Purchasing price assessment of leverage items: A Data Envelopment Analysis approach

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Abstract

In the Kraljic Portfolio Matrix (KPM) 'leverage' items are purchases with a high financial impact but which have a limited risk associated with the market. For these items, what is relevant is the consistency between the value attributes of the product/service and the price set by the supplier. This paper develops a three-step Data Envelopment Analysis (DEA)-based approach aimed at assessing the purchasing price of 'leverage' items and at providing practical managerial suggestions. The Purchasing Price Assessment DEA (PPA-DEA) approach considers the value attributes of the purchased product/service as Outputs of the relationship, and the purchasing price and volume as Inputs. Furthermore, a distinction between Pure Technical Efficiency and Scale Efficiency is also developed in order to highlight the most effective tactical initiatives that could be carried out. The approach is then tested on two supply categories of an Italian mechanical company. The results show how the approach is capable of providing meaningful insights into the prices set by the suppliers, and of supporting effective managerial actions. These results contribute to the literature on purchasing portfolios and to the literature on DEA as it is applied to Supply Chain Management (SCM). They contribute to the former by providing a technical approach to the taking of tactical decisions on 'leverage' products and services, and to the latter because this is the first study to use DEA to assess purchasing prices on the basis of the value attributes of the purchased product/service.

Keywords: Leverage Items; Purchasing Price; Data Envelopment Analysis.

1. Introduction

In the modern business environment efficient and effective Supply Chain Management (SCM) plays an increasingly important role in determining the strategic success of companies (Talluri and Narasimhan, 2004; Boute and Van Mieghem, 2014; Li 2013). Suppliers, together with raw materials, components and services, provide a relevant and growing contribution to the overall value generated by their customers (Liker and Choi, 2004; Jain et al., 2009). Their flexibility, after-sale service and support for innovation contribute to how quickly and efficiently the company can react to the market's needs and requirements (Hopkins, 2010). Indeed, in this context having a clear purchasing strategy becomes a real value driver for the company (Hesping and Schiele, 2015). In order to develop the purchasing strategy, the vast majority of companies use a so-called 'portfolio approach'. This involves clustering suppliers on the basis of relevant strategic features, and designing different strategies for each cluster (Gelderman and Van Weele, 2003; Montgomery et al., 2018).

The dominant methodology upon which the afore-mentioned purchasing portfolio approach is based is the Kraljic Portfolio Matrix (KPM), which was presented by Peter Kraljic in a renowned article published in the Harvard Business Review (1983). In KPM suppliers are classified according to two dimensions: financial impact (usually measured via the amount purchased) and supply risk (measured by considering the switching costs, the number of available suppliers and the amount of specific investments etc.). When both these values are high the suppliers are labelled 'strategic' and several aspects other than the selling price affect the management of the relationship. These are flexibility, reliability, and the competency to assist and support the company throughout the process of engineering its products. In other words, this means being capable of developing a long-term, strategic relationship (Vitasek, 2016; Caniels and Gelderman, 2005).

On the other hand, when we are dealing with so-called 'leverage items' and the financial impact is high, but the supply risk is low, the strategic dimension loses relevance because suppliers are widely available, and it is not expensive to move from the current supplier to a new supplier or suppliers (Razmi and Keramati, 2011). Consequently, what is really relevant for the buyer is the consistency between the purchasing price paid to the supplier and the value attributes of the product/service. With the term value attributes, we mean the features of the product/service that are valuable for the customer (Lancaster, 1971). Nevertheless, despite the relevance of the relationship between price and value attributes, and the high impact of this group of suppliers on the profit of the company (Zhengfeng et al., 2007), there is a lack of operational approaches able to assess the purchasing price of 'leverage items'. Indeed, in the field of operational research there are a few examples of purchasing optimization models, but they have two main drawbacks: they are very complex and difficult to manage at company level, and the price is just one of the elements taken into consideration (Razmi and Keramati, 2011). As for the field of management accounting, there are few articles that develop diversified approaches for different supply categories. For instance, Ellram (1996) suggests applying value analysis and cost analysis to the suppliers of 'leverage' items, but without developing any operational approach to price assessment unless it is limited to competitive bids or analysis of price lists.

Given this gap in the literature, the aim of this paper is to develop and test an approach able to assess the purchasing prices of 'leverage' products/services on the basis of the value attributes of the products/services purchased. For 'leverage' products and services the purchasing relationship can basically be seen as an Input/Output relationship where the purchasing price and the volume purchased are the Inputs for the buyer and the value attributes of the product/service are the Outputs obtained. For this reason, we based our price assessment approach on Data Envelopment Analysis (DEA – Charnes et al., 1978), which is widely known and used to measure the efficiency of Input/Output relationships. Accordingly, we propose a DEA-based Purchasing Price Assessment approach (PPA-DEA), which is able to highlight the efficiency level of purchasing prices and provide a breakdown between Pure Technical Efficiency (related to the supplier) and Scale Efficiency (related to the size of the transaction). PPA-DEA is a comprehensive managerial approach, so it does not only consider the step that involves data analysis, but also the upstream steps (selection and collection of data) and those that are downstream (definition and development of a suitable action plan).

The approach we developed was applied to two supply categories (92 purchased items in total) of a small mechanical company. Several relevant managerial considerations were generated, and cost savings were obtained. Moreover, the approach was demonstrably parsimonious as it required a limited amount of time in relation to the financial results obtained.

The contribution of our work is twofold. From a theoretical point of view, it contributes to the development of purchasing portfolio models with an approach that works on a tactical level (single category – specific supplier) while KPM works on a strategic level (supply categorization). Moreover, our work also contributes to the more general literature on the use of DEA to select and manage supply relationships (Ho et al., 2010). From a practical point of view, on the other hand, it provides the buyers and purchasing managers with a practical, easy-to-apply approach that is able to assess the purchasing price of 'leverage' items.

This paper is organized as follows. In the second section we shall present the theoretical background before moving on to the development of the PPA-DEA approach in the third section.

The methodology applied will subsequently be described in section four, while section five will report on the results obtained and section six will be dedicated to a discussion on the findings. Finally, in the last section conclusions will be drawn, limitations identified, and the future developments of the research shall be outlined.

2. Research Background

2.1 Leverage items: the relevance of purchasing price assessment

Purchasing costs account for over 70% of the total cost of goods sold (Van Weele, 2009) and this value increases to 80% or even higher values if we take into account the overall total cost of ownership of supply relationships (Ellram, 1994) and include the costs of order management, quality management, inbound logistics, warehouse(s), accounting and so on. Furthermore, it is widely known that Supply Chain Management (SCM) is able to impact the capability of the company to generate sustainable value (Mentzer et al., 2001; Padhi et al. 2012). Consequently, bringing purchasing competences into line with business strategy becomes a critical factor in improving business performance (Carter and Narasimhan, 1996; Gonzalez-Benito, 2007; Talluri et al., 2013). Indeed, Hesping and Schiele (2015) proposed an interesting multilevel framework aimed at aligning purchasing strategy and business strategy with the aim of increasing overall business performance (Figure 1). At the first level the company defines its own strategy, which affects the functional strategy of the Purchasing Department at level 2. After this, the purchasing strategy must be deployed at three more levels: 'strategic' (level 3), 'tactical' for each category (level 4), and then for each supplier (level 5).

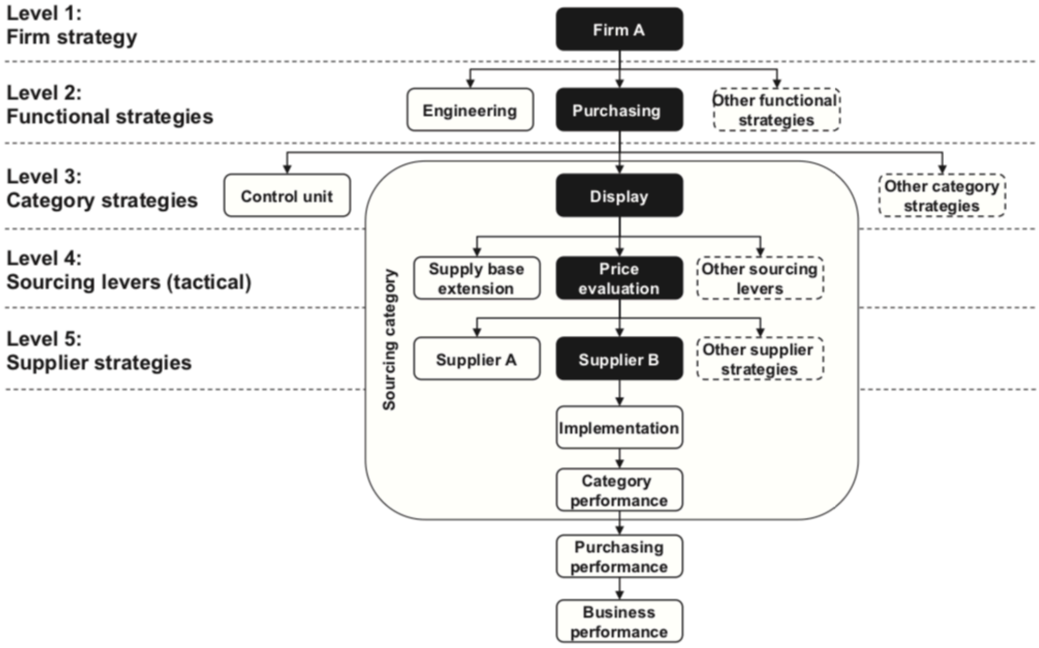

Figure 1: a multilevel approach to purchasing strategy development (Source: Hesping and Schiele, 2015).

