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Evaluating the Efficiency of Human Capital formation in the Italian University: Evidence from Florence

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Abstract

The purpose of this paper is to apply a generalized version of the Farrell measure of technical efficiency to estimate *output-efficiency* of the human capital formation in the University of Florence through the utilization of the Data Envelopment Analysis (DEA) on a selected set of *inputs* and *outputs*. We use the Program Evaluation procedure as well, in an attempt of sharing the variation in efficiency to factors that are out of the control and to factors that are under the control of the graduates.

Keywords: *Data Envelopment Analysis (DEA), input, output, technical efficiency, frontier, Decision Making Units (DMU), output-efficiency, bad output, Program Evaluation.*

1 Introduction

Over the last 15-20 years, significant changes have occurred in the Italian Public Administration (PA), where, in order to improve the management and the overall activity, the concepts of efficiency, effectiveness and quality of the public services have been introduced and made operational.

The Italian university system is a part of the PA and recently it has been involved in an overall reform, which is now becoming effective.

This reform, besides introducing organisational, financial and economic statutory autonomy, will be completed by empowering the university system itself to manage its own curricula according to the general criteria established by the Ministry of University and Scientific and Technological Research (MIUR).

It aims at achieving a number of results: the reduction in drop-out rates, the increase in the number of graduates, the improvement in conditions and work opportunities for young people with a degree are among the most relevant.

In other words, the above reform tries to increase the efficiency and the effectiveness of the university system as well as the quality of graduates.

In fact, it is somewhat commonly believed that the Italian university system is not as efficient and effective as it would be and that the quality of the graduates is in some cases unduly poor.

Therefore, it is important to analyse the present situation, in order to be able to better know the actual condition of studies, both as such and for the sake of comparing it to the one which will be obtained after the above reform will have produced its first effects.

As there is a number of commitments the university should fulfil, both from the academic and from the scientific points of view - ranging from the increase of the overall national knowledge to the formation of skilled workers and to the promotion and improvement of the scientific research - in this paper we will focus on efficiency only, i. e., on the way in which the graduates are "produced" and will refer to the specific situation of the University of Florence.

The paper is organized as follows. In section 2, the process of production of a graduate, or, in other words, of production of human capital, will be discussed and modelled. In section 3, the concept of Data Envelopment Analysis (DEA) in the university system is outlined. In section 4, the data used in this paper is discussed. In section 5, the results from the efficiency estimation and from the Program Evaluation (PE) are presented. In section 6, some observations and concluding remarks are given.

2 The process of production of the human capital in the university system

The formation of a graduate in the university is a very complex process, as it involves cultural and intellectual elements, like lectures, tutorials, discussion, seminars as well as material and non-material goods, like libraries, class rooms, computers and services of assistance to students, secretary offices, tutorship.

All this activity is carried out with the aim of forming graduates.

As such, it can be viewed as a process of production in which a young man who enters the university with a given cultural and knowledge background and a set of educational training is transformed, after a given number of years during which he is submitted to a "cultural transformation" process, into a young man with a higher level of educational training.

In other words, the university, through the training it delivers, transforms a cultural "raw" material into a cultural "refined" material (output), through the application on it of a certain number of inputs, such as teachers, textbooks, class-rooms, etc. The student himself who is submitted to the cultural transformation process can be viewed as an input.

Therefore, the analysis of such a transformation process can be performed in the neoclassical analysis of production framework.

Nevertheless, it is evident that the process which ends up by forming a graduate is a process of production of a very peculiar kind, which is beyond the traditional schemes of the neoclassical approach, proposed and elaborated for the analysis of the "classical" productive processes, that is, those processes in which a set of material and/or non-material inputs are transformed into one or more material and/or non-material outputs.

Here first of all, besides the factors of production of the "traditional" kind – e. g., the human and financial resources, the structures and the organisation of the institutions set up to carry out the necessary services - there is the raw material represented by the students who come from the high school: they differ from each others as far as sex, age, school leaving certificates and above all, individual psychological, human, household characteristics are concerned.

Indeed, the latter is the very peculiar feature which characterises this productive process: out of the set of inputs, there is one which, far from being always the same, takes specific characteristics in each realisation of the productive process.

Moreover, the student is not "passive", but actively participates in the process and affects the results.

The final output too is not a conventional one, as it is represented by a graduate with a given amount of knowledge, what is difficult to evaluate and measure.

Furthermore, in neoclassical approach it is implicitly postulated that the production process is not affected by the "external" conditions represented by the characteristics of the area where the process takes place. Of course, it is affected by external infra-structures like roads, ports, means of transportation, etc. of the area, but the output will only depend on the specific conditions of the process.

On the contrary, the result of the educational process is heavily affected by conditions other than the intrinsic ones, like the activity of research carried out and the general living and studying atmosphere in the university, as well as the socio-economic context of the area in which the university is situated.

As a consequence, the above condition that the process is carried out in an isolated way is violated.

Additional difficulties are raised by the fact that some factors cannot be observed and quantified. Consequently, they cannot be inserted as inputs in the process.

Thus, one is facing a production process in which it is hard to identify, quantify and measure all the inputs as well as to define and measure the output.

Nevertheless, it is possible, as we shall show below, to identify a reasonable set of inputs through which to produce a graduate.

In the neoclassical approach to production, there is the need for precisely identifying the unit of production which, by using a given set of inputs, obtains a given set of outputs.

The efficiency of the process is measured by referring to a group of units which produce the same outputs by using the same inputs in the same productive conditions and by using the same technology.

This set is usually defined as a production set in which the production units are represented geometrically in a input-output space where every point is a production unit.

Through the comparison of the production units, one gets a measure of the efficiency, which, as it is well known, can be absolute or relative. The measure that is used since long time is that of relative efficiency or, the frontier efficiency.

In this paper we are interested in the measurement of the frontier efficiency of the university process of production in Italy. Then, our problem is to identify the production unit which, by using the above mentioned inputs, does produce a graduate that could be compared to other production units which carry out the same activity.

