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Mario Salerno

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Evaluating the efficiency of research in academic departments: an empirical analysis in an Italian Region

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3 **Evaluating the efficiency of research in academic departments:**
4 **an empirical analysis in an Italian Region**
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12 **Abstract.**

13 This paper investigates the efficiency of university departments on science, technology and
14 medicine in an Italian Region (Lombardy). The aim of the paper is twofold: (i) to analyze the
15 changes in productivity in recent years (from 2004 and 2007), and (ii) to detect factors that
16 are potentially affecting efficiency. We benefited from a new and unique dataset (called
17 QuESTIO) developed by the Lombardy Regional Government.

18 Using facilities and academic staff as inputs, and research grants and publications as outputs,
19 we modelled the research activity of academic departments. The methodological approach for
20 computing efficiency scores is DEA (Data Envelopment Analysis); Malmquist indexes have
21 been used to measure changes in productivity, while Kruskal-Wallis tests were employed to
22 study the potential determinants of efficiency.

23 We obtained two main results. First, we found that in the period considered, the academic
24 departments improved their efficiency but, at the same time, the efficiency frontier worsened.
25 Second, we highlighted that external and measurable factors (like scientific sector, proportion
26 of tenured staff, location, etc.) have a limited impact in explaining efficiency differentials. Both
27 results are discussed in terms of policy implications.

28 **Keywords.**

29 University research, efficiency, research policies, Data Envelopment Analysis, Malmquist
30 index

31 **JEL Codes.**

32 C14, H41, H52
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1. Introduction and motivation

In recent years, Higher Education Institutions (HEIs) have been increasingly studied. In nowadays “knowledge economy” their importance for economic development, social equity, mobility, social cohesion and integration is widely acknowledged (Brennan & Teichler, 2008). Furthermore, given the difficult situation of public finances, considerations about resources allocation have been raised in many countries, calling for more evaluations and accountability. For these reasons the so called ‘New Public Management’ movement, started at the beginning of the 1980s in the public sector in general, has been also increasingly affecting the universities. New Public Management (Hood, 1991; 1995) represents the request to public organisations to become more managerial, in particular by drawing on practices and models from the private sector. This process has been driven both by universities themselves and by governments through reforming efforts. The results, especially in many countries within Europe, share some common characteristics: i) the introduction of incentives schemes based on financial models for allocating public funds, ii) new or strengthened assessment procedures and evaluation agencies, and iii) more emphasis on universities’ autonomy (OECD, 2003).

In this work we explored how the recent changes in the university system affected the efficiency of university research. In particular we were interested in understanding whether an overall increase in efficiency can be recognised and/or whether differences are present between universities given the previously noted enlarged autonomy. As a matter of facts, normally the majority of the reforming efforts have been directed towards education activities, whilst an increase in efficiency of university research has been assigned to incentive systems and evaluation processes. These are expected to have had an overall positive effect on the system, but at the same time they have left the universities in charge of finding and managing the ways to obtain better results. Given the autonomy of the universities and the decentralisation of responsibilities significant differences in terms of efficiency changes are thus expected between and within universities. Furthermore, the idea that performance differentials in terms of research are key for competition among departments is well-established in the literature (Curran, 2000).

We decided to focus on universities research activities and not on education or knowledge/technology transfer activities. Universities’ education activities constitute the first and original mission of the universities, but at the same time, they are normally carefully regulated by laws and already widely studied in terms of efficiency and quality (e.g. Madden et al., 1997; section 2). Indicators such as number of degrees awarded, rate of success, years of study, etc. have been widely used both

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to evaluate the universities and to introduce new policies. The opposite holds for universities' knowledge/technology transfer activities. First of all, even if some argue for this to be a third mission for academia and call for "entrepreneurial universities" (Clark, 1998; Etzkowitz, 2003), others refuse this perspective and signal the risks of focusing on and expanding the role of these activities. Moreover, the efficiency analysis of these activities is hampered by the difficulties in finding the right indicators. As a matter of facts, there are many different knowledge/technology transfer activities (e.g., spin-off, consultancies, research projects with firms, patents, etc.) and their evaluation can be based only partially on economic values given the not for profit nature of universities (Landoni and Verganti, 2006). Finally, we decided to focus on the research activities because we share the vision that they are the core activities of universities, driving and informing both education activities and knowledge/technology transfer activities. This relationship especially holds for transfer activities because the value of the results transferred heavily rely on the underlying research they are based on.

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Deleted: The link to education activities is more complex (Elsen et al., 2009). A strong relation is generally understood to be present in a modern university (Clark 1997), but some authors underline that it could be weaker than expected and needed (Robertson & Bond, 2005). For instance literature indicates that students' understandings of research, even at postgraduate level, may be poor (e.g. Zamorski 2002). And others (e.g. Bonaccorsi et al., 2006) point at a potential trade-off between education and research performances.¶ The importance of university research activities is also recognized at a political and economical level (e.g. in the 2000 Lisbon Declaration) and by the presence of specific evaluation system in many countries (e.g., in the U.S., U.K. and Australia) that are continuously improved and adapted to changing times (Hicks, 2009). Moreover, the growing phenomena of externally-funded academic research raised concerns for a renewed attention to the results of research activities (Hagermann, 2009).