The idea that a 'strategic' approach to purchasing must be developed at the category level according to the specific features of each category is well known and accepted (Rozemeijer et al., 2003), and the so-called "purchasing portfolio approaches" represent the application of this idea to the field of practice (Gelderman and Van Weele, 2003; Wynstra and Ten Pierick, 2000). In these approaches different supply categories are clustered according to their specific features and different strategies are designed for each cluster (Knight et al., 2014). The most established purchasing portfolio approach is the Kraljic Portfolio Matrix (KPM – Kraljic, 1983), which classifies supply categories according to the financial impact of purchasing (usually measured via the total amount purchased), and the risk associated with the supply market (measured via the number of available suppliers, switching costs, and the complexity of the supply market). The combination of high and low values for these two dimensions generates four quadrants that represent four different clusters, each requiring specific 'strategic' approaches[1] (see Figure 2).

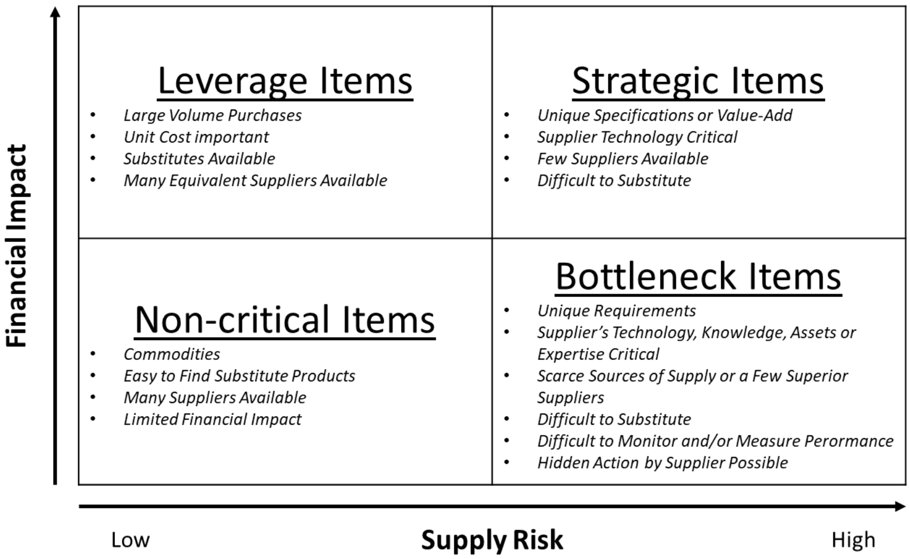

Figure 2: the Kraljic matrix (Source: Kraljic, 1983).

If we limit the analysis to the two categories with high financial impact - i.e. 'leverage' and 'strategic' items - a contingent strategy is necessary for each of them. While the purchasing strategy for 'strategic' items is basically aimed at developing a long-term win-win relationship with the suppliers (Jensen, 2017), the target for the 'leverage' items is "to exploit the full purchasing power" (Kraljic, 1983, p. 112) in order to reduce the purchasing price on the basis of the value of the product/service purchased. Developing a long-term relationship with the supplier

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[1] Several authors have reviewed the Kraljic model by proposing alternative classification dimensions. Van Stekelenborg and Kornelius (1994) identified both the need to control the internal market demand and the external supply market; Olsen and Ellram (1997) proposed introducing the complexity of managing the purchase and its strategic relevance; Bensaou (1999) focused on the specific investments of both the buyer and the supplier; Gelderman and Van Weele (2000) identified the dependency of both the buyer and the supplier as dimensions of analysis and classification. Each of these models allows us to identify 4 different purchasing categories by adopting different classification dimensions.

is not a priority for the buyer: alternative suppliers are widely available, switching costs are low, and the potential savings generated by new suppliers is potentially very high (Kraljic, 1983; Caniels and Gelderman, 2007). If we apply Williamson's renowned model (1986), the relationship with 'leverage' suppliers is affected by limited rationality and high opportunism, while the amount of specific investments is low, and, as a result, the purchasing approach must be focused on competition rather than on cooperation (see Table 1).

Behavioural assumptions		Specific Investments	Purchasing approach
Limited Rationality	**Opportunism**		
Absent	Present	Present	**Planning**
Present	Absent	Present	**Promise**
Present	Present	Absent	**Competition**
Present	Present	Present	**Governance**

Table 1: the determinants of the purchasing approach (adapted from Williamson, 1986).

When moving to the tactical and supplier-based levels (levels 4 and 5 in Figure 1), the main goal of the purchasing activity therefore becomes to obtain the requested level of value attributes at the lowest price. With the term 'value attributes', we refer to all those features of the product/service purchased that are valuable for the customer and that affect his/her decision to buy as well as to the price he/she is willing to pay (Lancaster, 1971). Value attributes can be proxied either by the technical features of the product/service (the volume, weight, presence of a specific feature, number of certain components), or by more qualitative aspects quantified through more subjective evaluations (the brand, overall perception of quality, technological development, safety, etc.). For the 'leverage items', on the other hand, the buyers need frameworks and tools that can assess the purchasing price on the basis of the specific value attributes of the product/service purchased. On this point Kraljic suggests the "introduction of proven purchasing analysis approaches, such as commodity analysis or value analysis, to help develop action plans" (Kraljic, 1983, p. 116).

2.2 The role of the buyer in the pricing process

While a number of studies have been focused on developing frameworks and tools to select and develop 'strategic' supply relationships (Glock et al., 2016), there is a lack of knowledge about practical approaches able to support the buyers' activity for 'leverage' items where price negotiation plays a critical role. Firstly, the literature on pricing in BtoB markets is much less developed than the one focused on BtoC relationships. In fact, in their broad literature review of studies on pricing in the last two decades, Kienzler and Kowalkowski (2017) found that over two thirds of the papers were focused on BtoC, that only one sixth was focused solely on BtoB, and that the rest of the studies were either generic or focused on both of these relationships. Secondly, the focus on processes, techniques and approaches developed by the supplier to set the price (Kienzler and Kowalkowski, 2017) predominated, while the role of the supplier in the process was neglected. The purchasing company is therefore mainly viewed as a passive agent who waits for the offer developed by the supplier. In this context it should also be noted that most of the studies were focused on the steps of the pricing process in order to increase the effectiveness of the outcome for the supplier (Lancioni, 2005). Furthermore, the framework that was widely adopted was the one developed by Nobles and Gruca (1999), which highlights ten potential pricing strategies grouped into four pricing situations: new products, competitive situations, product lines and cost-based. The buyer's perspective is therefore completely neglected while the supplier is the main actor in the process.

More recent approaches have developed cooperative pricing models where the final price is the outcome of a collaboration between suppliers and customers, or even several tiers of the supply chain (Formentini and Romano, 2016). Of particular interest for our purposes is the branch of research related to value-based pricing (VBP). VBP starts by overcoming the traditional and widely adopted cost-plus pricing approach (Shipley and Jobber, 2001), which does not take into account the value generated for the customer (Brennan et al., 2007). VBP develops a new approach based on the value generated for the customer where different actors within the supply chain work in a cooperative way in order to align the price with the value provided to the final customer (Christopher and Gattorna, 2005; Hintertuber, 2008; Farres, 2012). With the VBP approach the supplier develops an internal process to define the price, but the value and the whole product configuration is mediated and affected by the value perceived by the buyer, who plays a very active role in communication and discussion with the supplier (Figure 3).