One way of proceeding would be to consider the faculty as the production unit, as it seems reasonable at all to think of a faculty that, by using inputs like teachers, class-rooms, libraries etc., is able to produce graduates. But, since we had to restrict the analysis to the University of Florence only in order to eliminate as much as possible the influence of environmental factors, and since the faculties of the University of Florence account for eleven, the production space would be too reduced to obtain significant results.

In order to increase the number of units in the production space, the degree courses could be considered as production units, whose number is rather higher than that of faculties, accounting for about 40. Unfortunately, the degrees courses reveal many problems and inconsistencies, mainly due to the strong heterogeneity, even stronger than that of the faculties, that characterises them.

To solve the problem of modelling the above very peculiar and unusual production process and of identifying the most proper production unit, we started from an interesting proposal by Catalano - Silvestri (1992) who represent the production process of the university education like one in which the university institutions supply services used by the students to carry out production activity. In other words, the student is regarded as a production unit, as if he was an entrepreneur in the business world.

We have extended this representation to the case in which a production unit produces itself. Indeed, this is a very particular representation, as in the neoclassical theory of production framework there is no example of such a production process.

In the case of university education, where the student is at the same time input, leading part and beneficiary of the production activity, it seems reasonable to picture such a representation and to consider the student as a production unit who, by using didactic resources and equipment offered by the faculties he/she attends as inputs, produces him/herself as a graduate.

Thus we have modelled the production space as an input-output one where the points are represented by students.

This means that the production process rotates around the student, who becomes an atypical production unit, as he is not an enterprise which is organised and structured for the production activity. The process itself is a peculiar one, as it is if, to refer to the standard process modelled in the neoclassical theory framework, a production unit, instead of producing whatever an output, did selfproduce itself. Nevertheless, in the activity of production of knowledge undertaken in the university system, this is a reasonable and sustainable modelling, as it allows to catch the peculiar characteristics of the process and to describe the intrinsic meaning of the university training activity, while fulfilling all the basic conditions of the neoclassical theory.

Of course, there are some questions that should be taken into account. The most relevant one is the identification of the output of the process, which no longer can be represented by the "number of graduates", as it was if we had taken as production unit the faculties or the degree courses. Now, the outputs do not appear as much clear and easy to be identified, both because many of them are of a qualitative type, and because of the characteristics themselves of the process which make it more difficult to identify them: they might be variables which characterises the graduate, like for instance, the final score, the average score of his university career and the like.

There is, here, a difficulty in the interpretation of the outlet of the process, as there is a mixture of efficiency and effectiveness inborn into the process itself, difficult to be disentangled. In fact, the graduate can be confused with the graduate who finds a job, so that one can take as the output the graduate who found a job – what may be viewed as the final step of the process – case in which, however, the efficiency, i. e., the way in which the graduate has been produced, mixes with the effectiveness, i. e., whether the graduate has found a job[1].

Moreover, it is not always easy to select the inputs of the process, not only due to the qualitative nature of some of them, but also because of the complexity and peculiarity of the process.

Since the students who produce themselves as graduates are carrying out their production activity inside the university and since the Italian university is mostly public (roughly more than 90% of universities are public), we put our analysis in the technical approach framework, thereby considering the students as public enterprises.

Public enterprises, unlike the private ones which have the only objective of profit maximization, pursue a multiplicity of goals which are both difficult to quantify and, in part, inconsistent each other. Technical efficiency constitutes the only objective that can be attained without prejudicing the others (Pestieau-Tulkens, 1990). Consequently, the analysis will be conducted in the technical frontier efficiency framework.

Among the possible approaches to construct technical production frontiers, Data Envelopment Analysis (DEA), as a non parametric approach, has several features that make it very appealing.

In contrast with the parametric approach which claims for a specific functional form, DEA calculates a maximal performance measure for each production unit (or from now on "Decision Making Unit" (DMU)) relative to all

[1] It may happen that a graduate produced with the maximum of efficiency does not find a placing in the labour market and, vice versa, that a graduate produced much less efficiently finds a job and a good salary. This will hardly depend upon the labour market conditions and on the demand for specific types of graduates.

the other DMUs in the observed population with the sole requirement that each DMU lies on or below the frontier.

For the efficiency to be evaluated in the DEA framework, it is enough to choose suitable inputs and outputs and to make some assumptions about the technological structure concerning convexity, disposability and returns to scale.

The flexibility of the method makes it possible to model a production process incorporating the specific characteristics associated with education discussed above.

3 DEA frontier efficiency in the university system

The utilization of the DEA approach for the measurement of frontier efficiency has received a great deal of attention since the introduction of the concept of non-parametric approach.

Suggested first in 1978 by Charnes-Cooper-Rhodes, DEA has proved itself a powerful tool for the measurement of frontier efficiency, as it is particularly suitable in cases where the non-parametric approach is needed, like in engineering problems, or allowed, like in cases where the analysis can be conducted without taking account of prices.

In the university production of graduates, DEA has been used by Breu - Raab (1994), who have measured the relative efficiency of the "best" 25 U.S. News and World Report-ranked universities from available "performance indicators". They selected five performance indicators as input and two student satisfaction-performance indicators as output for each of the 25 universities considered in the analysis and applied an output oriented DEA model with constant returns to scale. DEA has been used by them only to obtain an efficiency "student satisfaction" ranking to be compared to the U.S. News quality rankings of the best universities.

Beasley (1990, 1995) has used DEA to compare university departments efficiency in the United Kingdom. He considered the theoretical inputs and outputs for a university department production as opposed to those actually available. Thus, he specified, for each department, three input measures and eight output measures. He improved the basic DEA model by adding some contrasts on the input/output weights to better represent the relative importance of input/output measures. In addition, he developed a DEA based model for the simultaneous determination of the teaching and research efficiencies of university departments.

