

# Measuring the Quality of Performance in the CNR Public Research Institutes: a Comparison of Methods

La Qualità della Performance negli Istituti di Ricerca Pubblica CNR: un  
Confronto tra Metodi

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**Riassunto:** Il lavoro propone il confronto tra due metodi, l'Analisi delle Componenti Principali (ACP) e la Data Envelopment Analysis (DEA) utilizzati per misurare la performance di 108 istituti del CNR<sup>1</sup>. I risultati ottenuti con i due metodi mettono in evidenza diversi punti critici legati sia ai metodi in sé che alla teoria necessaria all'analisi di quel "particolare" processo produttivo, che è la produzione scientifica.

**Keywords:** ACP, DEA, Efficiency, Quality of Research Production Process.

## 1. Introduction

Nowadays, Public Research plays a fundamental role in the production and diffusion of inventions and innovations in a society based on knowledge. The scientific production process can be considered as a particular one, producing scientific research (patents, publications, ect) as product, which user is society as a whole.

Smith gave the following definition: "quality is the goodness or excellence of *any* product, process, structure or other thing that an organization consists of or creates." (Smith, 1993, p.241).

And according to Zanella, Smith's "definition is in agreement with different aspects of Quality: *real* and *virtual quality*, (measured through customer satisfaction), *product/service's quality* depending on its intrinsic performance and physical characteristics as well as on producer's system, *quality* extended to results of operations pertaining to structures, functional areas, organizational aspects of a production system. Special attention is paid to relationship between quality and economic factors [...]. Total Quality Management aims to a global cultural change within the system producing goods or services" (1995). In fact, TQM is oriented to Results, Processes, Quality System and thus to customer satisfaction, efficiency and continuous improvements.

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<sup>1</sup> The dataset was kindly offered by Dott. Mario Coccia, (CERIS- CNR of Turin) that we would like to thank for his kindness and availability.

On this basis, we suppose that quantitative methods (for example ACP and DEA) can be applied to measure quality of the (scientific) production process in the CNR public research institutes, through the measurement of their performance and efficiency.

## 2. A Comparison between ACP and DEA Models

The literature regarding the performance and efficiency of public research institutions is scarce. In fact, the definition of inputs and outputs is generally troublesome in the public sector, because of the lack of prices, especially for outputs. Moreover, labour costs are often available meanwhile data on material capital in nominal values are generally unavailable.

However, in the specific field of the Italian CNR Institutes, Coccia (2005) proposed some definitions of inputs and outputs. The Italian CNR Institutes' main activity is the scientific research, and only occasionally the external teaching. Thus, outputs are scientific articles, books, technical reports, software, patents and so on; meanwhile inputs are human resources, equipment, libraries and sources of financing. According to the *systemic approach*, research bodies are systems producing goods and services with its own inputs, scientific production process and outputs.

We shared Coccia's idea about the *systemic approach* and partially the definitions of inputs and outputs, in order to perform a DEA analysis on the same CNR dataset.

The dataset contains information about 108 institutes of the CNR of Italy, used to draw up the 2003 CNR report.

In particular, Coccia performed an ACP (Analysis of Principal Components) by the following inputs and outputs:

Inputs (number of personnel, cost of personnel), Outputs (public financing, self-financing, n° of personnel in training, n° of courses held by researchers, n° of national and international publications, n° of national and international presentations at conferences). Applying the ACP method on the standardised variables, three principal components have been identified with cumulative variance of 77,29%. The first component (with 47,09% of variance) is strongly related to the cost of personnel ( $r=0,95$ ) and research personnel ( $r=0,95$ ), public funds ( $r=0,77$ ), international publications ( $r=0,70$ ). The second and the third component explain a small percentage of variance, 18,17% and 12,03% respectively. By the three components, the cluster analysis of the 108 CNR institutes shapes two clusters: an A cluster (78 smaller size and lower performances institutes) and a B cluster (30 bigger size and higher productive institutes). According the standard classification of research fields, the institutes are classified into: Basic Sciences, Life Sciences, Engineering Sciences, Earth Sciences, Human and Social Sciences. The ACP findings highlight that the best performers (higher productivity and bigger size) institutes belong to Basic Sciences, followed respectively by Life, Engineering, Earth Sciences, while no institute belongs to the Human and Social Sciences (see Tables 1 and 2).

In order to pursue our aim, we relate the concept of quality to the production process of the CNR institutes and we measure the quality of institutes' performances by DEA (Data Envelopment Analysis). Indeed, we make the hypothesis that each institute has a sort of production process, oriented to produce research. As known, DEA (Charnes et al.1978) was primarily used to measure the efficiency of similar but autonomous Decision Making Units (DMU), i.e. any multi-inputs/outputs firm in the private sector. Efficiency can be measured fairly easily if there is only one input and one output, but when there are multiple inputs and/or multiple outputs, weights must be

assigned to each input and each output. DEA gets around this problem and, checking on each DMU separately, determines (by linear programming technique) whether or not there is some combination of all other DMUs in the system that can achieve the output of the  $j$ -th unit with fewer inputs. As DEA does not require either the specification of the production function or input/output prices in order to determine the technical efficiency, it has become especially popular in the analyses relating to public sector. The efficiency score of a DMU is defined as the ratio of the weighted sum of its outputs to the weighted sum of its inputs. The weights are generated by DEA model itself. The efficient frontier is made up of a piecewise linear combination of the efficient units. More generally, if we consider a set of  $n$  DMU consuming  $m$  inputs and producing  $s$  outputs, the efficiency of, say, DMU  $a$ , is measured by solving:

$$\text{Max } h_a = (\sum_r u_r y_{ra} / \sum_i v_i x_{ia})$$

subject to:

$$\sum_r u_r y_{rj} / \sum_i v_i x_{ij} \leq 1, \quad j=1, \dots, n; \quad r=1, \dots, s; \quad i=1, \dots, m \quad u_r, v_i > 0$$

where  $u_r$ ,  $v_i$  are the output and input weights;  $y_{rj}$  and  $x_{ij}$  are the amounts of the  $r$ th output produced and  $i$ th input consumed by unit  $j$ . The solution gives, for each DMU the relative efficiency score ( $E=100$  max efficiency and  $E < 100$  inefficiency).