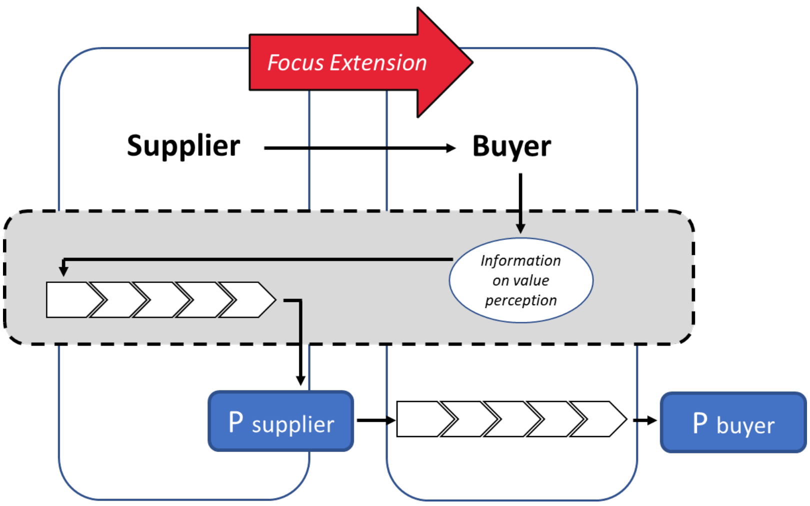

Figure 3: The pricing process based on a value-based dialogue between the supplier and the buyer (Formentini and Romano, 2016).

With the value-based pricing approach the customer finally becomes a participant in the pricing process with the supplier, but the latter remains the leading actor. What is still missing is an approach that is able to support the buyer when assessing the price of a specific product/service on the basis of its value attributes and in accordance with the value-based pricing approach. In this context, the aim of this paper is to develop and test a rigorous approach to purchasing price assessment which can assess the purchasing price of a 'leverage' item on the basis of its value attributes.

3. A DEA-based approach to purchasing price assessment

3.1 Data envelopment analysis to assess the efficiency of purchasing prices

The idea at the core of this approach is to assess the efficiency of the purchasing price through Data Envelopment Analysis (DEA). As previously stated, the purchasing activity of a 'leverage' item can be seen as a process where the customer pays a price (Input) to obtain a certain level of value attributes provided by the product/service (Output). As a consequence, by knowing the specific Inputs and Outputs of the process and the related quantity levels, it is possible to assess the efficiency of the price, i.e. the capability of obtaining a given set of attributes at the lowest price. For this purpose, our model suggests applying a widely known efficiency assessment approach called Data Envelopment Analysis (DEA). DEA is a linear-programming based technique developed by Charnes et al. (1978) to assess the efficiency of specific 'units' called Decision Making Units (DMUs). DMUs transform a vector of Inputs into a vector of Outputs. In the context of this study, a DMU is a single product/service purchased and for which the purchasing process transforms a certain amount of money (price) into a set of value attributes.

DEA is a non-parametric approach: it does not need to pre-define a specific production function and as such it allows us to evaluate efficiency when the relationships between the multiple Inputs and Outputs are unknown or complex. The final outcome provided for each DMU is an 'efficiency score' obtained by maximizing the ratio of the weighted sum of Outputs to the weighted sum of Inputs. The DMUs with the highest efficiency scores are the 'best in-class' and define the frontier enveloping all the other DMUs.

The first DEA model is called CCR, which stands for the initials of the authors Charnes, Cooper and Rhodes. CCR provides reliable efficiency scores under the assumption of constant returns to scale (i.e. when a linear relationship exists between Inputs and Outputs).

Let us now suppose we have a set of m DMUs, and that each DMU i ($i = 1,\ldots,m$) uses n Inputs x_{ji} ($j = 1,\ldots,n$) in order to obtain z Outputs y_{ki} ($k = 1,\ldots,z$). In this scenario we can now also consider the Input and Output multipliers as u_j and v_k, respectively. If such multipliers are known, the efficiency score of a DMU can be measured by the ratio between the weighted Outputs and the weighted Inputs as such:

$$\sum_k v_k\, y_{ki} \Big/ \sum_j u_j\, x_{ji}$$

Otherwise, if the multipliers are unknown, a particular non-linear programming problem has to be solved (as suggested by Charnes et al., 1978). This model allows us to calculate the efficiency of a specific DMU$_t$ by solving the following maximization problem:

$$max \quad \sum_k v_k\, y_{kt} \Big/ \sum_j u_j\, x_{jt}$$

$$s.t. \quad \sum_k v_k\, y_{ki} - \sum_j u_j\, x_{ji} \le 0, \quad \forall\, i$$

$$v_k, u_j \ \ge \ \varepsilon, \quad \forall\, k, j$$

Where ε represents a non-archimedean value its purpose is that of enforcing strict positivity on the variables. Moreover, the previous non-linear programming maximization problem can be converted to a linear programming problem. This can be done by applying the theory of fractional programming (Charnes and Cooper, 1962) and by making the following changes to the variables:

$\upsilon_k = wv_k$

$\mu_j = wu_j$

where $w = \left(\sum_j u_j\, x_{jt}\right)^{-1}$

In this case the following linear programming maximization problem has to be solved:

$$max \sum_k \upsilon_k\, y_{kt}$$

$$s.t. \quad \sum_j \mu_j\, x_{jt} = 1$$

$$\sum_k \upsilon_k\, y_{ki} - \sum_j \mu_j\, x_{ji} \le 0, \quad \forall\, i$$

$$\upsilon_k, \mu_j \ \ge \ \varepsilon, \quad \forall\, k, j$$

Starting from the initial CCR model, several extensions have been applied to the DEA. The most commonly used one is the BCC model (Banker et al., 1984), which was developed in order to manage variable returns to scale. These happen when the relationship between Inputs and Outputs is affected by the size of the Input and Output vectors. The BCC model can now be expressed as follows:

$$max \quad \left[\sum_k v_k\, y_{kt} - v_t\right] \Big/ \sum_j u_j\, x_{jt}$$

$$s.t. \quad \sum_k v_k\, y_{ki} - \ v_t - \sum_j u_j\, x_{ji} \ \leq 0, \quad i = 1, \dots, m$$

$$v_k, u_j \ \geq \ \varepsilon, \quad \forall\, k, j$$

v_t unrestricted in sign.

As with the CCR model, we can also explicit the equivalent linear programming model:

$$max \quad \sum_k v_k\, y_{kt} - v_t$$

$$s.t. \quad \sum_j \mu_j\, x_{jt} = 1$$

$$\sum_k v_k\, y_{ki} - v_t - \sum_j \mu_j\, x_{ji} \ \leq 0, \quad i = 1, \dots, m$$

$$v_k, \mu_j \ \geq \ \varepsilon, \quad \forall\, k, j$$

v_t unrestricted in sign.

The efficiency scores obtained by applying the CCR or the BCC model to each DMU may differ if variable returns to scale exist. In fact, CCR efficiency scores represent technical efficiency (TE), while BCC efficiency scores represent pure technical efficiency (PTE). More specifically, CCR measures the level of inefficiency in the Input/Output configuration as well as that caused by the dimension of the operations, while BCC provides a measure that is net of scale inefficiencies, i.e. only related to Input/Output configuration. The result obtained by dividing TE by PTE is named Scale Efficiency (SE) and it measures whether a DMU is operating at the most suitable dimension level or not.

A second relevant aspect that must be defined is the orientation of the model: the Input-oriented model is aimed at minimizing the Input(s) for a given level of Output(s), while the Output-oriented model's target is to maximize the level of Output(s) for a given level of Input(s) (Charnes et al., 1981). All the models presented in this section are Input-oriented, reflecting the focus on the price dimension.

The DEA model is well-known and already applied by academics and practitioners in several fields, ranging from hospitality (Huang et al., 2014) to banking (Quaranta et al., 2018), and from transportation to education (Liu et al., 2013). There is also a specific stream of literature that has already applied DEA to Supply Chain Management decisions specifically to assess the performance of suppliers (Talluri et al., 2013) and the total cost of ownership of the relationship (Visani et al., 2016).

DEA has also been proposed for pricing aims. Wang et al. (2016) proposed a DEA-based pricing approach named Competitive Pricing DEA, but again it is from the perspective of the supplier rather than the buyer, and the general idea introduced is not developed enough or tested in order to become an operational approach for purchasing departments aiming to assess the purchasing prices of 'leverage' items.

3.2 The approach

In view of the above considerations, the aim of this paper is twofold: a) to develop a DEA-based purchasing price assessment approach (PPA-DEA) able to evaluate the purchasing price on the basis of the value attributes of the product/service; b) to test the approach developed on two different 'leverage item' purchasing categories of a mechanical company. The proposed approach is composed of three consequential steps a) Data Selection; b) Data Analysis; and c) Action Planning (see Figure 4).