Sarrico–Hogan–Dyson–Athanassopoulos (1997) used DEA as a performance measurement tool for university selection, by considering the perspective of the applicant or potential student who is in the process of choosing a university. First, they categorised each factor/performance indicator as either input or output, and then converted the applicants' priorities into restrictions on the weights of each factor. Basically, DEA proved to be a useful technique for the aggregation of a indistinct mass of information.

None of the above papers dealt with the frontier efficiency of the university education system.

In this case, DEA methodology can be used to model the complex interaction existing among the different factors that are involved in university education production process, as discussed in paragraph 2.

To this aim, one must search for a flexible tool in the non-parametric frontier literature that allows to properly measure the technical efficiency of the graduates and that at the same time allows the characteristics of the education process to emerge during the analysis.

It must be stressed that in the university system production process, an increase in the usage of a proper subset of inputs, keeping constant the usage of all the remaining inputs, may result in a reduction of the output. This situation has been defined by Färe-Grosskopf- Lovell (1983) as "congestion". For instance, a possible source of congestion could be the actual length of study time that we consider as an input in our model. In fact, a preliminary analysis of the available database has shown that as the study time increases, the average grade of the final exams decreases (the correlation coefficient is significant and equal to -0.2). It is reasonable to presume that the student loses motivation if the length of study time exceeds its normal term by more than one or two years.

Congestion can be modelled and measured by assuming weak disposability of inputs (Byrnes-Färe-Grosskopf, 1988), which states that if all inputs are increased proportionally, output does not decrease[2], in a production space where the technology exhibits constant returns to scale.

A measure of congestion can be computed by taking the ratio between two Farrell measures of efficiency[3], the first one obtained by assuming strong disposability of input and the second one calculated by assuming weak disposability of input, as Färe-Grosskopf-Lovell (1994) suggested. This measure evaluates lost output because of a lack of strong disposability of input.

The actual length of study time could be considered as a "bad output"[4], as an alternative of defining it as an input, which in turn implies to model the production space according to the technology satisfying constant returns to scale and weak disposability of inputs.

The "bad output" is undesirable and therefore its quantity should be minimised instead of being maximised. Indeed, the classical theory hypothesis that inputs have to be minimized and outputs have to be maximized can be released and one can model a the process in which an output has to be minimized.

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[2] Formally, a technology exhibits weak disposability, if $\mathbf{x} \in L(y)$ then $\lambda\mathbf{x} \in L(y)$, $\lambda \geq 1$, where $L(\mathbf{y})$, the input requirement set, denotes all input vectors yielding at least output rate y and let $\mathbf{x} \in R^{s}_{+}$ be an input vector. Conversely, according to Farrell (1957), a technology is strongly disposable (free disposal of inputs: when any input increases, output does not decrease), if $\mathbf{x} \geq \mathbf{u} \in L(\mathbf{y}) \rightarrow \mathbf{x} \in L(y)$.

[3] The Farrell measure of technical efficiency is defined as one minus the maximum equiproportionate reduction in all inputs that still allows continued production of given outputs. A score of unity indicates technical efficiency because no equiproportionate reduction is feasible, and a score less than unity indicates the severity of technical inefficiency. The conversion of the Farrell measure to equiproportionate output expansion with given inputs is straightforward.

[4] Koopmans (1951) already mentioned that the production process may also generate undesirable or bad outputs, like smoke pollution or waste. Of course, undesirable outputs may also appear in non-ecological applications like health care, as complications of medical operations (Smith 1990).

Indeed, it is reasonable at all to assume that the student who produces himself/herself as a graduate wants to finish his/her university studies and get his/her degree in the institutional time established for the course program he/she attends. On the other hands – according to the organization of university study in Italy – the actual length of study time often exceeds the institutional one.

Thus, the output of the process which produces the graduate can be identified though two variables. The first one is the average grade of the exams that the graduate had to overcome during his university career.

Among the many approaches proposed in literature for inserting undesirable outputs in DEA, we have selected the indirect approach[5], which transforms the bad outputs values by a monotone decreasing function *f* such that the transformed data can be included as "good" or desirable outputs in the production set[6]. So, after re-transformation, any increasing in these values must be viewed as a decreasing in the undesirable outputs.

In order to make the transformed data significant, let's incorporate in the model the actual length of study time *U* by means of the transformation known as multiplicative inverse (Lovell et al. 1995, Athanassopoulos-Thanassoulis, 1995) expressed by $f(U)=-1/U$[7]

It must be underlined that when measuring the technical efficiency of the graduates according to a technology satisfying constant return to scale and weak disposability of inputs, an excessive number of units would be defined as Farrell efficient[8].

Therefore, in order to evaluate the efficiency of the education process at the University of Florence, we have selected a constant return to scale and strong

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[5] On the contrary, the direct approach uses the original data but modifies the assumptions on the production technology in order to treat the undesirable outputs appropriately. In particular, the direct approach, suggested by Färe et al. (1989), replaces strong disposability of outputs by the assumption that outputs are weakly disposable while only the sub- vector of desirable outputs is strongly disposable. Recall that outputs are strongly disposable if $(\mathbf{x}, \mathbf{y}) \in P$ implies that $(\mathbf{x}, \mathbf{y}') \in P$, $\forall \mathbf{y}' \leq \mathbf{y}$ and weakly disposable if $(\mathbf{x}, \mathbf{y}) \in P$ implies that $(\mathbf{x}, \pi\mathbf{y}) \in P$ for $0 \leq \pi \leq 1$.

[6] The production possibility set or technology set, denoted by P, is the set of feasible activities. It can in general be written:

$$P = \{(\boldsymbol{x}, \boldsymbol{y}) \mid \boldsymbol{y} \text{ can be produced by } \boldsymbol{x}\}$$

where **y** is the vector of *m* outputs ad **x** a vector of *s* inputs.

