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PERMANENT SEMINAR ON EFFICIENCY AND PRODUCTIVITY

A RESOURCE-BASED INTERPRETATION OF TECHNICAL EFFICIENCY INDEXES[*]

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Abstract

During the last two decades, the measurement of technical efficiency indexes has become a very popular field of research. Recent refinements in estimation tools and techniques have contributed to increase the interest on efficiency analyses. The empirical success of the efficiency literature has been obscured by the lack of a rigorous theory explaining the economic meaning of technical inefficiency. The objective of this article is to outline an interpretation of currently estimated indexes of technical efficiency within the framework of the resource-based view of the firm. The problems inherent to the definition of technical efficiency as a relevant theoretical concept are examined and, then, the link between technical efficiency and firm resources and capabilities is discussed.

Key words: technical efficiency, X-inefficiency, resource-based view, capabilities

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1. Introduction

Research on efficiency and productivity analysis has been vast during the last two decades. The bulk of the efforts were devoted to further develop the quantitative techniques available for empirical analysis. Many different indexes and computational procedures have been used in an endless list of empirical applications (Seiford, 1996; Førsund, 1999). The standard approach undertaken in the empirical literature on efficiency measurement consists in fulfilling the next four steps: 1) collect data on inputs and output(s) from a set of decision making units (DMUs) *assumed to be homogeneous*, 2) select the estimation technique—basically, econometrics or linear programming—that best suits the nature of available data or the type of indexes the author wants to obtain, 3) estimate the efficiency indexes, and 4) explain the indexes through the lens of a second stage regression analysis or analysis of variance. This last step involves searching for variables capable of distinguishing between efficient and inefficient DMUs.

Paradoxically, the huge advance that has taken place within the measurement field deeply contrasts with the alarming lack of rigorous theoretical background on the notion itself of "technical efficiency". The familiar expression "technical efficiency" refers to a very fuzzy concept, one that is more ambiguous than currently acknowledged. Standard microeconomic theory of production does not consider the possibility that firm behavior may be inefficient, at least from a productive or technical point of view. Thus, the very notion of technical inefficiency cannot be rationalized with the tools of the neoclassical theory of the firm. Paradoxically, the efficiency literature has evolved extremely linked to the analytical framework of the neoclassical theory of production. However, it is common to read efficiency analyses that do not even attempt to briefly discuss the real economic meaning of the indexes reported.

The objective of this article is to explore possible interpretations of technical efficiency indexes as are currently estimated in the literature. To accomplish this task, the paper is structured as follows. First, the traditional approach to the concept of productive efficiency and Leibenstein's (1966) theory of X-inefficiency are critically reviewed. Then, an alternative resource-based technological interpretation of empirically estimated indexes is introduced. This approach is argued to overcome some of the limitations of alternative interpretations. The final discussion suggests the existence of a strong relationship between resources, capabilities, technology, and efficiency.

2. Traditional approach to the concept of technical efficiency

Following Koopmans (1951), a DMU is said to be technically efficient if and only if it is not possible to increase any of the outputs or to reduce any of the inputs without reducing some other output or increasing some other input. The literature on the measurement of technical efficiency has strongly relied on this definition. Thus, a preliminary step before measuring efficiency indexes is to determine which processes are considered to be possible and which processes are not. This amounts to analytically represent the firm's *technology*. The different techniques at hand characterize the technology by establishing the set of input-output vectors that are considered to be feasible, i.e. the production set. Feasibility is usually established by means of well-defined technological properties. Then, efficiency indexes are obtained by measuring the distance between the observed input-output vector and a benchmark, as defined by the frontier of the production set.

Distances to a set—i.e., inefficiencies—can be measured along many different paths. The most common approach is to measure the maximum equiproportionate expansion in the observed output vector of the DMU under analysis that is technologically feasible or, alternatively, the maximum equiproportionate contraction in the input vector. Such, radial indexes of technical efficiency were first proposed by Debreu (1951) and Farrell (1957), who developed an algorithm that could be used in empirical estimation. The fact that Farrell's radial measures have been by far the most widely used in the literature is due to their correspondence with Shephard's (1953) distance functions, which have a dual interpretation in terms of cost reduction or revenue increase. Other non-radial indexes of technical efficiency are also available (Bogetoft and Hougaard, 1999; Färe and Lovell, 1978; Russell, 1985).

