" of the performance frontier by listing the usual suspects: technology and aggregate set of policies that boil down to choices in plant design and investment and plant operations (or in other words, structural and infrastructural factors). So, at this point we have two kinds of inputs (structural and infrastructural factors) and consequently we can have two performance frontiers (one for the structural and one for infrastructural factors, while keeping the other set of factors constant). We can also notice the similarity between asset frontier and design capacity (maximum output that can be attained at a plant) on one hand, and operating frontier and effective capacity (measured capacity) on the other. Introducing these traditional capacity management terms (Black- stone, 1989) also helps us to understand that there is no asset frontier without operating frontier and vice versa—both structural and infrastructural inputs are needed for the operation of a manufacturing unit, so after aggregating and rescaling the inputs, the two frontiers can be shown on the same graph. Design capacity (like the asset frontier) exists only on paper. As soon as the plant starts operating, it becomes possible to measure actual output and the effective capacity (the operating frontier) can be calculated (taking into account the efficiency and utilization rates).

Schmenner and Swink correctly point out the difference between the performance frontiers based on structural (asset frontier) and infrastructural (operating frontier) inputs, however the question of inputs, other than the above mentioned differentiation is not discussed. They present the relationship between these performance frontiers in Fig. 1. However, I believe that some clarifications of this figure are needed to give us a better understanding of the proposed relationships. Their Fig. 1 shows performance on the horizontal axis and cost on the vertical axis. The axes do not have arrows but I assume that it was just an oversight and the values increase from the left to the right and from the bottom to the top. One of the required clarifications concerns the role of cost in this figure. So far cost has not been mentioned in the text, yet it makes its debut on the vertical axis of Fig. 1. Traditionally, cost is considered as one of the competitive priorities and as such it is a function of investments in equipment (structural factors) and manufacturing systems (infrastructural factors), so I would argue that it belongs to the performance dimension—and the authors agree. On pp. 107 and 108, Schmenner and Swink write that "The performance frontier concept results from enlarging the scope of this definition [Samuelson's definition]. First, the nature of "output" is expanded to include all dimensions of manufacturing performance (e.g., cost, product range, quality), consistent with the notion of data analysis...".

Clearly, the above discussion indicates that the inputs are under our control (the manufacturing unit decides in what and how much it will invest), while the outcome, the performance is not. Therefore, being a traditionalist, I would put "performance" on the vertical axis and the inputs on the horizontal one.
For the sake of simplicity and because the two terms are meaningless without each other (there is no asset frontier without operating frontier and vice versa, as we pointed out earlier), instead of producing two graphs, we can combine the two input factors of different nature into an index of manufacturing practices that reflects the total manufacturing inputs, investments and choices made at the manufacturing unit. It is recognized that item-level measurements such as product costs (an output measure) and investment in training (an input measure) are important (Hauser and Katz, 1998). However, aggregation is needed otherwise we will be lost in the details and we will never see the big picture — the most important requirement for making strategic decisions. While we acknowledge that aggregation is needed, discussing the aggregation question (how can the individual input or output variables be combined into aggregate indices) is beyond the scope of this paper, nonetheless it is worth noting that the different approaches (using summated scales, conversion tables like Voss et al. (1995) or factor scores like Vastag and Whybark (1991), for example) have different theoretical and practical implications.

Considering the law of diminishing returns, the performance frontiers have to be concave (Schmenner and Swink, 1998, p. 110); “more and more resources must be expended in order to achieve each additional increment of [performance] benefits,” however, some caution is warranted here. Asset-related performance improvements aimed at changing the design capacity normally follow a step-function; you have to invest a given (and industry-, and technology-dependent) amount of money to increase the production output, otherwise the asset frontier is constant. The operating frontier may be a concave curve but it may have “jumps” in it — downward jumps or performance decreases, at the introduction of a new technology and upward jumps or performance improvements that cannot be attributed to investments in structural factors and can be explained only by human factors (changes in work attitudes, or increased organizational learning for example that would be the best exemplified by another company with the same investment but with a different socio-technical system in place). Fig. 2 illustrates this situation. Schmenner and Swink (1998) treat the asset frontier as if it were of the same nature.
as the operating frontier, which clearly it is not. Regarding the operating frontier we are in agreement; they also illustrate the “jumps” in their representation.

Additionally, both the asset and the operating frontier depend on the bottlenecks of the manufacturing process. The bottlenecks are the function of the product mix and if product mix changes go beyond a certain tolerance level, new bottlenecks are created. For a given product mix, a distinction has to be made between the structural bottlenecks of the asset frontier and the “floating,” operating bottlenecks. While the former is technology-related and as such more or less independent of the firm, the latter is firm-related and it may show great fluctuations over a variety of operating conditions and cultures. Consequently, if a manufacturing unit produces two different product mixes then it may very well have two frontiers for each set of input factors as illustrated in Fig. 1. Obviously, the same plant cannot have two different sets of operating and asset frontiers at the same time, so we can think of them as historical measures associated with the production of these product mixes. Moreover, the “distance” between the asset and operating frontiers may also reflect product mix effects. In Fig. 1, the workers skill levels (the infrastructural factors) are better suited for producing product mix B than product mix A, while the assets are more suitable for product mix A.