[7] We could also insert the actual length of study time *U* as a desirable output by using the additive inverse, suggested by Koopmans (1951) and applied by Berg et al. (1992), where $f(U) = -U$, so to generate the same technology as by inserting undesirable outputs as inputs. It should be noted that in the university education production process the direct approach cannot be used as the assumption that characterizes the direct approach, i.e. that it is impossible to reduce undesirable outputs without at the same time reducing desirable outputs time cannot be satisfied. In fact, the student can increase the average grade of exams and decrease the time of study at the same time.

[8] In the efficiency estimation assuming weak disposability of input and considering 10 input and 1 output about 70% of the graduates would be defined as efficient. Probably, this is because with many input and output dimensions a unit may have a number of inputs and/or outputs that differ from other units and we might not find another unit to compare it with. Such a unit will be defined as efficient (but with no other references than itself) not necessarily because it is better than another, but because it is different. A possible solution to this problem would be the use of super-efficiency model (Andersen and Petersen, 1993) for ranking efficient units.

disposability of inputs model. In so doing, we can introduce both many more inputs in the model than in the previous case and consider the real time of study as a bad output.

Furthermore, since some inputs are not under direct control of the individual graduate, we have chosen an output oriented model.

Thus, in short, the student by using human resources (professors and researchers), capital resources (lecture halls, university furniture and equipment, books and journals from the library) and individual inputs (the final high-school mark that reflects the knowledge acquired in high schools), produces him/herself as a graduate after a certain number of years with an average grade of exams.

Let x_{ik} and y_{jk} denote respectively the levels of the *i*th input used and of the *j*th output yielded by the graduate *k*. Hence, introducing a set of *n* graduates, characterized by the pair of vectors (**x**, **y**), the technology set *P* that satisfies constant return to scale[9] is estimated as a piecewise linear set by:

$$P = \left\{ (\boldsymbol{x}, \boldsymbol{y}) \middle| x_{ik} \geq \sum_{\mathrm{j}=1}^{\mathrm{n}} \lambda_{\mathrm{j}} x_{ij} \; (i = 1,..,s) \;\; y_{rk} \leq \sum_{\mathrm{j}=1}^{\mathrm{n}} \lambda_{\mathrm{j}} y_{rj} \, (r = 1,..,m), \lambda_j \geq 0 \; (j = 1,...,n) \right\} \quad [1]$$

where λ_j is the weight of observation *j* when defining the reference point on the frontier[10].

The estimation of the output efficiency measure of each graduate is a linear programming problem with *m+s* constraints which can be solved for each production unit in a standard way[11]. Formally[12]:

$$\begin{aligned} & \max \phi_k \\ & \text{s.t.} \\ & x_{ik} \geq \sum_{\mathrm{j}=1}^{\mathrm{n}} \mu_{\mathrm{j}} x_{ij} && i = 1,...,s \\ & \phi_k y_{rk} \leq \sum_{\mathrm{j}=1}^{\mathrm{n}} \mu_{\mathrm{j}} y_{rj} && r = 1,...,m \\ & \mu_j \geq 0 && j = 1,...,n \end{aligned} \quad [2]$$

9 Constant returns to scale means that the set P that satisfies the restrictions of the technology forms a cone: if (**x**, **y**) belongs to the technology, then so does (η**x**, η**y**), if η≥0. So, equi-proportionate contractions and expansions of feasible (**x**, **y**) remain feasible.

10 It is assumed that the envelopment surface or frontier of the data is done as tight as possible, that is minimum extrapolation and inclusion of all observations is assumed.

11 To compute the output efficiency measure, we have used AMPL, A Modelling Language for Mathematical programming.

12 Essentially, the DEA problem in equation [2] takes the *k-th* DMU and then seeks to radially expand the output vector, $\boldsymbol{y}_k$, as much as possible, still remaining within the feasible set *P*. The radial expansion of the output vector produces a projected point, *(λ**x**, λ**y**)*, on the surface of this technology. This projected point, called *reference point*, is a linear combination of the observed data points. The efficient units, when calculating the efficiency score for an inefficient unit, are termed referencing units, or *peers*.

where $\phi \geq 1$, and ϕ_k^*-1 is the proportional increase in outputs that could be achieved by the graduate *k*th keeping inputs fixed. The Farrell output oriented technical efficiency measure for graduate *k* is defined as $\theta^*_k=1/\phi^*_k$. Therefore, the graduate *k*th is efficient if $\theta_k=1$ and inefficient otherwise.

However, it should be noted that the Farrell measure is not equivalent to the Koopmans' definition of technical efficiency[13]. Consequently, a production unit is fully technical efficient if $\theta^*_k=1$ and all slacks[14], i.e. the input excesses and the output shortfalls, are zero.

The comparison of graduates' efficiency can be misleading, as efficiency may be due to the different equipment and mix of subjects present in the different faculties.

Since the capability of distinguishing between individual and programme or faculty inefficiencies is an important aspect in the context of evaluating technical efficiency in the university process of education, we will try to isolate the share of performance that can be due to the belonging to the faculty.

Indeed, we can consider the faculties as an intermediate level above the production units level which represents a group of graduates who share certain joint characteristics such as: study subjects, equipment, classrooms and so on.

Thus, in order to identify the efficiency of the faculties, separately from the potential efficiency of the individual graduates, we will apply the Program Evaluation (PE) procedure[15]. In particular, starting from Brockett-Golany (1996), we will use the Kruskal-Wallis[16] nonparametric rank statistics to evaluate the statistical significance of the observed differences among programmes or faculties after adjusting for differences in individual efficiency within the faculties.

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[13] Koopmans (1951) provided the following definition of technical efficiency: a producer is technically efficient if, and only if, it is impossible to produce more of any output without producing less of some other output or using more of some input.