Any of these indexes can be interpreted as an index of total factor productivity. Efficiency indexes are relative measures obtained from multiple comparisons between each DMU and the best practices observed, which define the frontier of the production set. Figure 1 illustrates the common approach to efficiency measurement. The most productive DMUs shape the best practice frontier; then, efficiency is measured as the distance between the inefficient DMU and the frontier; there exist many different paths to measure distances, reflecting the preference of the researcher for different efficient benchmarks. The selection of appropriate benchmarks constitutes a critical topic of debate in efficiency analysis (González and Álvarez, 2001).

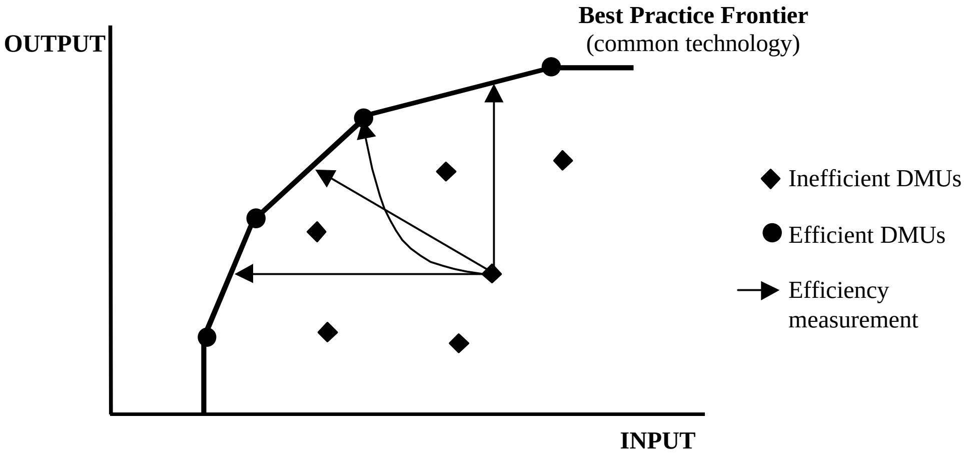

Figure 1. Measurement of relative technical efficiency

Today, despite there is considerable debate about certain topics in the efficiency measurement literature, it is clear that we know how to measure relative efficiency and we have plenty of techniques and tools available to conduct empirical analyses. In contrast, there is little (if any) guidance regarding *what are we actually measuring?* Empirically estimated indexes reflect the fact that some DMUs seem to perform better than others. But, what is the reason? Putting it in a different way, what are the sources of the inefficiency score we are measuring, where does it come from? Without answering these basic questions, efficiency measurement would be of little practical use for managerial purposes.

Surprisingly, although efficiency is a central concept in economics and management sciences, it is far from easy to find deep theoretical discussions of efficiency in production. The very notion of inefficiency violates central assumptions of mainstream economics. Recall, that the neoclassical firm is defined as a simple mathematical production function, sometimes referred to as *a black box*, which transforms an input vector into an output vector, through an established and well-defined technology. Within this theoretical framework, real observed output should always match potential output. The profit maximization postulate rules out the possibility of resource misuse or suboptimal decision making. When we replace neoclassical assumptions with a more realistic notion of the firm the cost minimization assumption appears as an oversimplification. Suboptimal decision making and resource waste seem to happen in real production processes. Although traditional production theory has been used to develop the techniques to measure such misperformances it cannot explain why they do occur.

3. The theory of X-inefficiency

The only serious attempt to construct a theory of productive inefficiency is due to Harvey Leibenstein, who sharply departed from the neoclassical theory of production. After thorough analysis of empirical evidence, he suggested that, in general, firms do not minimize production costs. According to Leibenstein (1966) inefficiency in production, and not allocative inefficiency, is the principal source of inefficiency in the economy. Unlike Farrell (1957) he did not use the term “technical inefficiency” or “productive inefficiency” to refer to his notion of inefficiency in production. Instead, Leibenstein (1966) coined the term “X-inefficiency” to refer to the amount of forgone output that occurs as a consequence of motivation deficiencies along the firm’s hierarchy.