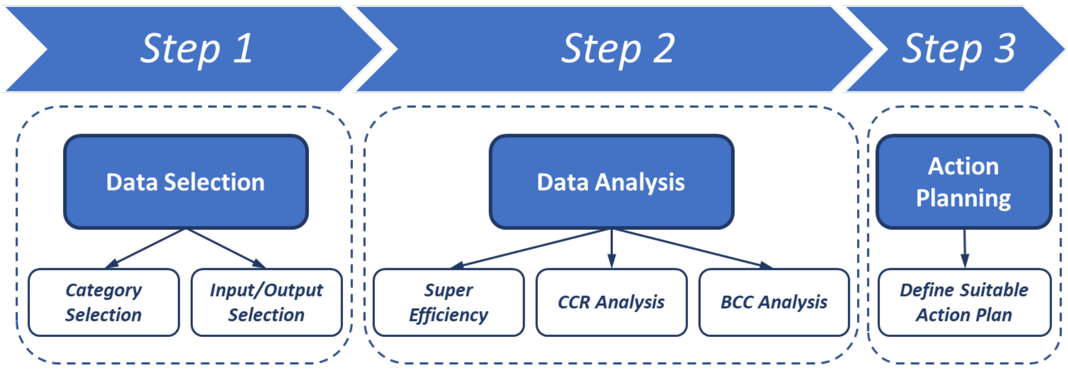

Figure 4 – The proposed approach to measure price efficiency using DEA.

3.2.1 Step 1 – Data Selection

In this first step two main issues must be addressed: which supply categories to analyze and which data to collect. In relation to the former, the proposed approach fits well with 'leverage' supply categories where the purchasing process can be seen as an exchange between a purchasing price (and volume) and a set of value attributes. Where the relationship with the supplier entails a strategic role (strategic items in the Kraljic matrix) or where the risk associated with the specific supply is high (bottleneck items), other factors like risk management targets, containment of switching costs and limited availability of alternatives play a relevant role, thus limiting the potential effectiveness of the proposed approach. On the other hand, it is not worth developing such an approach for the fourth purchasing cluster in the matrix - the non-critical items - because the potential saving is negligible. Additionally, given the properties of the DEA the analysis should be focused on categories for which Inputs and Outputs can be objectively or subjectively quantified, or at least codified (e.g. binary variables representing the presence or absence of a specific feature). Furthermore, the supply categories investigated should be significant in terms of the total amount purchased as well as homogeneous, in as much as they should be composed of DMUs that share the same value attributes.

In order for a supply category to be selected, it should include a minimum number of DMUs for the DEA approach to be carried out effectively. A good rule of thumb is that the number of DMUs should be at least three times the number of Inputs *and* Outputs selected (Coelli et al., 2015). Once the DMUs are identified, the Inputs and Outputs have to be carefully evaluated and selected. Ultimately, the goal is to understand the suitable Inputs and Outputs on the basis of the features of the specific business relationship. As mentioned above, from a customer perspective the Inputs represent what the customer puts into the relationship, while the Outputs consist of the features of the product/service obtained. Selecting the Inputs is fairly intuitive because they are usually represented by the purchasing price and volume, the Outputs, on the other hand, depend on the specific supply category. Furthermore, it should also be noted that since minimizing the number of Inputs and Outputs impacts the DEA's outcome positively, it is essential to include only the most relevant Input/Output dimensions.

3.2.2 Step 2 – Data Analysis

Three different analyses must be carried out to conduct the analysis: a) a Super Efficiency analysis; b) a CCR Analysis; and c) a BCC Analysis. The main difference between the conventional DEA model and the Super Efficiency DEA model is that in the latter the DMU under evaluation is not included in the reference set so that its efficiency score may be greater than 1 (Banker and Gifford, 1988). Efficiency scores much greater than 1 often signal data errors in the Input/Output or specific operational conditions affecting the Input/Output relationship of one or a few specific DMUs. Keeping these 'outliers' in the DEA analysis would affect the shape of the efficient frontier and the efficiency score of all the remaining DMUs. As a consequence, and according to the literature (Banker and Chang, 2006), the PPA-DEA approach excludes all the DMUs that obtain a score higher than 1.2/1 from the analysis.

Next a conventional CCR-DEA model is carried out. The Output of this second stage is the list of efficiency scores for each DMU, in a range between 0 and 1 and the potential saving (i.e. the purchasing discount) obtainable by transforming each inefficient DMU into an efficient one. The potential saving is worked out as follows:

$$Potential\ saving = (1 - efficiency\ score) * amount\ purchased \qquad [1]$$

This second value is more important than the efficiency score from a managerial point of view because managers normally focus their attention on the items with the highest potential saving, regardless of the specific efficiency score. After calculating the potential discount, a synthetic efficiency score can be calculated for each supplier that weights the scores of all the DMUs purchased from the supplier by the amount purchased.

$$\text{Weighted Efficiency Score of the n DMUs of a Supplier} = \frac{\sum_{i=1}^{n}(Amount\ purchased\ i * Efficiency\ Score\ i)}{Total\ amount\ purchased\ from\ the\ supplier} \qquad [2]$$

Finally, a BCC DEA model is carried out in order to take into consideration the possibility of variable returns to scale in the purchasing relationship. The returns to scale may increase because of quantity discounts, but they can also decrease when the supplier faces difficulties in managing higher volumes, or when further investments are required in order to expand the production capacity. Moreover, the Scale Efficiency (SE) of each DMU can be worked out by dividing the efficiency score provided by the CCR approach by the one provided by the BCC. While the score generated by the BCC analysis represents the Pure Technical Efficiency (PTE) related to the purchasing process of the specific DMU, the Scale Efficiency (SE) measures the capability of purchasing the given DMU at the right volume.

Each DMU can be represented in a graph with the PTE on the horizontal axis and the Scale Efficiency in the vertical one (see Figure 5).

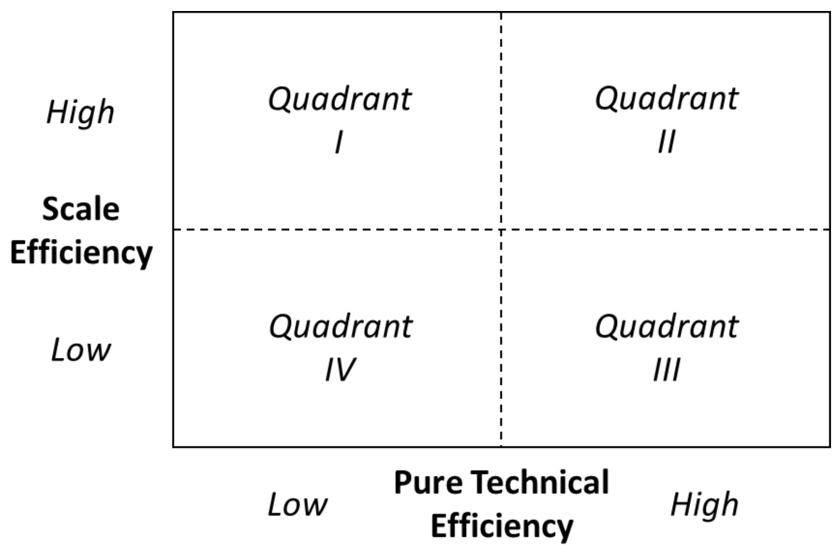

Figure 5 – The matrix jointly showing Pure Technical Efficiency and Scale Efficiency of each DMU.

Using the average (or median) values as the threshold between low and high values for the two dimensions, four quadrants can be defined: a) *Quadrant I*: DMUs with high SE but low PTE for low competitive prices; b) *Quadrant II*: DMUs with high SE and high PTE for efficient supplier relationships; c) *Quadrant III*: DMUs with low SE but high PTE for inefficiencies due to purchasing volumes; and lastly d) *Quadrant IV*: DMUs with low SE and low PTE for inefficiencies due to both low competitive prices and inefficient volumes.

3.2.3 Step 3 – Action Planning

With the exception of the second quadrant where the relationship is already efficient, it is now possible to define an action plan for all the DMUs included in each quadrant (see Figure 6). In the first quadrant the scale is efficient but the relationship with the supplier is not. In this case, the company could switch to a more efficient supplier or could scout the market in search of more efficient suppliers. In the third quadrant the scale of the relationship is inefficient, and therefore the company could increase the volume purchased by bundling several purchases and negotiating them with a single supplier rather than managing specific negotiations for each DMU. In the fourth quadrant inefficiencies due to both low competitive suppliers and volumes are identified. The goal here is twofold. First of all, the company should switch the specific purchase to suppliers with higher PTE. In so doing the total volume purchased from the specific supplier increases, thus reducing the effect of scale inefficiencies. Moreover, a preference order of intervention can be established, which is the potential saving measured by the proposed approach.