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In this work with the term "research" we adopt the standard definition provided by the OECD: "Research and development is a term covering three activities: basic research, applied research, and experimental development" (OECD, 2002) but we consider only research activities that are normally carried out within universities.

Furthermore in this work, as it is done in the evaluation systems previously cited, we focus our efficiency analysis on university departments and not on the university as a whole. Universities are composed of different research departments and usually they significantly differ in terms of fields of activities and thus publication outputs, co-authorship behaviors and thus efficiency. We believe that an analysis at the level of the university can put forward mixed results, while an analysis at the level of single departments is more precise and coherent with the objectives of an efficiency analysis. For this reason, in order to obtain a sample of comparable departments we focused our attention only on natural science departments, not considering the arts and humanities ones. The choice of the department level for the analysis is coherent with the focus on research activities: normally education activities are managed by organizational entities inside the university that are transversal to more departments and many transfer activities are centralized in a single organizational unit (i.e. Liason office or Knowledge / Technology transfer office).

Our analyses consider departments located in the Lombardy region (Italy). We have chosen a regional focus in order to have similar contextual variables in terms of policies, economic environment, etc. for the universities included in the analysis.

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Furthermore, Lombardy is one of the more advanced European regions both in terms of (i) economic development and (ii) research activities and universities: more than 9.4 millions of habitants, GDP per capita >34,000 €; 12 universities are located in the Region – out of about 70 in all the country, and more than 230,000 students.

Finally, the regional level is increasingly recognized as a relevant level of analysis in terms of research and innovation activities. Many authors (e.g. Cooke et. al., 1997; Porter, 1998; Lechner e Dowling, 1999) underline that it is at a local level that the majority of the connections between the different innovation actors take place. The localization of knowledge and the role of proximity as a driver of economic development (e.g. clusters) have also highlighted the importance of regional and local government in fostering and strengthening the actors and their relationships.

To summarize, the focus of the paper is on efficiency of research activities in scientific departments in the Lombardy Region (Italy). Our research questions are two:

- did changes in the overall efficiency of departments' research occurred between 2004 and 2007?
- which are the main factors affecting efficiency?

The paper is organized as follows: the next section present the more recent literature on the topic, then the methodology and the data used are introduced, finally results are presented and conclusions are drawn.

2. Background

The international literature about universities' efficiency – through non-parametric techniques – has been developed both at institution-level (Athanasopoulos & Shale, 1997; McMillan & Datta, 1998; Ng & Li, 2000; Avkiran, 2001; Abbott & Doucouliagos, 2003; Flagg, et al, 2004; Warning, 2004) and department-level. The latter is more relevant for the context of the present study.

The contributions by Johnes & Johnes (1993; 1995) highly influenced our methodological approach. In a first paper Johnes & Johnes (1993) measured the research performance of UK economics departments, by using staff numbers as inputs and publication counts and grants as outputs; the same strategy was adopted again for deriving efficiency scores of economics department in a subsequent paper (Johnes & Johnes, 1995). The authors ran several DEA models to test the robustness of results and claim for a possible use of results for policy purposes,

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2 especially for establishing an optimal allocation of resources across departments.
3 These two contributions are the most important as they focus exclusively on the
4 research dimension of the universities' work.

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6 Madden et al. (1997) studied the efficiency of economics departments in 29
7 Australian universities. Inputs were teaching and research staff, outputs were
8 graduates and publications (for teaching and research respectively). As in other
9 studies listed below, here the focus was both on teaching and research performance,
10 even if the analysis were conducted at subunit level (that is at departmental level
11 instead of institutional level). The specific objective of the Madden et al. (1997) study
12 was to verify whether policies promoted by the governments impacted on the
13 productivity; they confirmed that there was actually an increase in productive
14 efficiency.

15
16 Thursby (2000) analyzed the efficiency of the Economics Research Departments in
17 the US. He defined efficiency as follows: "(...) a department is deemed technically
18 efficient if, when compared to departments with similar level of inputs, it could
19 produce greater research outputs without increasing its inputs usage, or equivalently,
20 it is one which, compared to departments with similar levels of outputs, could
21 produce the current levels of outputs with fewer inputs" (p. 400). He used publication,
22 citation data and number of Ph.D.s as outputs, and faculty size, full professors,
23 graduate students, federal grants, library acquisitions and a dummy for private
24 ownership as inputs. He found that the average level of efficiency in US is incredibly
25 high (67% of economics departments appear as efficient). Seen from a European
26 perspective, this result is not so unexpected.

27
28 Moreno & Tadepalli (2002) focused on 42 academic units distributed across 7
29 colleges in the US. They used staff, financial resources and proxies for structures
30 (e.g., building space) as inputs, and number of students, FTE enrolments and grant
31 awards as outputs. In discussing their results, they evidenced that efficiency scores
32 do not illustrate information about effectiveness – that is, they argue that a qualitative
33 dimension is necessary for this purpose. Lastly, as their background is strongly
34 managerial, they also suggest a use of efficiency analysis as a planning tool, not only
35 for evaluating universities' activities.