The hypothesis underlying the notion of X-inefficiency states that the motivation to reduce production costs comes primarily from external pressure. The CEO of a firm operating in a highly competitive industry would support more pressure to reduce costs than the monopoly's CEO. This amounts to assume that the reason why firms do not maximize profits is because of effort discretion. Effort discretion propagates along the hierarchy because managers do not act in an omniscient way as to minimize costs. Instead, they typically rely on financial reports showing deviations from a priori established targets. Only if these deviations are large enough an energetic response can be expected from management in order to control slack. If results are good enough, the risk that managers start resting in their laurels is considerable, because the motivation needed to search for improvement is absent, even though further improvement may be feasible.

Leibenstein (1966) supported his view that X-inefficiency was an important issue with a large collection of empirical evidence. He cites studies by the International Labour Organisation-ILO (1951, 1956, 1957a, and 1957b) which report cost savings derived from "simple reorganizations of the production process, e.g., plant layout reorganization, materials handling, waste controls, work methods, and payment by results" (Leibenstein, 1966: 399). More often than not, the savings were as large as 25% of previous production costs. The conclusion is that the nature of the *managerial input*, external pressure, and the incentive systems employed to motivate workers and managers have a deep impact on production results.

Leibenstein (1966) stresses the importance of motivation when he analyses the possibility that suboptimal behavior may be due to a relative lack of knowledge. This explanation of inefficiency would imply that any DMU obtaining more output without using more input than the average do so because it owns a superior knowledge background. Against this interpretation, Leibenstein points out that most of the improvement that seems to be achieved through better knowledge is actually induced by the pressures of motivation. In many instances the knowledge was already there, but not the motivation to exploit it or develop it. Evidence from the ILO productivity missions suggests that, sometimes, managers returned to their old (less productive) techniques, not because they lacked the required knowledge, but because the pressure that motivated the use of the new (and better) techniques had disappeared. In other instances, of course, the motivation may exist but not the knowledge required in order to minimize costs.

The theory of X-inefficiency departs from neoclassical theory in three main ways. First, labor contracts are described as incomplete. This implies that an unavoidable degree of effort discretion will be present in the behavior of workers and managers. Actual behavior is then ruled not just by contract but by custom, authority, moral constraints, incentive systems, and other institutional arrangements. Second, not all factors of production are marketed. This is an important issue in the case of knowledge. The firm cannot buy all the required knowledge in the optimal quantity at the optimal moment. Unfortunately, this was not a central issue in Leibenstein's theory. Third, the production function is not completely specified or known. A given input vector can result in different output vectors, depending on the motivational and organizational schemes. The technology is a complex thing that cannot be represented by a simple functional relationship.

In *The Xistence of X-Efficiency*, George Stigler (1976) strongly criticized Leibenstein's notion of X-inefficiency as an unnecessary and awkward concept (see also Leibenstein, 1978, 1979, for a reply). First of all, Stigler denies that motivation has something to do with the quantity of output that is produced by a group of workers. The argument is very simple. Motivation is the same for all individuals: to maximize their respective utility functions. Individuals do not have a particular interest in maximizing any output, but in maximizing their own utility levels. When the output increase is achieved through a higher effort, efficiency does not improve at all. Rather a different output vector obtains, one that includes more physical product and less leisure, for instance. But individuals want to obtain the output vector that maximizes utility, not the one that maximizes physical production. Parish and Yew-Kwang had expressed the same view: “If the monopolist (the inefficient firm) prefers to take it easy, this may just be a form of producers' surplus. Nevertheless, it maybe held that the monopolist is indulging in satisfying non-essential wants. (But...) each man is the best judge of his own interest...” (1972: 302).

On the other hand, despite it is true that contracts are incomplete, as Leibenstein points out, a great quantity of (managerial) resources may be required to enforce contractual accomplishment to the point that maximizes production (Alchian and Demsetz, 1972). Positive agency theory has called attention upon this fact: the objective of management is not to minimize the residual loss (inefficiency?) but the total sum of agency costs, which also include formalization, monitoring, and bonding costs. We cannot seriously argue that a firm is incurring any kind of productive inefficiency when it does not produce the maximum output, given the unavoidable existence of contractual constraints involved in team production. X-inefficiency would arise if it were possible to produce more at a lower cost and the firm didn't do it. Leibenstein theory falls into the *Nirvana fallacy*, a term coined by Demsetz (1969) to refer to the common practice of comparing the real world with an ideal world to conclude that the real world is (relatively) inefficient.