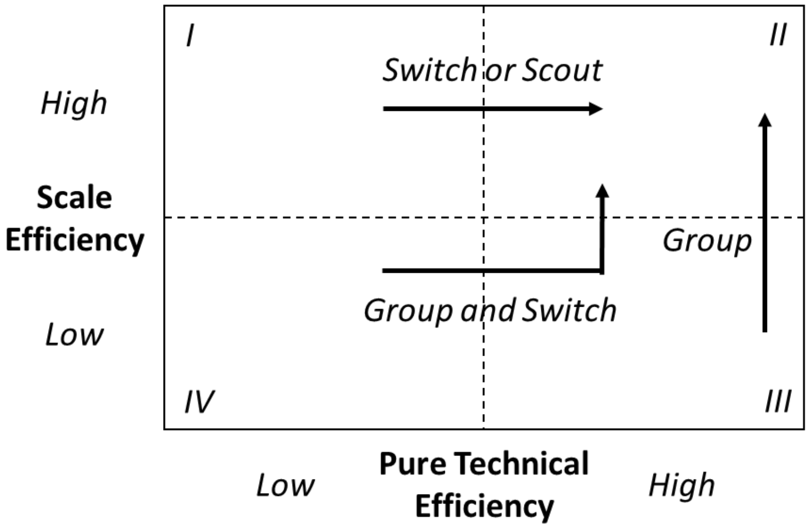

Figure 6 – The actions that could be put in place in the quadrants of the model.

4. Methodology

4.1 Company and supply categories selection

The proposed approach has been tested on two supply categories of a small Italian mechanical company that manufactures tractor cabs. The real name of the company is not disclosed for confidentiality reasons, so we shall refer to it as 'Forcab'. Forcab's revenues in 2017 were € 31 million and they had 105 employees. Forcab's customers are usually multinational companies in the agriculture machines industry who have a lot of contractual power in price negotiations. As a result, Forcab's final profitability in 2017 was very low (less than € 500,000).

The company was selected for the analysis for several reasons:

a) the amount of purchasing costs is very high (more than 65% of the revenues), and therefore the development of a more effective and efficient purchasing process is undoubtedly one of the priorities of the company;

b) a well-developed ERP system is available, and the company regularly collects reliable information about several products and services purchased, which is fundamental when selecting the Inputs and Outputs of the DEA process;

c) the Chief Operations Officer (COO), the controller and the directors of the purchasing and manufacturing departments showed maximum availability and interest in developing the process because they perceived potential value in its final outcome. They, together with the two researchers, formed what we called the 'DEA team'.

A first focus group meeting lasting 4 hours was conducted with the COO, the controller and the two directors in order to select the supply categories to be analyzed. The first hour of the meeting was dedicated to explaining the approach, its rationales, development steps and expected outcomes. Furthermore, special attention was dedicated to specific features requested for the target supply categories. At the end of the meeting the supply categories selected were 'Painting' (46 purchased items, € 1.76 million purchased) and 'Glasses' (53 purchased items, €1.34 million purchased). The two categories were selected for several reasons. The company already used a Kraljic matrix in order to classify the suppliers, and the two categories selected were the most relevant in terms of turnover within the 'leverage' quadrant of the matrix. For both the categories the managers of the company already had a rough idea of the potential Inputs and Outputs to include in the DEA model and information about them was already available in the company’s information system. Finally, the number of items in each category was more than enough to guarantee the reliability of the DEA approach. The diverse nature of the two supply categories also constituted an additional reason for their selection: while 'Painting' involves external work provided by regional suppliers with a continuous flow of materials between the company and the suppliers, 'Glasses' are raw materials bought from international suppliers with long lead times and complex logistical processes.

4.2 Development of the PPA-DEA approach

Once the two supply categories had been selected, we carried out the steps in the proposed approach as presented in Figure 4. First of all, a second focus group meeting with the same participants (the researchers, the COO, the controller and the directors of the purchasing and manufacturing departments) was called to identify the Inputs and Outputs. While the Inputs (purchasing price and volume for both the two categories) were easy to select and obtained a general consensus, the discussion about the Outputs was much more animated. The researchers played the role of facilitators and moderators in the discussion by asking predefined questions such as “which features of the purchased product/service do you take into account when evaluating the purchasing price?”, “what information do the suppliers usually request before setting the price?”, “which data are available on the features of the purchased product/service?”, “what further information could we collect if needed?”. The aim was to understand which Outputs would have been 'optimal' and to compare them with the 'available' ones. Weight, surface and sealing were selected as Outputs for the 'Painting' category, while thickness, surface, perimeter, number of holes and silk-screen printing areas were selected as Outputs for the 'Glasses' category.

Next the controller of the company collected the data related to Inputs and Outputs. This came mainly from the company’s ERP, but occasionally also from other sources such as excel files with technical features of specific products that had been developed by either the manufacturing department or the R&D department. The data were then checked by the COO, integrated or modified as required, and then sent to the researchers for analysis. The initial analysis highlighted high correlations between overall dimension and surface in the 'Painting' category (Pearson correlation index = 0.86), and between surface and perimeter in the 'Glasses' category (0.94). In order to keep the number of variables as low as possible the overall dimension and perimeter were then excluded from the analysis of 'Painting' and 'Glasses' because their correlation with the purchasing price was lower than the one for the surface of painted components and glasses. The data analysis (Super Efficiency analysis, CCR and BCC DEA models) was then run by the researchers using the software PIM DEA 3.2, and for the Super Efficiency analysis the threshold for excluding the outliers was set at 1.20 in accordance with the literature (Banker and Chang, 2006). No supplier was excluded after this step in the 'Painting' category. However, the results for two suppliers in the 'Glasses' category exceeded the threshold which led to their exclusion. Next the regular CCR and BCC DEA models were run, and the Pure Technical Efficiency and Scale Efficiency computed. Finally, the performance of each supplier was worked out and graphs were developed. The two researchers worked together during all the steps of the analysis in order to reduce the chance of technical mistakes.

The 'DEA team' discussed the results obtained in two further meetings (one for each category) with the aim of understanding the meaningfulness of the analysis. The DEA efficiency scores provided by the CCR and BCC models for all the DMUs were compared with the Output and Input values of each DMU in order to understand the most relevant sources of inefficiency. For the 'Painting' category the managers agreed that the scores generated by the procedure were meaningful and consistent with the contingent conditions of each negotiation. On the contrary, when discussing the results of the analysis for the 'Glasses' some values were considered inconsistent with the managerial perceptions of all the participants. More specifically, the 5 glasses with a 6-millimeter thickness appeared very inefficient (average efficiency lower than 0.4). The director of the purchasing Department pointed out that manufacturing those DMUs requires much more complex and expensive technology, so it would have been a mistake to include them in the same DMU set as the other glasses. Consequently, they were excluded from the analysis then the DEA with Super Efficiency was carried out again and the results were discussed. 2 DMUs emerged as outliers from the Super Efficiency analysis (with efficiency scores equal to 1.43 and 1.63), so they were excluded from the further steps in the analysis. The results of this second iteration, involving the remaining 46 DMUs, were discussed again by the 'DEA team' and the managers agreed on the meaningfulness of the outcome.

Finally, an action plan for each supply category was developed by defining the target DMUs and suppliers, and the potential initiatives put in place. After six months, during which the company carried out the plan, a final meeting was held in which the 'DEA team' discussed the results obtained for each of the two supply categories.

Table 2 reports the main steps in the analysis and the time taken by each of them[2].

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[2] The Table does not take into account all the operational activities performed by the managers to put in place the action plans discussed together with the researchers (meetings, negotiations with the suppliers, search for new suppliers, revision of some components, etc. These activities are the operational consequences of the proposed approach, but not specifically part of it.

Step	Activity		Output	Managers		Researchers		Total people involved	
				People involved	Work hours	People involved	Work hours	People involved	Work hours
Data Selection	**1**	Focus group with the COO, the controller and the director of the purchasing and manufacturing departments	Supply categories to be analysed	4	12	2	6	6	18
	2	Second focus group of the 'DEA team' (one for each category)	List of inputs and outputs of each supply category	4	32	2	16	6	48
	3	Data collection about Inputs and Outputs	Input and Output Values for the two supply categories	2	44	0	0	2	44
Data Analysis	**4**	Data Analysis (super efficiency analysis, CCR and BCC DEA models development)	Efficiency scores and ranking for both the two categories	0	0	2	32	2	32
	5	Assessment of the meaningfulness of the obtained results (one for each category)	Requested revisions	4	24	2	12	6	36
	6	Repeated analysis (only for the 'Glasses' category)	Revised efficiency scores and rankings of the 'Glasses' category	0	0	2	12	2	12
Data Planning	**7**	Development of an Action Plan for each supply category	Action plan for each supply category	4	32	2	16	6	48
	8	Final assessment of the results obtained by the action plans	Assessment of the results generated by the approach and the main issues to manage	4	24	2	12	6	36
Total					**168**		**106**		**274**

Table 2: steps, activities, output and time needed by the development and assessment of the proposed approach.

5. Findings

5.1 Painting category

Figure 7 reports the efficiency score calculated through the CCR model and the potential savings worked out with the formula [1] for each supplier in the 'Painting' category. 6 fully efficient DMUs emerge from the analysis. The median Efficiency Score is 0.769 (mean value = 0.774), while the total potential savings are € 328,960 (mean value = € 7,150).