According to the standard theoretical background (Hoenack & Collins 1990, Rizzi 2001), we performed DEA with the hypothesis of CRS (constant returns of scale) on the same CNR dataset by different models: Model 1 (same Coccia's inputs and outputs); Model 2 (Inputs: number and cost of personnel, public and self-financing; Outputs: n° of personnel in training, n° of courses held by researchers, n° of national and international publications, n° of national and international presentations at conferences); Model 3 (Inputs: number and cost of personnel, public financing; Outputs: self-financing plus the same outputs of Model 2). Model 4 (Inputs: number of personnel, public financing; Outputs: same outputs of Model 3) is an own model.

### 3. A Comparison of the empirical findings

As shown in Table 1 and 2, DEA results are strongly different from ACP ones, especially regarding the Human area, which is not quoted among the best performers by ACP. The only similarity emerges in the Earth area, while a relevant difference lies on the Basic area. The most interesting result is the performance of human institutes, which, according to DEA, produce efficiently in spite of their low inputs (personnel and public financing). It is worth to note the different DEA Models results. On one hand, the choice of more inputs leads to an increase of number of efficient institutes. On the other hand, the use of different inputs leads to an increase of efficient institutes in the Basic and Engineering areas (see Model 2 versus Model 3 and 4). In table 2, we compared the lower performers institutes from ACP and DEA (the arbitrary chosen threshold is an efficiency score  $< 75\%$ ). In spite of different inputs used by the four DEA models, the percentage of inefficient institutes is quite the same for Basic and Life areas. As well as for the best performers, the main difference between the two methods lies on Basic and Human areas. Another feature of this classification is the similarity of the percentage of the lower performers in Life and Earth areas according

to both methods. Summarising, we compared the findings from ACP model and from different DEA Models: an our model (Model 4) and some of them designed according to the literature. The ACP findings highlight the primary role of the component 1, which contains both the research personnel and the cost of personnel: variables that we think as alternative in our model (Model 4). On the other hand, DEA let us to compare each DMU to the other ones, (i.e. a relative comparison). This is probably the main reason of the differences between ACP and DEA results, especially regarding the presence of efficient institutes in the Human Sciences area. In fact, the Human Sciences institutes with a low amount of public funds produce as efficiently as those institutes using an high amount of public funds.

**Table 1:** Percentage of the best performers CNR Institutes per area (Effic. score =100%)

|             | BASIC Sc. | LIFE Sc. | EARTH Sc. | HUMAN Sc. | ENGIN Sc. | Total |
|-------------|-----------|----------|-----------|-----------|-----------|-------|
| ACP         | 53,3%     | 20%      | 10%       | 0%        | 16,7%     | 100%  |
| DEA Model 1 | 22,2%     | 27,8%    | 11,1%     | 16,7%     | 22,2%     | 100%  |
| DEA Model 2 | 19%       | 19%      | 8%        | 39%       | 15%       | 100%  |
| DEA Model 3 | 27,3%     | 18,2%    | 9%        | 27,3%     | 18,2%     | 100%  |
| DEA Model 4 | 25%       | 20%      | 5%        | 30%       | 20%       | 100%  |

**Table 2:** Percentage of the lower performers CNR Institutes per area (Effic. score < 75%)

|             | BASIC Sc. | LIFE Sc. | EARTH Sc. | HUMAN Sc. | ENGIN Sc. | Total |
|-------------|-----------|----------|-----------|-----------|-----------|-------|
| ACP         | 15,38%    | 34,62%   | 8,97%     | 24,36%    | 16,67%    | 100%  |
| DEA Model 1 | 30,9%     | 32,3%    | 7,4%      | 14,7%     | 14,7%     | 100%  |
| DEA Model 2 | 31%       | 31%      | 11%       | 8%        | 19%       | 100%  |
| DEA Model 3 | 31,9%     | 31,9%    | 6%        | 15,1%     | 15,1%     | 100%  |
| DEA Model 4 | 29,9%     | 31,3%    | 9%        | 14,9%     | 14,9%     | 100%  |

## References

- Charnes A., Cooper W., Rhodes E. (1978) Measuring the Efficiency of Decision Making Units, *European Journal of Operational Research*, 2, 429-444.
- Coccia M. (2005) A Taxonomy of Public Research bodies: a systematic approach, *Prometheus*, 23, 63-82.
- Hoenack S., Collins E. (1990) *The Economics of American Universities*, State University of New York Press.
- Rizzi D. (2001) L'efficienza dei dipartimenti dell'Università Ca' Foscari di Venezia via DEA e DFA, *Economia Pubblica*, 3, 103-136.
- Smith G.F. (1993) The meaning of quality, *Total Quality Management*, 3, 235-244.
- Zanella A. (1995) Total Quality Management and the Role of Statistics, *Total Quality Management: Proceedings of the First World Congress*, Chapman, 137-146.