[14] To discover the possible input excesses and the output shortfalls we must solve the following linear programming problem by using our knowledge of ϕ_k^*:

$$\max w = \sum_{i=1}^{s} s_i^- + \sum_{r=1}^{m} s_i^+$$

s.t.

$$s_j^+ = \sum_{j=1}^{n} \mu_j y_{rj} - \phi_k y_{rk}$$

$$s_i^- = x_{ik} - \sum_{j=1}^{n} \mu_j x_{ij}$$

$$\mu_j > 1, \quad s_j^+ \geq 0 \quad s_i^- \geq 0$$

[15] The name "Program Evaluation" was first introduced in Charnes, Cooper and Rhodes (1981).

[16] The main reason that motivates the use of rank statistics in this context, instead of parametric statistical procedures based on the efficiency ratings, is that the nonparametric statistical technique for inference is more consistent with the characteristics and goals of DEA than nonparametric analysis. Furthermore, the statistical distribution of efficiency scores is generally not known. The transformation of the efficiency measures into the corresponding ranks allows the use of non parametric robust test statistics, with known asymptotic statistical distributions.

Synthetically, after splitting the group of all graduates into eleven faculties, let's make the DEA model [2] to run separately for the eleven groups, to evaluate the graduates' efficiency measure. Then, let's adjust inefficient graduates up to their own faculty frontier in order to eliminate their inefficiency. We will thus obtain an inter-faculty envelope with the estimated individual inefficiency eliminated. Finally, let's apply the Kruskal –Wallis rank test statistic to this pooled DEA set, in order to verify whether the eleven groups share the same distribution of efficiency measures.

Besides allowing to catch significant differences of programmes efficiency across faculties, the PE procedure provides us with a basic tool for the identification of the crucial factors in the achievement of a given efficiency level.

In fact, the total technical efficiency measure can be decomposed according to the above procedure. As we will heuristically show in paragraph 5, the total measure is equal to the product of a "within" measure obtained when considering the graduates of each faculty separately, and a "between" measure obtained from a pooled DEA.

Obviously, the "within" measure is of a great relevance as it shows the importance of the individual characteristics of every student. On the other hand, the "between" measure is very significant because it allows to estimate the weight of the structural factors.

4 The data and the model

As we have already underlined, several variables involved in the university process of education are not easy to be used, both because many of them are relative to the student's capabilities, and because of the difficulty in collecting data regarding the faculties.

The aim of inserting in the DEA procedure all the inputs and outputs identified and selected for the university system education production model must often call the data actually available to account.

The data used in the analysis is taken from the survey on job opportunities of the 1998 graduates from Florence University conducted over 2,489 graduates by the Department of Statistics "G. Parenti" in 2000 (February and May) and from the Florence University administrative archives.

After considering only the graduates who did not move from one course program to another during their university career and checking any possible outliers, the following inputs, grouped by kind resources, have been selected for each of the resulting 2,277 graduates.

Human resources:

1. average number of full and associate professors per graduate (ANFAP);
2. average number of researchers per graduate (ANR);

Capital resources:

3. average number of sits in the lectures halls per student (ANS);
4. average number of lectures hall per student (ANH);

5. average number of books in the library per student (ANB);
6. average number of journal and reviews in the library per student (ANJ);
7. average number of university furniture per student (ANF);
8. average number of university equipment (ANE).

Individual input:

9. final high-school mark (HSM)

As the output of the educational production process[17] we have first specified the average grade of the exams (AG). To introduce the bad output as a good output in the model we have applied the multiplicative inverse on the effective length of study[18] compared to the obligatory length, $f(U)= 1/u_j$. So, the transformed data represents the institutional time of studying relating to the effective one (LS).

Some descriptive statistics of the input and output variables required for the efficiency analysis are shown in Table 1.

Table 1. – Summary statistics for the input and output data

Variable	*Mean*	*Minimum*	*Maximum*	*St. deviation*
ANFAP	0.0234	0.0070	0.1376	0.0260
ANR	0.0135	0.0068	0.0519	0.0095
ANS	0.3523	0.1779	1.7094	0.3110
ANH	0.0045	0.0015	0.0204	0.0040
ANB	49.0639	1.9895	163.6049	49.1524
ANJ	0.1581	0.0335	0.4825	0.1217
ANF	0.6465	0.2249	2.4920	0.5391
ANE	0.3630	0.0321	1.9053	0.4643
HSM	48.5463	36	60	7.3671
AG	27.0685	20.68	30.00	1.6195
LS	0.5700	0.1463	1.0129	0.1600

In order to provide more information on the variables involved in the analysis, let’s describe briefly the procedures used to determine the previous input measures.

It should be noted that the data on human resources (that is the professors and researchers) and resources of capital (such as classrooms, equipment, books), in some cases are referred to the faculty and in others to the administrative unit, like departments and libraries.

Thus, in order to refer them to the graduates, it has been necessary to subdivide them. The subdivision and the subsequent attribution to each graduate

[17] It should be noted that the final score, with a highly skewed distribution, seems not to be an appropriate indicator of academic ability.

[18] We have modified the actual study time in order to consider males in military service while attending university.

according to his/her actual study time have been made on the basis of specific hypothesis.

In general, in order to obtain the information about an individual level regarding a selected period of time from 1990-1998, the resources offered by each faculty have first been compared to the number of students enrolled in the corresponding years and then summarized by computing an arithmetic mean[19].

Furthermore, as far as human resources are concerned, the ordinary professors have been considered together with the associated professors, based on the assumption that there is no significant difference in the quality of the teaching delivered to the students. On the other hand, the researchers have been taken separately, as their teaching quality has been considered different from the previous one, due to the shorter career teaching time.

In order to determine the amount of the faculty's facilities offered to the student, the data relative to the number of lecture halls and the number of sits[20] in a lecture hall - available in the different faculties of the university in 1994,1995 and 1996 - have first been computed by assuming an increase/fall of the number expressed by the average annual rate of variation.

As the data concerning the bibliographic equipment, such as the number of inventoried books, and the number of periodicals[21], are available for each library of the University of Florence, it was decided to attribute the different libraries to each faculty according to the scheme in Table 2.