The contributions from transaction cost economics, agency theory and property rights theory allow for a generalization of the neoclassical view of the firm, and a rationalization of the behavioral deviations that sustain the notion of X-inefficiency. Within this framework in mind, Leibenstein arguments can be reinterpreted by the statement that individuals react to environmental opportunities and constraints depending on their preferences—i.e., the gain derived from effort and the gain derived from leisure—and their budget constraints. The budget constraints include the own cognitive ability of people to perceive and scan the state of the environment (De Alessi, 1983; DiLorenzo, 1981). This way, the theory of X-inefficiency can be accommodated within the framework of a more general theory of transaction and/or agency costs, which explicitly considers friction as an essential component of a theory of the firm[1].

[1] Bogetoft (2000) has developed a model that links agency theory and efficiency measurement showing that DEA based production plans may generate optimal results under conditions of

"Leibenstein's collection of postulates and related variables of X-efficiency appears to be a combination of some of the axioms and some of the implications of generalized neoclassical theory" (De Alessi, 1983: 70).

In this setting, inefficiency does not arise unless firms adopt different contractual solutions to the same contractual problems. Jensen and Meckling (1979) raised the same point by explicitly including the structure of property and contractual rights into the specification of the production function to analyze the relative efficiency of a spectrum of potential firm organizational structures. Under this view, all the issues related to the firm's *legal structure* (Ellerman, 1984) can be considered as substantial part of the production function. The most salient features of the legal structure are the distribution of rights between the firm's stakeholders: 1) voting rights, 2) the rights to the stream of economic profits and, 3) the rights to the net book value. These rights differ considerably in their scope and nature between labor managed firms (e.g., worker cooperatives) and conventional capitalist corporations. Such differences may determine important differences in the operating results and, thus, in measured inefficiency. But, this is not the only way in which firm heterogeneity determines efficiency scores. In the following section we examine the role of firm heterogeneity on firm technology and measured inefficiency.

4. Firm heterogeneity

The theoretical difficulties with the concept of efficiency discussed above have not deterred the growth of empirical studies. Researchers have found important cost differences among firms in almost every sector of the economy and have interpreted these differences as the result of technical inefficiencies. However, empirical measurement refers to relative efficiency indexes, which are obtained through comparisons among firms that are considered to be similar or homogeneous. These analyses directly compare the input-output vectors of a set of firms by means of linear programming—under the (strong) assumption that the firms in the sample are comparable, i.e., employ a common technology—or through the estimation of an empirical production function—-under the (strong) assumption that the function, i.e. the technology, is common to all the firms in the sample.

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asymmetric information between the principal and the agent, in the sense of minimizing the agent's information rents.

Although this is the way the empirical literature has developed, it is evident that if some (efficient) firms do better than others (inefficient) this can only happen if "they are heterogeneous". There exist differences among firms that are not registered in accounting reports, given the inherent complexity of assigning a monetary value or even of identifying many critical resources. The difference between the firm with the lowest costs and the rest reflects the existence of unregistered resources that are not being accounted for by the researcher. These differences are what we are commonly calling (relative) “technical inefficiency”. The residual we observe and call inefficiency comes from somewhere, even though we do not know exactly from where—if we did, we would presumably not call it inefficiency. Two identical firms should always obtain identical results, except for random, and thus unimportant, shocks.

When an engineer asserts that "machine A is more efficient than machine B” he is well aware that he is talking about different (heterogeneous) machines. He does not formulate the *ceteris paribus* clause on the technology, as it is *explicitly* done in the economic efficiency studies. The word inefficiency is simply employed to summarize differences that exist and have concrete causes, although sometimes difficult to identify. Leibenstein's attempts to defend a theory of X-inefficiency entirely based in motivational deficiencies are condemned to incompleteness, because the term just refers to a way of speaking about motivational differences that have concrete sources. The issue of productive inefficiency is, thus, an issue of heterogeneity and therefore investigating a more basic question can approach it more accurately: why are firms different?

5. A resource-based approach to technical inefficiency

The study of technical efficiency has been traditionally formulated on the basis of observable variables—physical inputs and outputs—and assuming an implicit common technology for all the firms that enter the analysis. This implicit technology is an oversimplification that represents the possibilities of transformation of physical and observable inputs into physical and observable outputs. But, in reality, the technology (possibilities of transformation, production set) differs across firms even in the same industry, because different firms usually possess some resources and capabilities which are unique and play a role that is ignored in the estimation of inefficiency. This type of resources includes intangibles, such as knowledge, culture or trust, which are hard to observe, quantify, evaluate, and imitate. Some of these resources are the basis for competitive advantage or disadvantage at the operations level and, as such, should be also the basis for observed inefficiency indexes.