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37 Koksal & Nalcaci (2006) derived efficiency scores for 14 university departments at
38 the Middle East Technical University (METU) in Turkey, by using staff salaries, a
39 composite indicator of previous research quality and number of students as inputs,
40 and number of publications, graduates, and teaching indicators as outputs. Thus, in
41 their contribution, the authors focus also on the teaching activity of the departments.
42 They decided to use weights for teaching and research loads as suggested by
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2 university's administrators through a preliminary survey. The paper suggests that the
3 models adopted for computing efficiency can serve to set new targets for inefficient
4 departments.
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6 Gimenez & Martinez (2006) focused on cost efficiency of the departments at the
7 Autonomous University of Barcelona. They computed cost-efficiency scores and
8 separated cost excess into three categories: technical efficiency, fixed factors, scale
9 of size. The units of analysis were 42 departments, and again the focus is on both
10 teaching and research activities. The inputs chosen were: expenditure on temporary
11 hired teaching and research staff, operational expenditures, expenditures on tenure
12 staff. To measure the outputs, they employed the following variables: results of a
13 government evaluation process of research, teaching load (measured through credits
14 granted) and students' opinions. The authors suggest that their analyses can be
15 used to assess the differences between (i) the observed cost of the units and (ii) the
16 cost they would achieve assuming long-term cost minimization. Their result tells that
17 size does not matter in determining efficiency, while higher proportion of non-tenured
18 staff is associated with higher efficiency levels.
19

20 In another exercise presented by Kocher et al. (2006) the analysis is focused on the
21 productivity of research in economics across 21 OECD countries. The focus of the
22 paper is on research and the outputs selected are top publications (and impact
23 factors), while inputs are R&D expenditures, number of universities and total
24 population. This study is quite different, however, with respect to the relevant
25 contributions for the present paper, as the unit of analysis is the country (neither the
26 university nor the department). The results suggest that research productivity can be
27 raised through an increase in the scale of operations.
28

29 An interesting issue is to analyze the related literature about the Italian universities'
30 research. To the best of the authors' knowledge, there are only two specific
31 contributes which specifically analyze the efficiency of universities in producing
32 research outputs (Pesenti & Ukovich, 1996; Rizzi, 1999), and just one attempting to
33 focus on teaching production (Agasisti & Dal Bianco, 2009).
34

35 The two contributions at departmental level (Pesenti & Ukovich, 1996; Rizzi, 1999)
36 use a similar set of variables and focus both on teaching and research outputs. The
37 main scope for these contributions is to provide information and suggestion for
38 allocating resources within a university.
39

40 Contributes about the efficiency of Italian higher education has been conducted at
41 institution-level (thus, not considering separately the structures devoted to teaching
42 and research). The reason for this choice can be summarized by the idea that the
43 strategy and the mission of universities is defined at macro(institution) level, then the
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2 balance between teaching and research is decided by the decision centres at
3 institution level (Bonaccorsi & Daraio, 2007, p.22).

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5 Among these contributions at an institutional level Agasisti & Dal Bianco (2006)
6 studied the efficiency of 58 Italian public universities, by using number of staff,
7 financial resources and students as inputs, and graduates and research grants as
8 outputs. They suggest the use of efficiency analysis for policy purposes, especially to
9 evaluate the differences in terms of performance between efficient and inefficient
10 units. Later, Agasisti & Salerno (2007) analysed the cost efficiency of another sample
11 of Italian universities, by adding some qualitative measures for inputs and outputs.
12 They conclude that a redistribution of inputs across universities could lead to an
13 overall improvement of efficiency in the Italian HE sector.

14
15 Bonaccorsi et al. (2006) used a robust non-parametric technique (developed by
16 Daraio & Simar, 2005) to take in account external conditions affecting the productivity
17 of universities. The inputs and outputs adopted are quite similar to previous studies
18 (that is, staff numbers, expenses and spaces as inputs, and publications and
19 graduates as outputs), but they also include some “external” factors: university size,
20 number of departments within the university, percentage of private funding, number
21 of curricula activated. Their conclusions are there economies of scale and scope are
22 not relevant factors in explaining (in)efficiency, but that a strong role is instead played
23 by the external factors – clearly, such result affects the policy considerations.

24
25 To sum up, the literature seems to suggest that, to analyse research efficiency of
26 universities – that is, the efficiency in the production of research outputs:

- 27 • inputs can be classified under three main groups: human resources, financial
28 resources and structures (e.g. facilities, buildings, etc.);
- 29 • outputs can be grouped into publications and grants.

30
31 Clearly, the best indicators to measure these classes of inputs/outputs are
32 questionable, but the general emerging consensus is on a productive process that
33 can be described with such indicators. The present paper moves from these
34 suggestions, and it focuses on the efficiency of research activities in scientific
35 departments in the Lombardy Region (Italy).