Table 2. – Assumed correspondence library-faculty

Faculty	*Library*
Agricultural Sciences	Agricultural Sciences (Technological sciences Library)
Architecture	Architecture (Technological sciences Library)
Engineering	Engineering (Technological sciences Library)
Economics	Economics, Statistics (Social Sciences Library)
Law	Law (Social Sciences Library)
Political Sciences	Political Sciences, newspaper library (Social Sciences Library)
Humanities	Literature, Geography, American (Humanities Library)
Sciences of Education	Sciences of Education (Humanities Library)
Medicine and Surgery	Medicine (Biomedical Library)
Pharmacology	Pharmacology (Biomedical Library)
Biology and Mathematics	Anthropology, Animal Biology Botany, Chemistry, Physics, Geo - mineralogy, Mathematics. (Biomedical Library)

[19] We have considered the actual time of attendance only.

[20] In particular, the number of sits, even if obviously correlated to the number of lecture halls, provides some information regarding the extension of the area available to the students and the conditions in which the lectures are delivered.

[21] The missing data of the series of periodical publications regarding 1992, 1993, 1994 have been reconstructed by using the average annual rate of variation

Moreover, the average number of furniture per student and the average number of equipment per student have been calculated by using the information taken from the inventory of the goods[22] of the University of Florence.

Thus, after selecting the most important commodity categories[23] for the analysis, we have proceeded to make series of available goods for each faculty in the period 1990-1998.

Since every department or institute is usually formed by lecturers from different faculties, in order to decompose the available data, we have parceled the goods out in proportion to the number of the teachers who are in the faculty's department[24].

Lastly, as the knowledge acquired by students in high schools can facilitate their university career, by improving their final level of efficiency, we have considered the diploma mark as an input. In fact, the diploma mark and the kind of diploma are the only available information on the graduate's capabilities as for the faculties he had chosen (the faculties do not select students according to their qualification).

5 The results

The measures of input-efficiency for each of the 2,277 graduates have been obtained by using the XPRESS Solver[25] to carry out linear programmes according to the DEA model [2].

The distribution of the Farrell output efficiency measures of the graduates is presented in Table 3.

It shows that 1,089 graduates, representing about 40% of the total, have an efficiency above 90%.

It should be noted that 161 graduates, out of 2,277, are identified, with a score of 1.0, as being fully efficient. All in all, the whole group shows an efficiency above 50%.

The data shows slight variability in the patterns of efficiency among the graduates, though the distribution is skewed to the right, as can be seen in Figure 1. The range of scores works out to be 0.477.

[22] In particular, for all sort of furniture, we knew the year of their loading and that of their unloading, the commodity category and the administrative unit of destination, that is to say departments, institutes, Dean's offices and Libraries.

[23] Since we want only to consider the goods purchased by the administrative units for teaching purposes, we have left out everything set aside for research, commercial and welfare activity . We could make this kind of allocations of costs per administrative unit by referring to the information taken from the budget and control sector.

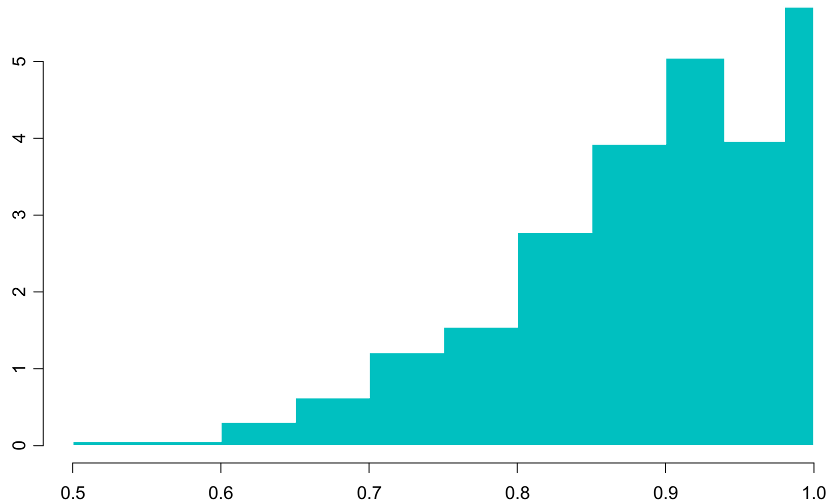
[24] The goods purchased by the Dean's Offices have been wholly attributed to the faculties; as for the libraries, on the contrary, we have followed the attribution scheme shown in Table 1.

[25] To define the optimisation problem [2], AMPL has been used.

Table 3. - Frequency distribution of the technical efficiency measures

Efficiency score	*Frequency* n_i	*Percent frequency* p_i	*Cumulative percent frequency* P_i
0.50-0.60	13	0.6	0.6
0.60-0.65	34	1.5	2.1
0.65-0.70	72	3.2	5.2
0.70-0.75	137	6.0	11.2
0.75-0.80	175	7.7	18.9
0.80-0.85	314	13.8	32.7
0.85-0.90	443	19.5	52.2
0.90-0.94	465	20.4	72.6
0.94-0.98	357	15.7	88.3
0.98-1.00	267	11.7	100.0
Total	*2277*	*100.0*	

Figure 1. - Distribution of the graduates' technical efficiency measure



It should be noted that under the output augmenting orientation, where given inputs and outputs are sought to be maximized, the average score is 0.877 while the median score is 0.895 (as reported in Table 8 below).

This means that on average inefficient graduate should be able to increase outputs by 12,3% without having to increase inputs. In other words, the graduates below the envelope, that is, with efficiency scores less than 1, can achieve a higher average grade of exams with the same level of input indicators.

In order to verify if the 161 graduates identified as Farrell efficient are also Koopmans efficient, we have examined the input excesses and the output shortfalls. Positive slacks[26] have been found in four cases only.

[26] It should be noted that these four cases show an efficiency measure equal to 0.9999, we have approximated to 1.0.