2. Extension of the theory of performance frontiers

In the Schmenner and Swink (1998) paper the performance frontier was examined mostly at a “within-firm” level. Here we broaden this view to look at “between-firm” level issues including competition. Let’s assume now that Company A produces Product Mix A and Company B produces Product Mix B and they have competing products. Schmenner and Swink argue that the “distance” between the asset frontier and operating frontier determines whether the trade-off or the cumulative model (Ferdows and DeMeyer, 1990) is used; as the two frontiers move closer to each other, the cumulative capabilities model is replaced by the trade-off model (p. 110): “The law of trade-offs states that no single plant can provide superior performance in all dimensions simultaneously. We would expect to find support for this law if all competitors use similar technologies and are operating near the asset frontier.
If all plants are far from the asset frontier, however, one plant can simultaneously provide higher levels of product quality, flexibility and delivery at a lower manufactured cost if, through betterment, its management approaches create an operating frontier which is superior to its competitors’.

I would like to propose a different explanation that is consistent with the suggested theory but expands it. First, let me offer a new interpretation of the distance between the asset and operating frontiers. This distance can be interpreted as a firm, industry and country dependent “asset utilization” measure. Generally, there is a pressure to minimize this distance and keep the operating frontier as “close” to the asset frontier as possible through “utilizing” (using this term in the traditional capacity utilization sense) the production potential of the assets. The primary advantage of doing so is the potential to reduce unit cost. However, Schemmer and Swink argue very persuasively that the law of diminishing returns and diminishing synergy may make it undesirable after a certain point to move the operating frontier closer to the asset frontier. Moreover, high capacity utilization tends to reduce flexibility and as a result in each firm, industry, and country there is an asset utilization level that is considered normal and acceptable. So we can say that there is pressure to keep the operating frontier in the proximity of the accepted “asset utilization” level of the firm, recognizing that this level is influenced by many factors and this prescription may not necessarily be realistic or desirable for a firm at any given time. Firms often struggle with strategic alignment within their operations and/or are unsuccessful in mastering new assets as they are invested in. Therefore competing firms even in the same industry may well generate operating/asset frontiers comparable to those depicted in Fig. 1.

In a static view, the choice between the two models, cumulative or trade-off capabilities model, depends on the positions of the operating frontiers relative to each other. Fig. 1 depicts a situation where Company B “betters” Company A as shown by its higher operating frontier; it offers superior performance in all, or depending on the aggregation rules used, most of the dimensions simultaneously. The Japanese car manufacturers offered superior performance not because their asset frontiers were superior (“farther away” from the horizontal axis) — they did not have more technical resources than other car manufacturers — to those of the other car manufacturers, they were successful because their plants were operated more efficiently, they competed based on the superiority of their operating frontiers (Flaherty, 1996; p. 163). “By now the observations that convinced Americans that there was a new and better Japanese management system are familiar. In the late 1970s, the US–Japan manufacturing cost differential on small cars was over US$2500, or roughly 100% of Japanese manufacturing cost per vehicle. The cost differential was not caused entirely by labor price differentials because the labor hours per vehicle in comparable operations were by most estimates also much lower in Japan…The cost differentials were not caused by capital investment or by advanced technology: the technology used in even the leading Japanese auto plants in the early 1980s was a generation behind that in the US plants, and capital per car was significantly smaller (even when the suppliers were taken into account). There was also a substantial quality differential, measured in terms of defects found within the first month of owning the car. Finally, US companies built fewer models, had longer periods between major model upgrades (6 years for US average vs. 4 years in Japan), and seemed to experience a greater penalty for variety than the Japanese plants”.

Summing up, in the short term the relative position of the operating frontiers has the greatest influence on the competitive positions of the firms. Currently Company B betters Company A because it possesses a higher operating frontier. In a dynamic approach, the utilization level (the distance between the asset and operating frontiers) also influences the firms’ decisions. We can call it the interaction effect, assuming that the operating and asset frontiers are the two effects that influence the manufacturing performance of firms. In Fig. 1, we could assume that Firm A has invested in the most capable equipment

---

1 The logic described in the second part of this paragraph and the notion of the “interaction effect” discussed in the following paragraphs were suggested by one of the anonymous reviewers. While I give credit to them for this contribution, I take responsibility for any misinterpretation of their suggestions.
that enables products to be manufactured to the highest quality standards but the workforce is still in the early stages of the learning curve on how to use this state-of-the-art technology. Alternatively, Firm B is using older equipment that does not have the same capability but the employees know how to run the machines at close to perfection. What are the likely changes each firm would make to its operations and assets over a longer period of time? Firm A has not yet mastered their assets and therefore will focus on cumulative gains to improve operational efficiency. At some point they may determine that they do not have the ability to use the assets effectively, regroup and create a new asset frontier by investing in different assets. Firm B made the most of its assets and it can do no more (or very little) to maintain or change its position in a rapidly changing marketplace, unless they invest in new assets. The actual behavior would be dependent on how these two firms are actually performing in the marketplace, their recognition of their performance, their culture regarding proactive/reactive management, and many other factors.