If we take a resource-based perspective, we must accept Stigler's (1976) explanation of what Leibenstein (1966) called X-inefficiency: if firms obtain different amounts of output from given inputs it is because they are using different transformation technologies. In other words, because they control different sets of intangible resources which are not accounted for in the specification of the efficiency model. These include the firm's knowledge, culture, absorptive capacity, incentive systems, organizational routines, legal-contractual structure, and other institutional arrangements that evolve along time within the organization.

The resource-based view of the firm considers that the *ceteris paribus* clause should not be applied across firms, even within a given industry, because the level of resource heterogeneity is typically high. Resource heterogeneity allows different firms to achieve different observable output levels from given observable inputs, generating economic rents that can be sustained from competition (Barney, 1991; Dierickx and Cool, 1989; Lippman and Rumelt, 1982; Peteraf, 1993; Wernerfelt, 1984). The resource-based view provides a satisfactory explanation of the mechanisms that allow for permanent differences in firm performance among direct competitors. The control of heterogeneous and hard to imitate resources provides some firms with a competitive advantage.

According to Dierickx and Cool (1989) a useful analytical classification distinguishes *flow* from *stock* resources. Flow resources are those that can be immediately obtained whenever needed. In general terms, flows can be easily identified and a monetary value can be attached to them. Examples of this type of resources are machinery, human force and even market share. In contrast to flows, stock resources generate internally from flows along a period of time through an *accumulation process*. Stocks are idiosyncratic resources deeply embedded in the firm and thus imperfectly mobile. In general it is difficult and, more often than not, impossible to attach stocks a precise monetary value. Dierickx and Cool (1989) point out that a market cannot exist to trade this type of resources.

On the other hand, capabilities refer to the firm's ability to accomplish tasks by appropriately combining sets of resources. Scientific terminology has distinguished among *capabilities* (Amit and Schoemaker, 1993; Grant, 1991), *competencies* (Teece, Rumelt, Dosi, and Winter, 1994), *core competencies* (Prahalad and Hamel, 1990), and *distinctive competencies* (Andrews, 1971; Ansoff, 1965; Hofer and Schendel, 1978; Selznick, 1957). All these terms refer to the same concept, a set of specific firm abilities that are the basis for competitive advantage.

Available data for efficiency estimation is usually limited to flow variables, even though stock variables and complex capabilities may be constitute the most valuable assets employed by the firm. Figure 2 summarizes some of the resources and capabilities that distinguish firms and are not typically accounted for in efficiency measurement experiments.