So, the overall picture that comes from the shape of the distribution of efficiency measures is not an unfavourable one.

As we have underlined in the previous sections, the characteristics of the students, such as capabilities, socio-economic status, sex, educational experience gained at high school and so on, can strongly affect the results.

For this reason, it is interesting to analyse the graduates who are relatively more efficient by comparing groups of graduates on the basis of their general characteristics and central tendency, as measured by the mean.

Anyway, it is worth remarking that the differences among the mean technical efficiency calculated by grouping the units should be regarded bearing in mind the apparently very high general efficiency level of the graduates of the University of Florence.

The first characteristic we have considered is the kind of diploma (see Table 4).

Although there is relatively little variation in the average scores of the different types of diploma, the graduates coming from "Liceo linguistico", "Liceo classico" and "Liceo scientifico" have a relatively higher efficiency score. Therefore, it seems that they are more suitable for university studies. On the contrary, the less efficient graduates are those coming from technical high schools.

Table 4. - Summary statistics of the efficiency measure of the graduates by kind of diploma

	Mean	***Median***	***Min***	***Max***	***25^{th} Percentile***	***75^{th} Percentile***	***Standard deviation***	***Coeff. of variation***
"Liceo scientifico"	0.873	0.890	0.558	1.000	0.813	0.944	0.093	0.107
"Liceo classico"	0.891	0.910	0.626	1.000	0.845	0.963	0.092	0.103
"Liceo linguistico"	0.922	0.937	0.727	1.000	0.891	0.978	0.070	0.076
Teacher's Training institute	0.892	0.913	0.644	1.000	0.842	0.963	0.087	0.097
School of Commerce	0.871	0.872	0.546	1.000	0.814	0.931	0.078	0.090
Institute for Geometer	0.886	0.902	0.627	1.000	0.856	0.941	0.081	0.092
Technical College	0.817	0.831	0.584	1.000	0.737	0.890	0.102	0.125
Art	0.902	0.908	0.663	1.000	0.876	0.931	0.058	0.065
Vocational Institute	0.870	0.891	0.611	1.000	0.813	0.948	0.099	0.114
Total	**0.877**	**0.895**	**0.523**	**1.000**	**0.824**	**0.947**	**0.092**	**0.105**

From the analysis of the effect of gender on the efficiency measure, it seems that females have, on average, a better performance than males. In fact, as one can see in Table 5, the female average efficiency score is 0.886, whereas for male it decreases to 0.865.

Table 6 shows the mean efficiency of the graduates according to their working status while attending university.

Table 5. - Summary statistics of the efficiency measure by gender

	Male	Female	*Total*
Mean	0.865	0.886	*0.877*
Median	0.882	0.904	*0.895*
Min	0.523	0.546	*0.523*
Max	1.000	1.000	*1.000*
25th Percentile	0.806	0.840	*0.824*
75th Percentile	0.935	0.954	*0.947*
Standard deviation	0.094	0.089	*0.092*
Coefficient of variation	0.109	0.100	*0.105*

It can be observed that the mean efficiency for the graduates who have been working during their university studies is lightly above-average. Thus, it seems that if the student works, part time or full time, he/she can reach a higher performance. This characteristic is likely to be more evident if we had further information regarding the amount of time spent on work and study.

Table 6. - Summary statistics of the efficiency measure by working status during university attendance

	Working	Not working	*Total*
Mean	0.880	0.872	*0.877*
Median	0.896	0.891	*0.895*
Min	0.523	0.558	*0.523*
Max	1.000	1.000	*1.000*
25th Percentile	0.832	0.813	*0.824*
75th Percentile	0.948	0.947	*0.947*
Standard deviation	0.089	0.097	*0.092*
Coefficient of variation	0.101	0.111	*0.105*

Lastly, by examining Table 7, we can see that the graduates coming from Northern and Central Italy are more technical efficient than the others.

Table 7. - Summary statistics of the efficiency measure of the graduates by residence

Geographical area	***Mean***	***Median***	***Min***	***Max***	***25th Percentile***	***75th Percentile***	***Standard deviation***	***Coefficient of variation***
Florence	0.875	0.891	0.523	1.000	0.821	0.946	0.093	0.106
Tuscany	0.875	0.895	0.590	1.000	0.811	0.948	0.094	0.108
North and Centre	0.899	0.909	0.617	1.000	0.867	0.953	0.076	0.085
South and Islands	0.875	0.894	0.590	1.000	0.839	0.934	0.093	0.106
Rest of the world	0.877	0.905	0.630	1.000	0.823	0.938	0.089	0.101
Total	**0.877**	**0.895**	**0.523**	**1.000**	**0.824**	**0.947**	**0.092**	**0.105**

The above results show that the individual characteristics of the students keeps an important role in the realization of university formation.

Obviously, when comparing the graduates one must take into account the faculties where they come from. In fact, as we have already stressed, the internal organization of each faculty, such as the calendar of the exams, the type of subjects delivered and the facilities offered, does affect the graduate's performance.

The analysis of the average efficiency of graduates belonging to different faculties, shown in Table 8, allows to make some first comments on the faculty effect.

The aim of this analysis is not to calculate the efficiency of the faculty, as the productive unit is the graduate and not the faculty. What is intended to do is more simply to see which faculty have the most efficient graduates.