36 37 **3. Methodology and data**

38 39 *3.1. Methodology*

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41 The methodology is articulated accordingly to the two steps adopted to answer the
42 research questions of the paper: on one hand the efficiency analysis (including

efficiency scores of the departments, changes across time and time trends), on the other hand the effort to identify the determinants of efficiency.

The first choice is about the methodology to compute efficiency, because there are different methods to target the analysis of efficiency among different units. Data Envelopment Analysis (DEA) is a frontier, linear programming technique, introduced by the seminal work of Charnes, et al. (1978). It deals with the efficiency problem of complex organizations that produce many outputs using several inputs at a time.

In this paper we have only briefly discussed some characteristics of DEA, referring the interested reader to Johnes (2004); Cooper *et al.*, (2006), and Zhu (2003).

In a DEA model, the notion of efficiency is that of “technical efficiency”, defined as the relative ability of each Decision Making Unit (DMU) in producing outputs, where the term “relative” means that each organization is compared with any other homogeneous unit. DEA could be represented by a linear programming technique where each DMU tries to maximize the efficiency ratio (output over inputs) choosing the best set of weights. There are two ways to deal with a DEA formulation: (i) input oriented (that is, the ability to minimize inputs when outputs are given), and (ii) output oriented (maximization of outputs given a certain bundle of inputs). In this paper, we adopt this latter approach, as the typical problem for a research unit is to maximize outputs (e.g., publications, grants, etc.) given its inputs (e.g. research staff, laboratories, etc.).

DEA mathematical formulation can deal with both constant returns to scale (CRS) and variable returns (VRS). The seminal work of Charnes et al. (1978) introduced a constant return to scale (CRS) model where DMU dimension has no importance in defining efficiency performance (see equation 2). DMUs face the same efficiency frontier, independently of their relative size. Obviously, one can cast doubts on the comparability of small and large units. Larger units exploit common inputs to produce different outputs, whereas smaller ones benefit from substantial advantages in organizing activities. The BCC model, developed by Banker et al. (1984) introduces in DEA modelling the dimension factor. Smaller units are associated with increasing economies of scale, and bigger units with decreasing economies of scale. In the middle, there is a “grey area” of constant returns to scale. So, it is also possible to compute the scale efficiency. This is defined as the ratio CRS/VRS efficiencies, and interpreted as the ability of each institution to benefit (in terms of productivity) from its size – in other words, in a VRS formulation, each DMU is compared only with those units having a comparable size.

We also measure changes in efficiency across time, and our relevant period is between 2004 and 2007. For measuring the determinants of the changes in efficiency scores, we use Malmquist index (for more information about this index see

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We also measure changes in efficiency across time, and our relevant period is between 2004 and 2007. For measuring the determinants of the changes in efficiency scores, we use Malmquist index (for more information about this index see

Deleted: There are two main categories: parametric and non-parametric methods

Deleted: , that is the method chosen in the present study, belongs to the latter group, as it does not require a *priori* functional specification to mix input and output such as a production function. DEA

Deleted: The choice of a set of weights that combine several outputs and several inputs is the core of DEA analysis.

Deleted: .). Following Johnes (2006), the mathematical formulation is:

$$\max \phi_k + \varepsilon \sum_{r=1}^s s_r + \varepsilon \sum_{i=1}^m$$

(1) Subject to

$$\phi_k y_{rk} - \sum_{j=1}^n \lambda_j y_{rj} + s_r = 0,$$

$$x_{ik} - \sum_{j=1}^n \lambda_j x_{ij} - s_i = 0 \quad i =$$

Here, there are *s* outputs and *m* inputs. y_{rk} is the output *r* produced by the k_{th} unit. x_{ik} is the amount of input *i* used by the same k_{th} unit. Lastly, s_r is the output slack, and s_i the input slack.

Deleted: (although it has a different meaning to that usually applied in economics), simply adding the following constraint:

$$\sum_{j=1}^n \lambda_j = 1 \quad \dots \dots \dots (2)$$

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Johnes, 2004 and Coelli *et. al.*, 2006). Let us consider a DMU, named P that has a change in production position from P_t (in period t) to P_{t+1} (in period t+1). The change in the production frontier could have occurred in a non-neutral way - that is, it could be determined both by efficiency changes and shifts in the efficiency frontier. Thus, for measuring the change in the efficiency score, we have to break down the score in these two different components. Both of the components have a specific mean: the resulting score for the DMU could have positive or negative effects due to the own efficiency change or due to the shift (movement) of the frontier. Thus, the resulting efficiency index is composed by two parts. The first component of the equation is the ratio of technical efficiency in time period t+1 on the technical efficiency in the period t. Since it measures the change in technical efficiency, it is equal to 1 if no changes occurred, greater than 1 if the change was positive, and less than 1 if it was negative. The second component measures the shift in the production frontier: if it is equal to 1 it has no effect on the efficiency score, if it is greater than 1 it has a positive effect and if it is less than 1 it has a negative effect. In other words, a shift in a production frontier that makes worse the relative position of the DMU (the other DMUs are performing relative better than before) provides a second component less than 1. The index (Malmquist index) resulting from the combination of these two components will be equal to 1 if there is no net effect of changes in technical efficiency and frontier changes; it will be greater than 1 if the net effect is positive, and less than 1 if it is negative. In our analysis, we name "efficiency change" the first component and "frontier shift" the second one.