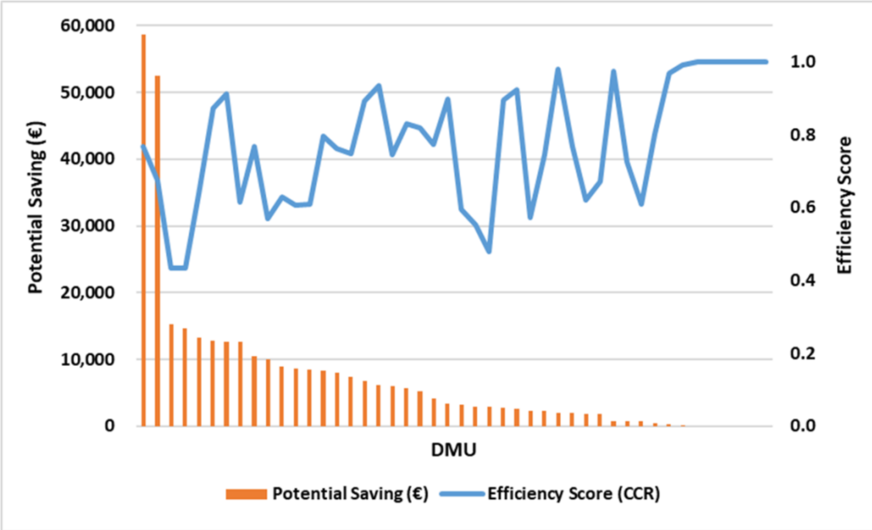

Figure 7 – Efficiency scores and potential savings for the DMUs in the 'Painting' category.

The figure clearly highlights the priorities for the company. Some DMUs show very low efficiency scores (even lower than 0.5), and the potential savings of the first two DMUs are much higher than all the remaining DMUs. The cumulated potential saving of the first two DMUs is € 161,145, while the 10 following DMUs account for less than € 119,000 of the cumulative potential savings. All the remaining 34 DMUs account for less than € 99,000 of the cumulated potential savings.

Next a Non-Decreasing Returns to Scale (NDRS) DEA model was run to take into consideration the returns to scale as well. An NDRS DEA model was chosen from the different BCC DEA model options because during the first focus group the director of the purchasing department highlighted the fact that the purchasing prices in this category are not supposed to increase when the volume purchased increases. At this point the various DMUs can be displayed in a matrix (see Figure 8) that reports the Scale Efficiency (SE) on the vertical axis and Pure

Technical Efficiency (PTE) on the horizontal axis. The size of each ball represents the amount purchased for each DMU and the colors identify the three suppliers in the category.

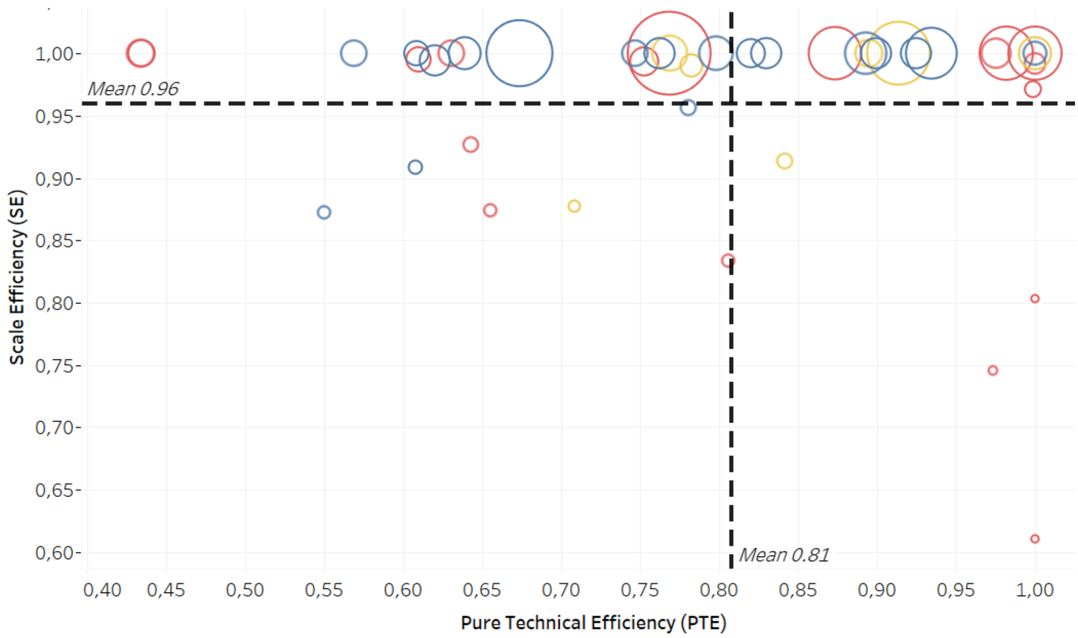

Figure 8 – The matrix reporting Pure Technical Efficiency (PTE) and Scale Efficiency (SE) for each DMU in the 'Painting' category.

After this, four different quadrants are identified by calculating the mean values of both SE and PTE (0.96 and 0.81 respectively). It is clear from the graph that most of the DMUs and the purchased amounts are included in the first and second quadrant which highlights an average high scale efficiency, while many suppliers are included in Quadrant I which signals limited Pure Technical Efficiency. Table 3 presents a detailed analysis of the distribution of the DMUs by supplier and quadrant.

Supplier		Quadrant I	Quadrant II	Quadrant III	Quadrant IV	Total: No DMUs / Potential Saving (€)	Total: %
Alfa	No DMUs	8	7	0	3	**18**	**39.1%**
	Potential Saving (€)	119,165	29,608	0	8,076	**156,850**	**47.7%**
Beta	No DMUs	6	8	3	3	**20**	**43.5%**
	Potential Saving (€)	113,401	15,949	1,899	7,258	**138,507**	**42.1%**
Gamma	No DMUs	2	4	1	1	**8**	**17.4%**
	Potential Saving (€)	14,501	15,364	1,899	1,840	**33,604**	**10.2%**
Total	**No DMUs**	**16**	**19**	**4**	**7**	**46**	**100%**
	Potential Saving (€)	**247,067**	**60,921**	**3,798**	**17,175**	**328,960**	**100%**
	No DMUs %	**34.8%**	**41.3%**	**8.7%**	**15.2%**		
	Potential Saving %	**75.1%**	**18.5%**	**1.2%**	**5.2%**		

Table 3: the analysis of the efficiency by supplier and efficiency quadrant for the 'Painting' category.

As shown in the table, the majority of the DMUs are included in the second quadrant where the relationships can be defined as efficient (41%), and in the first quadrant where the price set by the suppliers is non-efficient because of their low PTE (35%). In the first quadrant almost 75% of the total potential savings can be achieved (€ 247,067 out of a total of € 328,960). Indeed, the DMUs and the potential savings in this quadrant are related to supplier Alfa (8 DMUs and € 119,165 of potential savings) and Beta (6 DMUs and € 113,401 of potential savings), while a marginal role is played by supplier Gamma (2 DMUs and less than € 15,000 of potential savings). According to the approach presented in Figure 3, it is evident that the priority for this supply category is to move the most relevant purchases from Quadrant I to Quadrant II through a 'Scout or Switch' strategy focused on suppliers Alfa and Beta. An important saving could be achieved by switching to suppliers with higher PTE or by searching for more efficient suppliers that are not currently on the suppliers' list. Also, in Quadrant II - where the suppliers are theoretically already efficient - some potential savings arise (€ 60,921 and 18.5% of the total). As mentioned previously, Quadrant III and IV are not of interest for any managerial actions because the total potential saving of the 11 DMUs included in these quadrants is lower than € 21,000 (6.3% of the total).

Finally, a global evaluation of the efficiency of the three suppliers in the category was carried out by applying formula [2] (see Table 4).

Supplier	Turnover (€)	Weighted Efficiency	Potential Saving (€)
Alfa	701,058	0.78	156,850
Beta	774,545	0.82	138,507
Gamma	286,080	0.88	33,604
Total	***1,761,683***	***0.81***	***328,960***

Table 4: the analysis of the efficiency by supplier and efficiency quadrant for the 'Painting' category.

The first two suppliers account for almost the same amount purchased and their average efficiency is very similar. On the other hand, the average efficiency of Gamma - a new supplier introduced a few months before the project began - is higher than that of the two traditional suppliers. This result suggests the need to further develop the relationship with Gamma in order to generate more competition between Alfa and Beta, which are the largest painting companies in the region and have developed a sort of oligopoly in the area.

5.2 Glasses

Figure 9 presents the efficiency scores and the potential savings generated by the development of the CCR-DEA model for the 'Glasses' supply category.