3. Performance frontiers and the resource-based view of organizations

In this section, I argue that the logic presented in this paper and in Schmenner and Swink (1998) is consistent with the resource-based view of the organization (that is the competitive advantage of a firm is based on the dynamics of how the firm’s resources are acquired and managed).

In resource-based theory, competitive advantage is rooted inside a firm in assets that are valuable and inimitable. Wernerfelt (1984; p. 171) started his seminal article with the following distinction between resources and products: “For the firm, resources and products are two sides of the same coin. Most products require the services of several resources and most resources can be used in several products”. On the next page, he clarified what he meant by a resource: “a resource is... anything which could be thought of as a strength or weakness of a given firm. More formally, a firm’s resources at a given time could be defined as those (tangible and intangible) assets which are tied semipermanently to the firm”.

There has been a well-established connection between firms’ capabilities and competitive advantage—many of these papers written about this connection were rooted in operations management. Production competence (Cleveland et al., 1989; Vickery, 1991; Vickery et al., 1993; Dröge et al., 1994) and core competence (Prahalad and Hamel, 1990) were two of the terms used to describe this internal link. However, the resource-based view took this thinking a step further through positing that competitive advantage can be sustained only if the capabilities creating the advantage are supported by resources that are not easily duplicated by competitors. In this theory, the firm’s resources serve as “barriers to imitation” and include all assets, operational practices, information and knowledge controlled by the firm. Barney (1991; p. 102) gives a precise definition of competitive advantage and sustained competitive advantage: “a firm is said to have a competitive advantage when its is implementing a value creating strategy not simultaneously being implemented by any current or potential competitors. A firm is said to have a sustained competitive advantage when it is implementing a value creating strategy not simultaneously being implemented by any current or potential competitors and when these other firms are unable to duplicate the benefits of this strategy”.

A resource to have the potential of sustained competitive advantage must have the following attributes (Barney, 1991; Hart, 1995): (1) It must be valuable and nonsubstitutable in the sense it must contribute to a firm capability that has competitive significance and is not easily accomplished through alternative means, (2) It must be rare (it is not possessed by a large number of firms) and/or specific to a given firm (the ability of a firm to obtain a resource is dependent upon unique historical conditions), and (3) It must be difficult to replicate because either it is tacit (that is skill-based or people intensive, which makes it causally ambiguous, so it is difficult to understand why one firm consistently outperforms others firms) or socially complex (the resource depends upon large numbers of people or teams engaged in coordinated action such that few individuals, if any, have sufficient breadth of knowledge to grasp the overall phenomenon).
Both the asset and the operating frontier can be the source of competitive advantage but they are based on resources of different nature. The asset frontier is based on tangible resources, while the operating frontier is the function of the firm’s intangible resources. We agree with Barney and Zajac (1994) that their contribution to the specific strategies a firm is pursuing, and independent of the specific competitive context within which a firm operates. However, we argue that under typical conditions (excluding rare or unique technologies) the operating frontier is the better candidate for providing sustained competitive advantage. We propose the following exercise to illustrate this point through separating the sources of competitive advantage (Barney, 1986). Ask senior managers of a firm to list core competencies that are the basis of the firm’s sustained competitive advantage. Then cross off the list any competencies or success factors that are not valuable, rare, inimitable (or very costly to imitate), or for which the firm was not organized to leverage that competency. The factors left on the list will be specific to a given firm, causally ambiguous, and socially complex. In other words, it is very likely that we eliminated most or all of the structural factors (the elements of the asset frontier) and we are left with the infrastructural factors or the elements of the operating frontier. As the success and manufacturing prowess of the Japanese car manufacturers illustrated, heavy investments in soft, infrastructural factors can lead to sustained competitive advantages.

4. Conclusions and suggestions for further research

Recently, Samson and Whybark (1998) argued for focusing more operations management research on “soft issue management”. As they wrote (p. 4), “... ask yourself which would do more to improve things there [in a run-of-the-mill manufacturing plant], a new CNC machine or everybody truly being given and accepting responsibility for performance in a disciplined way (with the old equipment)”. In my reading, their call for focusing on soft issues is the recognition that these soft issues and resources may serve the hardest barriers to entry for other firms.

In this paper, I argued that (1) the operating frontiers of organizations represent unique resources; (2) the operating frontiers, in general, are more important than the asset frontiers in achieving a sustained competitive advantage because these soft resources are valuable, rare and specific to a given firm, and consequently they are difficult to replicate. It also follows from the very nature of these soft resources that survey-based methods in themselves are not well-suited to explore and determine the infrastructure-based sources of competitive advantage of a firm.

References