Moreover, we would detect the eventual stability of efficiency rankings across the period (again, the relevant period is between 2004 and 2007). In this case, we adopted one of the statistics suggested by Brockett *et al.* (1998). More specifically, we are interested in knowing if the efficiency of departments changed influencing the rankings or not over time. *"Ranking the set of $n \times k$ efficiency ratings and observing the sum of ranks associated with each DMU, one can learn about the relative position of the DMUs vis-avis each other across the whole period"* (Brockett *et al.*, 1998, p. 174). For this purpose, the basis of the analysis is a Kruskal-Wallis test (Kruskal & Wallis, 1952) where, "(...) the rejection of the null hypothesis leads to the conclusion that, in general, the different DMUs maintain their relative efficiency positions over time" (p. 175).

The second task in our methodology is to study some potential determinants of efficiency. To pursue this objective, we identified some external factors (e.g. "location" effects, "discipline" effects, etc.) and then we compared efficiency scores

Deleted: (called P)

Deleted: From an analytical point of view, the index is defined as (Johnes, 2004, pp. 621-624):¶

$$Mo = \frac{OP_{t+1} / OP_{t+1,t+1}}{OP_t / OP_{t,t}} \cdot \left[\frac{OP_t}{OP_t} \right]$$

... (3)

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¶ where OP_t is the radial distance between the origin O and the point P_t , and $OP_{t,t}$ measures the distance from the origin to the point $P_{t,t}$.

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Assuming the existence of n populations simultaneously under investigation, and that all n populations have the same distribution of ratings, then the statistic is:¶

$$H = \frac{12}{n \cdot k \cdot (n \cdot k + 1)} \cdot \left(\frac{R_1^2}{k} + \dots \right)$$

... (4)¶

¶ where $n \cdot k$ scores have been ordering (ascending order), and R_i denotes the sum of ranks corresponding to DMU_i .

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across different groups of units. The comparison was made by means of the Kruskal-Wallis test (Kruskal & Wallis, 1952). This test allows the researcher to detect if there are statistical differences across the groups analyzed (e.g., when comparing the efficiency scores of units located in a metropolitan area with those located elsewhere, the test indicates if this location effect generates a statistical difference between the average scores of the two groups).

Deleted: The analyses will be presented in the next section.

3.2. Data

In this paper, we used a unique dataset that consists of input and output variables about research and technology transfer activities in university departments located within the Lombardy Region. This dataset is based on information coming from QuESTIO system, a mapping of Research and Technological Transfer organisations developed in Lombardy Region. The QuESTIO system, launched in 2004 by the Regional Government, was intended to be a transparency and incentive tool for the Research and Technological Transfer market by reducing any information unevenness often binding cooperation among producers and users of knowledge. The system pursues such scopes by collecting, updating and publishing financial, organizational and structural characteristics of research organisations and Knowledge Business Intelligence Services in Lombardy.

Since it aims at presenting the most detailed picture of Regional community active in Research and Technological Transfer, the dataset has some specific criteria that are pivotal for our analyses. First, the system is focused on every structure where such activities are carried out, even where that structure is a part of a wider organisation. Second, these structures should have significant management autonomy so that their accountancy shall be determinable. The first criterion enables the regional administration to collect information on every single department, being acknowledged that departments belonging to the same university can differ significantly in terms of performances. As a consequence the university departments, as well as sections and institute of National Research Council or R&D unit belonging to a Company, provide data making solely reference to their specific resources and outputs. The second criterion assures that each structure included in the dataset is responsible (to some extent) for its strategy and performances thus justifying application of DEA technique.

University departments are main actors in Lombardy Innovation System; as a matter of fact they are 147 out of 364 structures mapped, which balance the presence of Knowledge Business Intelligence Services, which count for 151. The map is

Deleted: Mathematically, the test is computed as:

$$H = \frac{12}{N(N+1)} \left[\sum_{i=1}^k \frac{R_i^2}{n_i} \right] - 3($$

... (5)

where N is the size of the full sample, k is the number of subsamples, n_i is the size of the sub-sample i, and R_i is the sum of the rank indices of the sub-sample i.