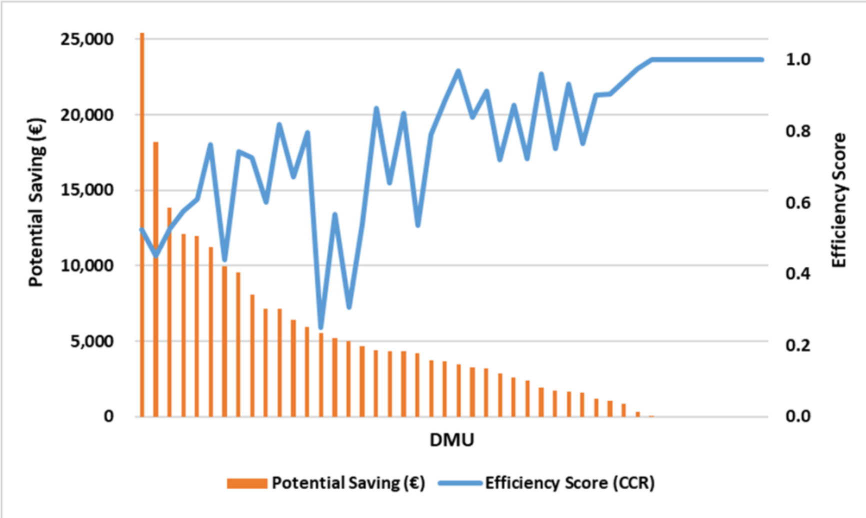

Figure 9 – Efficiency scores and potential savings for the DMUs in the 'Glasses' category.

8 fully efficient DMUs emerge from the analysis. The median efficiency score is 0.81, while the mean value is 0.78. The total potential savings are therefore € 220,376 with an average value of € 4,791 for each supplier. Even if the distribution of the potential savings is more regular than the one for the 'Painting' category, the 10 DMUs with the highest potential savings account for over € 127,000 while the remaining 36 DMUs account for less than € 93,000.

If we look at the matrix reporting Scale and Pure Technical Efficiency (Figure 10), we can see a low number of units included in the third and fourth quadrants, and this represents an average high Scale Efficiency (the mean value is 0.96).

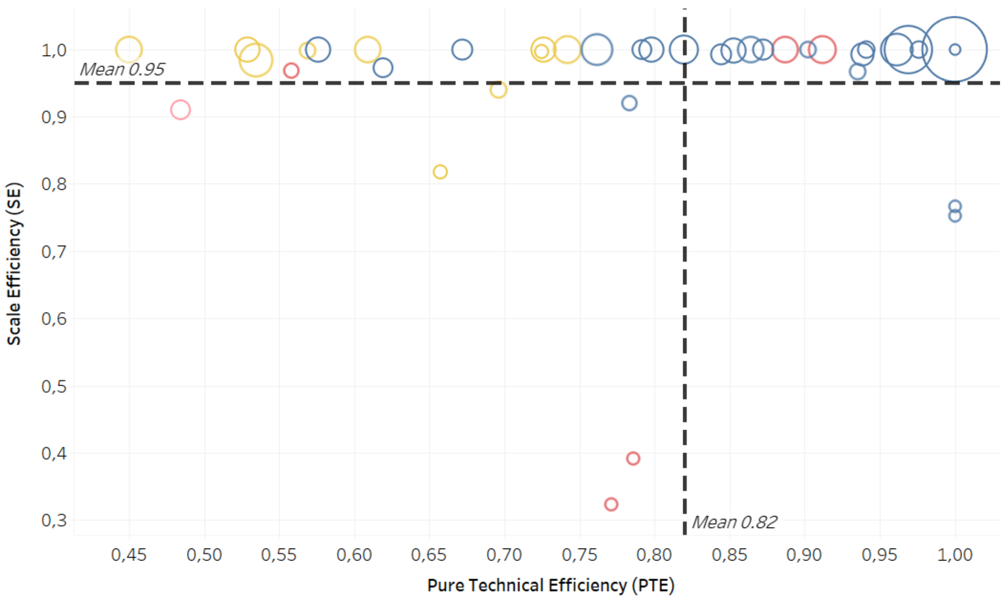

Figure 10 – The matrix reporting Pure Technical Efficiency (PTE) and Scale Efficiency (SE) for each DMU in the 'Glasses' category.

Again, as with the previous category, the highest saving potential lies in moving some DMUs from Quadrant II to Quadrant I through 'Switch or Scout' actions. Table 5 provides more details about the potential savings related to each supplier and quadrant. Globally, in the first quadrant we have 15 suppliers for an overall potential saving of € 146,005 (two thirds of the total), and these are mainly related to Supplier Delta (6 DMUs – € 46,626) and Epsilon (8 DMUs – € 94,683). As in the previous case some savings can also be obtained by working on the 'efficient' suppliers (Quadrant I – 17.8% of the total potential savings). In contrast with the previous category it should however be noted that a non-negligible amount of savings (€ 31,963, 14.5% of the total) could be obtained by switching suppliers and consolidating the volumes for the 6 DMUs in the fourth quadrant.

Supplier		Quadrant I	II	III	IV	Total No DMUs / Potential Saving (€)	%
Delta	No DMUs	6	21	2	1	30	65.2%
	Potential Saving (€)	46,626	32,293	3,270	2,852	85,041	38.6%
Epsilon	No DMUs	8	0	0	2	10	21.7%
	Potential Saving (€)	94,683	0	0	8,586	103,268	46.9%
Eta	No DMUs	1	2	0	3	6	13.0%
	Potential Saving (€)	4,697	6,845	0	20,525	32,066	14.6%
Total	No DMUs	15	23	2	6	46	100%
	Potential Saving (€)	146,005	39,137	3,270	31,963	220,376	100%
	No DMUs %	32.6%	50.0%	4.3%	13.0%		
	Potential Saving %	66.3%	17.8%	1.5%	14.5%		

Table 5: the analysis of the efficiency by supplier and efficiency quadrant for the 'Glasses' category

Finally, if we look at the average efficiency of the three suppliers (Table 6), it is evident that the company is doing most of its purchasing from the most efficient supplier (Delta – efficiency score = 0.89), but a relevant amount of money (more than € 366,000) is still spent on purchasing products from Epsilon (0.60) and Eta (0.71). The idea that emerges from these data is to switch some purchases from Epsilon to Delta, given the high gap in efficiency between the two suppliers. At the same time, however, Eta has 3 DMUs in the fourth quadrant (see Table 5) that could be moved to Delta as a single bundle in order to increase the PTE and the SE simultaneously and following what we defined as a 'Group and Switch' strategy (see Figure 6).

Supplier	Turnover (€)	Weighted Efficiency	Potential Saving (€)
Delta	777,953	0.89	85,041
Epsilon	255,835	0.60	103,268
Eta	111,229	0.71	32,066
Total	**1,145,017**	**0.81**	**220,376**

Table 6: the analysis of the efficiency by supplier and efficiency quadrant for the 'Glasses' category

5.3 The actions put in place and the results obtained by the company

As explained in the methodological section, after the discussion of the results and the definition of a suitable action plan, the managers of the company worked autonomously for six months and the researchers were not involved in the execution of the specific initiatives put in place. After this period a final meeting was held in order to discuss the practical results obtained.

In the 'Painting' category the management team had focused its attention on the first two DMUs (no. 27 and 26), which were responsible for almost one third of the total potential savings in the category. One of the two products was managed by supplier Alfa and the other one by supplier Beta. The purchasing manager asked for a quotation for the first DMU from the third supplier (Gamma) which had emerged as more efficient than both Alfa and Beta. Gamma replied that the product could not be painted in its plants unless the company could make some limited modifications to the design. If this were the case, they could apply a very high discount that would be able to provide the expected potential saving suggested by the PPA-DEA approach. At this point the director of the Technical Department became involved, and he confirmed that the requested change would not have affected the functionality or the overall aspect of the cab. After this, the technical modification was deliberated, and the supply switched to Gamma, which obtained a discount of 21% and a saving of € 53,500 on a yearly basis. With regard to the second DMU (no. 26), an analysis conducted by the managerial team revealed that it would have been impossible to change the supplier (Beta) for technical reasons. The team decided to show Beta's managers the results of the DEA-analysis - which compared the technical features of the product with other cabs presenting similar Input levels - and to explain the new purchasing strategy aimed at more involvement with the third supplier. Beta agreed to revise the price of the purchasing process even if the discount in this case was much lower than the one forecasted by the approach

(12% instead of 33%), thus generating a saving of € 19,000 on a yearly basis. The plan was to develop the same kind of analysis for the remaining cabs with a relevant saving potential.