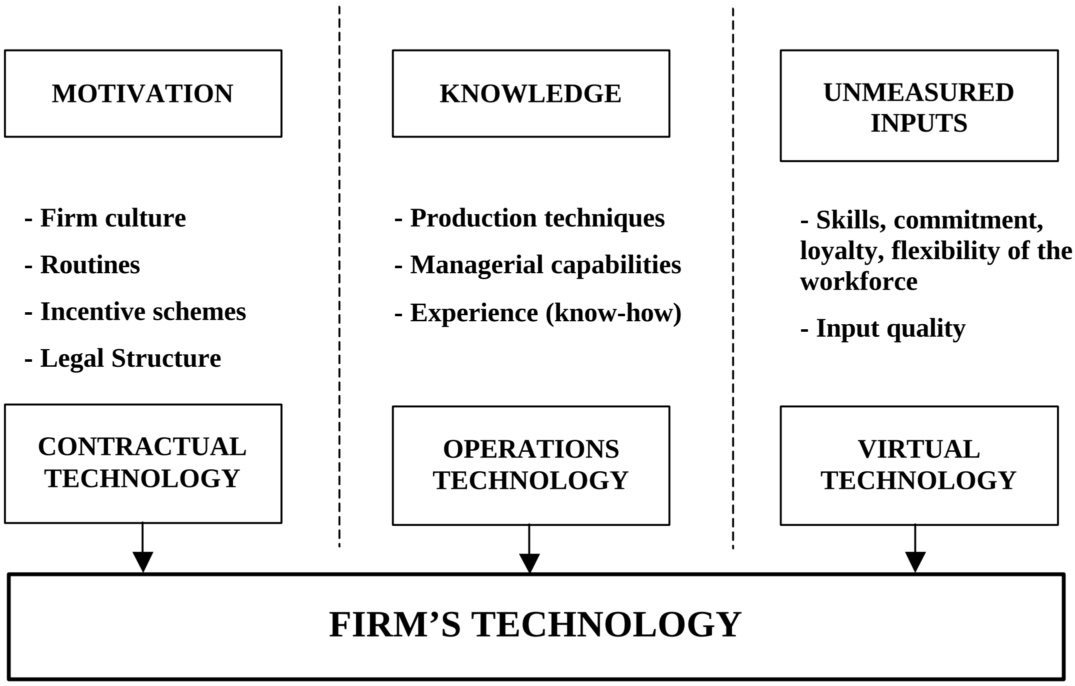

Figure 2. Factors and resources underlying the firm’s technology

Related to motivation—and thus to X-inefficiency—are factors such as firm culture, firm routines or incentive schemes, that evolve over time and can be considered as the basis of the contractual part of the firm technology. Under the heading knowledge we identify resources such as the production techniques, the know-how, and the managerial capabilities of the firm. These capabilities constitute an important part of what is commonly integrated in the production technology. Efficiency analyses usually misrepresent the input endowments of different firms. It is common to treat inputs as if they were homogeneous, but firms commonly differ in input quality and the skills and involvement of the workforce. All these factors that can be considered as firm resources are assumed to be common to all firms in efficiency measurement. But they determine why different firms convert inputs into outputs at different rates. As such, they determine different technologies for each firm. Farmers, for instance, may use feedstuffs of different quality, but efficiency analyses rarely take that fact into account—instead they limit to measure the tons of feedstuff consumed by the cows. If this is the case, farmers with different input quality are virtually using different technologies.

Therefore, it is possible to interpret current technical efficiency indexes as indicators of firm heterogeneity. More precisely, observed technical inefficiency arises from heterogeneity in resources and essential capabilities that are not included as inputs in the efficiency model and are related to motivation, knowledge, and use of superior inputs[2]. As Figure 2 suggests, heterogeneity in resources and capabilities may be interpreted as heterogeneity in the underlying technology employed in the firms' production processes. Figure 3 represents the underlying real technologies of a set of DMUs by dashed lines. The standard efficiency approach interprets the distance between a DMU and the Best Practice Frontier as a measure of technical inefficiency. Our approach considers that those indexes are measuring distances among different production technologies (functions) instead of measuring distances between the firm and a hypothetical, but inexistent, common production function. Given resource heterogeneity, the firms in the sample operate *on* different production frontiers. This view relates to the theory of X-inefficiency by considering the different incentive schemes employed by the firms as important parts of their production capabilities that shape the production technologies actually employed by the firms—the contractual part of the technology. Thus the average efficiency level would indicate the level of interfirm technological heterogeneity.

[2] Majumdar (1998) has proposed a similar interpretation of the technical efficiency indexes, suggesting the use of DEA to evaluate the differences in firms' capabilities.