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2 completed with 13 Hospital and medical research centres, 34 Public Research
3 Organizations and 19 company R&D units.
4

5 In order to better point out the capillarity of these structures within the territory, the
6 geographical analysis shows a concentration in the Province of Milan, and a little less
7 in Bergamo, Brescia, Pavia and Varese, which is explained by the presence of
8 universities in those cities, all of them accredited with their single departments.
9

10 We built our dataset by considering those university departments that provided
11 information for the whole period 2004-2007 (units for which there are not missing
12 data), by selecting the following variables:
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14

15 INPUTS

16 I1. Laboratories

17 This variable considers the areas (measured in square meters) devoted to
18 laboratories belonging to or accessible by the department. This data provides a
19 dimensional data related to the most distinctive and characterizing areas equipped
20 for scientific research.
21
22

23 I.2. High-Qualified Human Resources

24 It refers to persons who perform research and technology transfer activities,
25 regardless of their qualifications. They are mainly full professors, associated
26 professors, permanent researchers, post-Doc scholarships and PhD students. It
27 includes employees dedicated to activities in support of research, like: certification,
28 tests and measurements, patenting and commercialisation, financial assistance,
29 partners search, technologies monitoring, events organisation, editing of technical-
30 scientific "spreading publications".
31
32

33 I.3. Other personnel

34 This variable considers administrative personnel that should ensure the efficient
35 working of human resources devoted to research and technology transfer activities.
36
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38 OUTPUTS

39 O.1. Revenues from financed activities

40 Accomplished activities financed with regional or national calls for bids. This variable
41 denotes the ability of the department to compete with other research organizations in
42 getting public-funded research, thus measuring the amount of research that meet
43 requirements of national and regional R&I strategies.
44
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46 O.2. Revenues from financed activities from abroad

47 Accomplished activities financed shows the capacity of drawing on international
48 funding, like the European projects, resulting by working with third countries
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2 organizations. It reflects department down stream internationalization and it is a sign
3 of the research activities that are acknowledged at international level.
4

5 O.3. Revenue from orders

6 This variable measures how far research activities carried out in a department are
7 committed directly by companies or other institutions.
8

9 O.4. Yearly number of publications

10 This variable reports yearly articles signed by department human resources on the
11 international scientific press. This is the traditional and widespread variable used to
12 measure the output of research activities.
13

14 O.5. Doctorates in cooperation with external bodies

15 This variable sheds light on the capability of departments in attracting investments for
16 education finalized to research and to establish cooperation with institutions and
17 companies. Since this variable could be interpreted such as an indicator of
18 technology transfer activities, we investigated if it could alter the efficiency scores
19 and we ran a DEA model without considering it. The results are the same for almost
20 all the DMUs so we decided to keep it in the model.
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26 As discussed in the previous section the choice of input and output variables is
27 coherent with the most recent literature. The final sample contains 75 departments,
28 for 4 years – overall, there are 300 observations. Descriptive statistics are illustrated
29 in Table 1.
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33 <Table 1> around here
34

35 **4. Results**

36 In this section, we illustrate the results obtained through the DEA analysis on the
37 university departments in the Lombardy Region.
38
39

40
41 The results are presented in two main sections. The first is devoted to a description
42 of the efficiency scores with reference to the year 2007 (the last year available,
43 where the results are more stable as previously discussed). In this section one
44 subparagraph analyses the change in efficiency between the first year of our dataset
45 (2004) and the last year (2007) and another one explore the presence of time trends
46 in the efficiency scores. The second section refers to the study of statistical
47 differences among efficiency scores due to “external factors”, such as localization,
48 discipline subject, etc.
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4.1. DEA efficiency scores, year 2007

This section explores the results of the efficiency analyses both looking at a single year (2007) and at differences between years.

4.1.1. DEA efficiency scores, year 2007

Table 2 reports the descriptive statistics about the efficiency scores derived with reference to the year 2007 (the annex reports the specific scores for each department). As explained in the methodological section, we calculated CRS efficiency and VRS efficiency, as well as the “scale” efficiency computed as CRS/VRS scores (it is important to recall here that the model is output-oriented).

<Table 2> around here

The research efficiency of university departments in the Lombardy Region looks quite high (0.75 in terms of CRS efficiency, 0.78 in terms of VRS efficiency); actually, the high average efficiency is coherent with previous results derived across the world in the higher educations sector (Salerno, 2003). What is worth pointing out is a strong heterogeneity across departments – indeed, the standard deviation is >0.2 . A look at the lowest scores suggests that there are very poor performers which shows scores <0.5 .

Data about scale efficiency suggests that all the departments have almost reached their optimal scale of operations (given their present scale), as the scale efficiency score is very high (>0.93) and standard deviation is very low (about 0.1) in this respect.

The picture that emerges from this first analysis of efficiency scores is a sector where there is a number of very efficient units (both assuming constant or variable returns to scale) and a number of departments which experienced low levels of technical efficiency; thus, as the anecdotic evidence suggests, there is quite a strong differentiation among departments in terms of research efficiency.

As the focus of our paper is the efficiency of academic departments in the Lombardy Region, we also checked the robustness of our results by considering revenues from entities located in the Lombardy Region as a separate output (REV_LOMB). The correlation among results obtained by the baseline model and this modified model is very high (>0.97). the VRS efficiency scores for each department comparing the two models (also in this case the reference year is 2007) is available, on request, from the authors.

4.1.2. Efficiency changes between 2004 and 2007 – a Malmquist analysis

Following the methodology described above, we derived the Malmquist index, which allows us to disentangle the efficiency changes due to “pure” efficiency improvement (or worsening) and technological improvement (or worsening). The descriptive statistics about the results are reported in Table 3, while the detailed results are available on request from the authors.