In the 'Glasses' category the managers had focused their attention on the supplier Epsilon because of its very low average efficiency (0.6, see Table 6) and because of the high potential savings of the DMUs supplied by Epsilon and included in the first quadrant (8 DMUs and € 94,683, see Table 5). The idea was therefore to completely remove Epsilon from the supply base and to allocate the glasses bought from Epsilon to existing or new suppliers. This radical choice was only partially related to the efficiency analysis. Epsilon is a declining company, it is not well managed and in the last few years it has caused Forcab several quality or service issues. No specific formal action had been taken at the time of the last meeting, but the company had met a new Turkish supplier who they asked to provide an offer for the 8 glasses currently provided by Epsilon in the first quadrant. The offer provided by the potential new supplier would determine a saving of over € 65,000 on a yearly basis, even if some logistical costs would increase this by € 5-6,000. An alternative possibility would have been to assign the glasses currently provided by Epsilon to the most efficient supplier (Delta), but this choice would have assigned the supplier almost 90% of the total value of the glasses purchased, thus generating an excessive dependence on a single supplier.

6. Discussion

The aim of this study was to develop and test a DEA-based approach to assess the purchasing prices of 'leverage' products and services in order to derive suggestions for managerial actions. The general framework behind the approach is the requested relationship between price and value, according to the value-based pricing approach (Shipley and Jobber, 2001; Brennan et al., 2007). Its application to two supply categories of an Italian mechanical company provided several insights into the potential relevance and the critical issues of the proposed approach. Firstly, the results show the capability of PPA-DEA to provide a limited number of very clear indications that are able to support the managerial action. In the 'Paintings' category it highlighted two specific products (DMUs) responsible for a huge part of the total potential savings and clearly signaled the suppliers' Pure Technical Efficiency as the most critical problem. Moreover, it highlighted the higher efficiency of the new supplier (Gamma) compared to the two established ones (Alfa and Beta). This was therefore a clear signal for the company to switch the two most relevant DMUs from Alfa and Beta to Gamma. This switch was only partially possible for technical reasons, but the management was still able to take action to obtain relevant cumulated savings (€ 74,500 on just two DMUs). In the 'Glasses' category the main indication was the very poor efficiency of an important supplier, Epsilon. Given the high potential savings of some of the cabs painted by the supplier, the natural course of action was to switch to a new supplier, and again, the savings were very significant (around € 50,000 net of the logistical costs). This potential to provide few, 'easy-to-get' messages is a feature that the PPA-DEA approach shares with the portfolio models and KPM in particular. Despite the number of models that have tried to evolve the original (Bensaou, 1999; Gelderman and MacDonald, 2008; Lee and Drake, 2010; Padhi et al., 2012; Montgomery et al., 2018), KPM remains by far the most known and used approach to set purchasing strategies precisely because it is able to provide clear prescriptive indications (Wagner et al., 2013). Even if this 'direct' and prescriptive approach has been criticized for being too subjective (Homburg, 1995; Knight et al., 2014; Mohammed et al., 2011) and simplistic (Dubois and Pedersen, 2002), it is appreciated by purchasing managers for these very reasons.

If we look at the multilevel approach to strategy development reported in Figure 1, the PPA-DEA aims to play for 'leverage' items at levels 4 and 5 (tactics at the category and supplier level), which is the same role played by the KPM at level 3 (strategy at the portfolio level). The target is to provide a clear image of the main cost drivers and some prescriptive indications to support the managerial action. Furthermore, a second relevant point emerged from the case study and this is the limited amount of time needed to perform the analysis. If we look at Table 1, it can be seen that the whole process of selecting the categories, Inputs/Outputs as well as running and discussing the results required fewer than 280 labor hours. Moreover, once set up, the approach can be replicated with very limited need for time and/or resources because the most important part of the work (identifying the Inputs and Outputs of each category) only has to be done once. This is a relevant feature of PPA-DEA when compared with previous approaches developed for 'leverage' items (Razmi and Keramati, 2011), which are complex mathematical optimization models.

Moreover, the PPA-DEA approach is also very flexible as it is applicable to several steps in the relationship with suppliers (see Figure 11). Indeed, it could be applied either during the evaluation and selection phases in order to have a quick appraisal of suppliers' offers, or during the development of the relationship to provide continuous feedback on the competitiveness of the supplier's prices. Finally, it could also clearly be used in an ongoing manner to monitor the suppliers' performance.

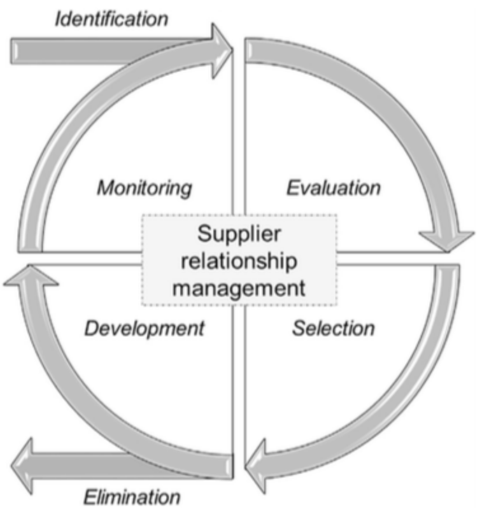

Figure 11 – The supplier relationship management process. Source: Glock et al., 2016.

On the other hand, the concrete application of the approach highlighted several critical issues that must be understood and managed. The first one deals with the identification of the Outputs and the homogeneity of the items included in every category. Even for very basic supply categories such as the ones involved in the analysis, the discussion on the proper Outputs to include in the analysis was very animated. Moreover, for the glasses we only later realized that mixing the 6-millimeter thickness glasses with the others would have been a mistake that could have jeopardized the whole meaning of the analysis. Given the DEA needs a minimum number of DMUs to guarantee an acceptable level of effectiveness, it could happen that non-homogeneous items are included in the reference set in order to increase the number of DMUs, and this could negatively affect the reliability of the results of the whole process. Furthermore, in this scenario the Super Efficiency analysis could only partially manage this issue. The second critical point is the availability of reliable data on all the Inputs and Outputs. In Forcab a recent and well-developed ERP system was available, and the management was very helpful in integrating the data with ad hoc research. This played an incredibly important role in supporting the robustness of the approach. Finally, the commitment and the organizational background of the managers involved in the approach are crucial for its efficacy. During the different steps in the analysis the managers of Forcab were a great asset to the whole process because of their experience and knowledge, and above all because of their enthusiasm for this innovative project. They were all young, well educated people and they were very interested in developing their competencies. They asked for references for DEA and became well versed in and able to use the DEA software autonomously. The last two factors (reliable data and committed people) are not so common - at least in SMEs - and this could constitute a severe constraint for the diffusion of the approach.

7. Conclusions

This study contributes both to the existing literature on purchasing portfolios as well as to the literature on DEA applied to Supply Chain Management. It contributes to the former by providing a technical approach to managing 'leverage items' and to the latter because it is the first study to use DEA to assess purchasing prices of 'leverage' items according to value-based pricing theory. Furthermore, this contribution to the literature is provided by developing a three-step DEA-based approach (PPA-DEA approach), and the results obtained show the potential capability of the approach to provide clear managerial insights in a parsimonious way. Both the DMUs and the suppliers may be ranked according to the DEA scores, and a potential saving at DMU and/or supplier level may be calculated. Indeed, clear managerial suggestions can therefore be derived from the approach. In the company analysed, simply by working on two supply categories the total savings potentially obtained with a 6-month action plan amounted to €

122,000 (€ 62,500 from the 'Painting' category and € 59,500 from the 'Glasses' category). This is an impressive result given the low profitability of the company (only € 500,000 of EBIT before the intervention).

This study does however include some limitations, which in turn offer opportunities for future research. First of all, the PPA-DEA approach has been tested in a single case study (two different supply categories), and therefore the generalizability of the results is limited. Further applications to different industries, companies and supply categories are thus required to better understand its potential in different contingencies. Secondly, the managers in the company selected to test the PPA-DEA approach were very cooperative and committed to the research since the perceived value of the final outcome was high. In a context or contexts where such commitment is not so forthcoming more issues may arise. Thirdly, PPA-DEA is only able to take into consideration the current suppliers of a company, while more efficient suppliers could exist outside the actual supply list. This is a common issue with DEA approaches applied to SCM management (Visani et al., 2016) because they define the efficiency frontiers on the basis of the past and known performances of the actual suppliers.

The research also opens several research avenues. The PPA-DEA approach could be used not only to assess an existing price or offer from the supplier, but also to forecast the efficient price of a new product or service purchased. Once the Output levels of a new item are known, it is possible to run the system 'backwards' in order to work out the efficient price. This would be useful for companies that need to provide a customer with a quotation for a new product before obtaining the quotation for the components from the supplier. Moreover, by adding further information about the service level, quality, reliability, and the financial strength of the supplier to the Output vector, the approach could also be applied to strategic purchasing relationships in order to test its capability to manage more complex relationships.

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