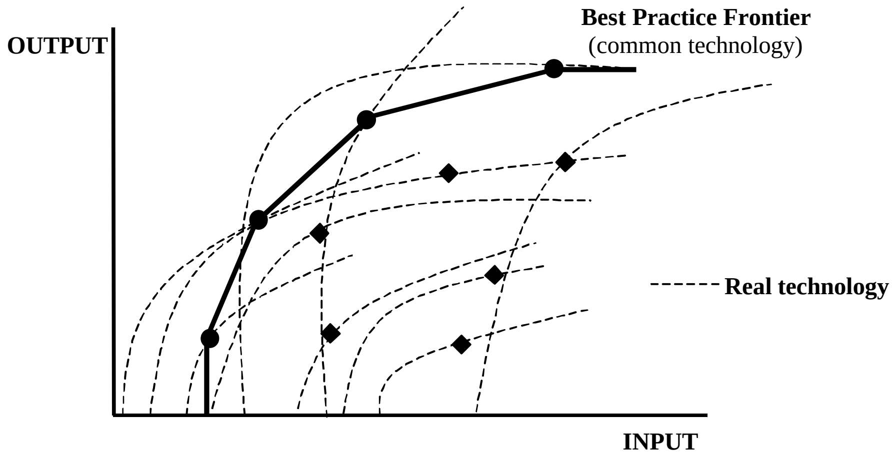

Figure 3. Interfirm technological heterogeneity

Stigler (1976) had already suggested that the apparent observation of production inefficiencies was the consequence of considering that the firms were using a common or representative technology, while they were in fact using heterogeneous technologies. In the same line, prominent strategy scholars such as Collis and Montgomery point out that "Finely honed capabilities can be a source of competitive advantage. They enable a firm to take the same factor inputs as rivals and convert them into products and services, either with greater efficiency in the process or greater quality in the output " (1997: 29). Thus, the emphasis of efficiency analyses should not be placed on the *measurement* part—i.e., computing how inefficient each firm is—-but on the *benchmarking* part—identifying the key success factors that determine the technological capabilities of best practice firms.

Summarizing, the inconsistency of the traditional approach to technical efficiency analysis rests on the assumption of a common technology. Taking into account that firm resources and core capabilities are developed through a time consuming and hard to replicate accumulation process seriously challenges the traditional assumption of a common technology. In fact, technical efficiency indexes may be of more practical help if they are interpreted as measures of the *relative* value of resources and capabilities possessed by the firm but not accounted for in the analysis.

6. Conclusion

Empirically estimated indexes of relative technical efficiency are obtained under the assumption that all the firms in the sample use a common technology. In our view, the homogeneity postulate amounts to assume that all relevant resources and outputs have been taken into account in the efficiency model. This would enable the researcher to perform meaningful interfirm comparisons. However, under the homogeneity assumption no theory is available that explains where do the observed performance differences between otherwise *identical* firms come from.

The resource-based view of the firm offers a consistent rationale to explain empirically estimated indexes. The assumption that firms are identical, i.e. that share a common technology and use identical resources as usually stated within the efficiency literature, is unacceptable. Instead, the resource-based view suggests that firms' resources and capabilities are widely heterogeneous, even within the same industry. Critical characteristics of resource accumulation processes, such as time compression diseconomies and causal ambiguity, seriously challenge the assumption of homogeneity. It is precisely resource heterogeneity that explains observed stable differences in *total factor productivity*.

Empirical analyses of technical efficiency interpret the residual as a measure of inefficiency. But the residual contains two different parts. One of them is statistical noise, product of uncontrollable random shocks. The other part, the one that is usually called technical inefficiency, is in fact a measure of the "error" that the researcher makes when assuming that firms are technologically homogeneous. According to Stigler "waste" (inefficiency) is error and “it will not become a useful concept until we have a theory of error” (1976: 216). We certainly do not have a theory of error, by we do have a resource-based theory that explains most of the systematic differences captured by the empirically estimated systematic part of the error term.

Within this framework, estimated indexes of technical efficiency measure the relative value of resources and capabilities not observed or not included in the empirical model, that were assumed to be homogeneous across firms. The very fact that empirical evidence repeatedly shows the existence of large performance differences in almost every industry that has been analyzed can be interpreted as an excellent test of resource-based theory. If heterogeneous resources didn't generate competitive advantages, observed inefficiency would tend to disappear over time, a trend that is not common in empirical studies (Bartelsman and Doms, 2000). Rather, many "inefficient" firms remain inefficient because of inferior resources. The empirical observation that some firms always belong to the higher efficiency groups suggests that their competitive advantages were sustained along time from competition.

Of course, technical efficiency indexes only measure strict technical differences among firms—more precisely, among their productive processes. Competitive advantage has a much wider scope. Resources and capabilities not directly productive enable the firm to achieve different profitability levels in the marketplace, by allowing to charge higher prices to customers. Thus, the interpretation of technical efficiency indexes suggested in this article as the relative value of resources and capabilities, or as a measure of the competitive advantage of the firm, must be restricted to the productive arena. In this way, we may speak of *productive advantage*, as a technical component of the competitive advantage, which can be measured with standard efficiency indexes.

The resource-based view of inefficiency indexes presented in this paper shares the same sources of criticism as the much more developed resource-based view of the firm, namely its tautological nature (Priem and Butler, 2001a; Barney, 2001; Priem and Buttler, 2001b). However, we do not claim to have developed a "theory of inefficiency" subject to empirical validation. We have just tried to provide a useful "perspective" that may help interpreting efficiency scores as they are currently estimated. The adoption of this perspective may serve to connect two important but, up to now, very distant fields of research. Fortunately, some advances in this direction have been already undertaken (Majumdar, 1998; Loredo, 2000).

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