<Table 3> around here

The picture that emerges highlights an interesting phenomenon. It looks like an improvement in productivity did not occur (because the Malmquist index is around 1) but, looking at the decomposition of the index, the reality appears more complex: an efficiency changes happened, it was very positive (the index is >1.6) and involved the major part of the departments (56 out of 70); on the other side, there was a relevant detriment of the technology environment (the “frontier shift” indicator is <0.7). It looks like the academic units improved their technical efficiency (that is, the ability to transform inputs into outputs) but, at the same time, the frontier worsened. In other words, what happened is that the “technological change” (in the Malmquist language) was negative.

What is “technology” in a regional research system, when we define research performance as the ability to attract financial resources and to publish in academic journals? Technology could be defined as the bundle of policies that should help in improving research efficiency, e.g. Information Technologies, research grants, support for publishing research results or to attract financial resources from international grants or companies, etc. Thus, the results contained in Table 3 suggest that, while the majority of the universities improved their efficiency, the system as a whole did not experienced an improvement in terms of technology available. A discussion about the potential responsibilities for such phenomenon will be reported in the last section, which deals with policy implications of our work.

4.1.3. Productivity changes between 2004 and 2007 – an analysis of “rankings stability”

Lastly, we analyzed the stability of rankings across our analysis period (between 2004 and 2007) by means of the H index proposed by Brockett et al. (1998). The index is equal to 177.96, and it must be compared with H^2 that is equal to 102.99. The rejection of the null hypothesis leads to the conclusion that some of the academic departments exhibit consistently better economic performance than others

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2 (as measured by the input-output factors that were included in our model) (see
3 Brockett et al., 1998).

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5 Reading this results together with the Malmquist index, it looks like the academic
6 departments improved their performance, but some units continue to perform better
7 than others. At the same time, the results show that some units are not efficient –
8 that is, the frontier actually worsened.
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on request, from the authors)

10 11 12 13 *4.2. DEA efficiency scores, year 2007 – the external factors affecting efficiency*

14 In this second section, given the evidence on the efficiency results, it is interesting to
15 explore which are the determinants of this efficiency or, in other words, what could
16 actually affect a department's performance.
17

18 To answer this question, we tested a number of different factors, by using the
19 Kruskal-Wallis test as methodological approach (see the data section). All the results
20 are listed in Table 4.
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24 <Table 4> around here
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27 *4.2.1 First external factor: are departments located in Milan metropolitan area* 28 *(regional capital) more efficient than other departments?* 29

30 We analysed this factor on the assumption that in a metropolitan area the
31 competition among research centres enforces departments' managerial efficiency. In
32 Milan, there is an important concentration of public and private research institutions
33 and the competition for resources is not limited to departments. The high
34 concentration of research facilities may justify a greater effort by departments in
35 fostering a more balanced use in input resources or may impulse an effort in control
36 for managerial quality. Elsewhere, Agasisti (2009) demonstrated that the effect of
37 competition on Italian universities' performance is positive – but, there, output was
38 defined through teaching dimension's measures.
39

40 We ran a Kruskal-Wallis test to verify the statistical difference between the efficiency
41 scores of departments located in Milan versus the other departments. We do not find
42 evidence of difference in efficiency performance between the two groups (indeed, the
43 observed value of the H statistic is nearly 0, and the p-value >0.9). This evidence
44 suggests that there is no "concentration" effect or "location" effect on efficiency
45 performance of university departments or, at least, in the relative rankings. At the
46 same time, this result may suggest i) the existence of no competitive pressure in a
47 high concentration area as Milan, or that ii) we have to look at overall concentration
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2 of research centres, and not only to university departments (e.g., there could be a
3 “university” effect which could dominate a “location” effect, or that iii) there is
4 competition but at the same time more opportunities to find resources (more demand
5 for research, and consequently the amount of resources is enough to guarantee a
6 sufficient level of grants for different departments without the need to compete one
7 against the others).

11
12 *4.2.2. Second external factor: can different scientific sectors affect university*
13 *department efficiency?*

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15 As we measured “output” by using i) publication counts and ii) research grants (of
16 different kinds), it is important to recall that there are some differences in the average
17 number and quality of publication across different disciplines (e.g. medicine versus
18 engineering or biology), as well as differences in terms of attractiveness of research
19 funds (e.g., in engineering fields it is simpler to attract grants for applied research
20 than in physics).

21
22 The idea that disciplines greatly vary in terms of costs and productivity is not new,
23 and the suggestion to take this factor into account is important to obtain not-biased
24 results (Sarrico & Dyson, 2004). Recently, Sarrico et al. (2009) demonstrated a
25 strong role of “subject mix” (defined as the disciplinary composition of institutions) in
26 explaining the efficiency differentials among Portuguese higher education institutions.
27 The authors acknowledged that “(...) *research production also varies significantly*
28 *from subject to subject, with medical, some natural and technical sciences being*
29 *more prolific in the number of articles than most of the social sciences and*
30 *humanities”* (p.290). Also Ramsden (1994), in his empirical analysis of Australian
31 research departments, adjusted the coefficients on the basis of discipline subjects.