Table 8. - Summary statistics of efficiency measure of the graduates by faculty

Faculty	*Mean*	*Median*	*Min*	*Max*	*25th Percentile*	*75th Percentile*	*Standard deviation*	*Coeff. of variation*
Agriculture	0.828	0.834	0.594	1.000	0.741	0.915	0.110	0.132
Architecture	0.919	0.917	0.791	1.000	0.888	0.954	0.044	0.048
Economics	0.851	0.848	0.697	1.000	0.808	0.891	0.059	0.070
Pharmacology	0.797	0.802	0.590	1.000	0.714	0.890	0.114	0.143
Engineering	0.939	0.938	0.771	1.000	0.909	0.987	0.050	0.053
Law	0.795	0.796	0.584	1.000	0.725	0.877	0.092	0.115
Humanities	0.863	0.897	0.630	1.000	0.778	0.947	0.102	0.118
Medicine and Surgery	0.835	0.860	0.596	1.000	0.738	0.930	0.114	0.137
Biology and Mathematics	0.812	0.831	0.523	1.000	0.731	0.891	0.107	0.132
Political Sciences	0.950	0.957	0.807	1.000	0.920	0.987	0.044	0.046
Science of Education	0.913	0.927	0.697	1.000	0.859	0.980	0.078	0.086
Total	**0.877**	**0.895**	**0.523**	**1.000**	**0.824**	**0.947**	**0.092**	**0.105**

A comparison among the average scores reveals that the engineering graduates show the highest average level of technical efficiency. Conversely, the law graduates seem to be the less efficient productive units.

To summarise what has been roughly discussed in this paragraph, one can say that the graduate's efficiency is affected by several factors depending both on student and on faculty. Hence, the isolation of the effects of these two components would be of great help in the analysis, to avoid the attribution of the results of good students to poor faculties' facilities and vice versa.

In order to solve this problem, we first tested the difference among eleven groups (faculties) in terms of efficiency. As already mentioned, since the theoretical distribution of the efficiency measure in DEA is usually unknown, we prefer to use nonparametric statistics, which are independent from the distribution of the DEA score.

Thus, the following PE procedure has been carried out. First, after splitting the group of all productive units into eleven faculties consisting of $n_1, n_2, \ldots n_{11}$ graduates (such that $n_1 + n_2 + \ldots + n_{11} = 2,277$), we made to run the DEA model [2] separately for the eleven groups or faculties to evaluate the efficiency measure (or intra envelop). In this way, the graduate's efficiency is determined independently upon the to faculties' facilities and organization. We have called it "within" or "individual" efficiency measure.

In each of the eleven groups separately, we adjusted inefficient graduates to their "level of efficient" value by projecting each production unit onto the efficiency frontier of the faculty. This adjustment removes the individual constituent of inefficiency while allowing programmatic efficiency differences to exist.

Second, we made to run a pooled (or inter-faculty) constant return to scale output oriented DEA model with all graduates at their adjusted efficient levels. The resulting measure is affected by factors depending on the faculty only. So, we can label it "between" or " facilities" efficiency measure.

We applied the Kruskal –Wallis rank test statistic[27] to these results to verify whether the eleven groups have the same distribution of efficiency measures.

The null hypothesis that there is no association between faculty and efficiency rating was rejected[28].

In order to explore the source of output loss, we can consider the means of the three measures calculated for each graduate.

The empirical decomposition of the technical efficiency measure into the "individual" and "facilities" components shows "facilities" to be the primary source of inefficiency for the student who got a degree in Pharmacology, Medicine and Surgery, Agriculture and Law. On the contrary, "individual" is the major source of output loss for graduates in Architecture and Political Sciences.

Table 9. – Means of the three efficiency measures

	"Facilities"	*"Individual"*	*General efficiency measure*
Agricultural Sciences	0.855	0.967	0.828
Architecture	0.962	0.954	0.919
Economics	0.904	0.941	0.851
Pharmacology	0.834	0.954	0.797
Engineering	0.999	0.940	0.939
Law	0.844	0.940	0.795
Humanities	0.888	0.971	0.863
Medicine and Surgery	0.855	0.976	0.835
Biology and Mathematics	0.858	0.945	0.812
Political Sciences	0.993	0.956	0.950
Sciences of Education	0.937	0.973	0.913
Total	**0.920**	**0.953**	**0.877**

[27] As it is known, the Kruskal-Wallis test statistic can be expressed by: $H = \frac{12}{n(n+1)}\sum_{j=1}^{k}\frac{R_j^2}{n_j} - 3(n+1)$ where k= the number of groups, n_j = the number of observations in the j^{th} group and R_j=the sum of the ranks in the j^{th} group. The H statistic has an approximated χ^2 distribution with k-1 degrees of freedom.

[28] In fact, the value of H was 1241.76, so we rejected the null hypothesis at a level of significance α=0.05.

6 Concluding remarks

This paper has focused on the measurement of the technical efficiency of the graduates of the Florence University. To this aim, the human capital formation has been viewed as a production process that is carried out by the student who enters the university, or, in other words, “the student who produces himself”.

Indeed, the student is an atypical production unit which, by using input like teachers, classrooms, books, journal and his/her capabilities, is able to produce himself /herself as a graduate.

Therefore, the analysis of the efficiency has been conducted according to the non-parametric frontier efficiency approach, in the neoclassical theory of production framework.

Searching for a flexible tool in the non–parametric frontier literature that allows both to adequately measure the graduates’ technical efficiency and the peculiar characteristics of the university education process to emerge, an output oriented DEA model, in which an undesiderable output is incorporated, has been estimated.

The results show that the general efficiency level of the 1998 graduates at the University of Florence seems to be very high.

In addition, we have analysed the graduates who are relatively more efficient by comparing groups of graduates on the basis of their characteristics, such as gender, kind of diploma, working status while attending university, and central tendency, as measured by the mean.

It turns out that the graduates coming from “Liceo linguistico”, “Liceo classico” e “Liceo scientifico” are more efficient than those coming from technical schools.

Also, there was evidence of a greater efficiency of females, of graduates from Northern and Central Italy and from those who have been working during their university study.

Furthermore, we have decomposed the total efficiency measure in two parts, a “within” component and a “between” one.

This decomposition is particularly attractive since it provides guidance in the search for the sources of the graduates’ efficiency variation. There is evidence that the major source of inefficiency is due to a lack of the faculty’ facilities offered to the students. We will further analyse this subject in order to find a mathematical decomposition of the general technical efficiency measure, as well as the whole set of the efficiency results, in order to carry out a deeper analysis.

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