32
33 We find a small, but statistically significant difference among university departments
34 classified by scientific sectors: the observed value of the H statistic is >8.4, near the
35 critical value (9.4), and the p-value is 0.07 (then the effect has statistical significance
36 at the 10% level). However, given the limited power of this effect, it is not easy to
37 determine which sectors outperform the others straightforwardly.

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45 *4.2.3. Third external factor: is there a “university effect”?*

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47 An alternative explanation of efficiency can refer to the existence of a “university
48 effect”, that is if a university is more efficient than others, then its departments could
49 be more productive than those belonging to other universities. This assumption finds
50 its justification in the setting of strategies at university levels, not at subunits levels. In
51 this respect, Bonaccorsi & Daraio (2007, pp. 22-23) pointed out that “(...) *the notion*
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2 of strategy is much more relevant and interesting if assumed at the overall university
3 level. On the one hand, most strategic decisions are made at university level. (...)
4 The fundamental reason for assuming the university level as the unit of analysis is
5 that at the university level the problem of attribution of inputs (in particular, human
6 resources, funding and physical capital) to specific units of outputs, can be kept
7 under control". Even if these authors recognized that a lower unit of analysis could
8 provide useful information on the actual research process, they suggest that a
9 "university effect" (due to different strategies and characteristics at macro-level) can
10 be detected.

11 Our tests suggest that such effect is not explaining efficiency differentials for our
12 sample (observed value of the H statistic is 9.4, well below the critical value of 14.06,
13 and the p-value is 0.22).

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21 4.2.4. Fourth external factor: does the number of tenured academic staff influence
22 efficiency?

23 The proportion of tenured research staff theoretically can affect the efficiency of a
24 department: there is anecdotic evidence that tenured and non-tenured staff face
25 quite different stimulus and incentives. Nevertheless, the direction of this influence is
26 not clear a priori: tenured staff is certainly more expert in attracting research grants
27 and in publishing academic papers, also thanks to reputational advantages;
28 conversely, non-tenured staff can have an incentive to be more productive, for
29 instance as a mean to obtain a tenured position. The promotion system can affect
30 productivity if researchers are satisfied with rules promoting this dimension (a
31 discussion of motivations behind researchers' activity is in Ramsden, 1994, pp.214-
32 215).

33 A complementary idea behind this question is that the different human capital of
34 researchers (in our paper, indirectly measured via the tenured status) can affect the
35 research productivity of the research groups – and so, of the department. In this
36 respect, an interesting example is the paper by Rodgers & Neri (2007), who
37 specifically attempted to correlate the human capital of researchers with the research
38 productivity of Australian departments of Economics. They have found that human
39 capital differential account for about 50% of the observed differences in research
40 productivity. If human capital is (even indirectly) captured by the tenured status (e.g.,
41 researchers with more experience should have reached their tenured position), then
42 we should expect a correlation between the proportion of tenured researchers and
43 the department's results. Ramsden (1994) showed that productivity of professors and
44 readers was much higher than that of lecturers.

Our analysis did not find evidence of a statistical influence of this factor on research efficiency (the value of the H statistic is 0.16 and the related p-value is >0.6).

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4.2.5. Fifth external factor: can departments' "longevity" affect research efficiency?

Finally, we looked at the possible effects due to the longevity of departments. As we measured inputs in terms of numbers of academic staff and laboratories/facilities, it is reasonable that older departments accumulated higher stocks of inputs that could influence their outputs.

A key assumption here is that older departments can favour more cohesion among its members, then facilitating the climate of "collaboration" and "common motivation" that some authors pointed out as a determinant of research productivity (Ramsden, 1994).

Another interesting point of view about this potential phenomenon is that it is related to the "critical mass" dimension. Among the economic aspects of research, Hare & Wyatt (1992) underlined that the ability in producing research relies upon the human capital accumulated by the individual researchers; thus, *"combining this process with the notion that there are economies of scale in research may dispose university departments to feel they need to have at least some critical mass of researchers working in the same area in order to function properly as research units"* (pp. 55-56). Consequently, it could be reasonable to assume that older departments are more likely to have reached such "optimal" scale dimension than the more recently established ones.

The statistical analysis did not provide statistically robust results on this effect, indeed the value of the H statistic is 1.172 – while the critical value is around 3.8, so that the p-value is 0.27).

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5. Discussion and policy conclusions

As highlighted discussing the literature on the topic, the analyses presented in this work are innovative in terms of data and methodology. Indeed, in this paper we have investigated the efficiency of university departments on science and technology and medicine in an Italian Region (Lombardy). The aim of the paper was (i) to analyze the changes in productivity in recent years (from 2004 and 2007), and (ii) to detect factors that are potentially affecting efficiency.

Discussing our results about the efficiency change between 2004 and 2007, some questions must be posed: how can a Malmquist index equal to 1 exactly be interpreted? How can we judge a frontier shift that is less than 1? Each academic

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2 unit, on average, is in the 2007 in the same position *relative to the frontier* than in the
3 2004 (indeed, also the H index calculated above suggests small changes in the
4 rankings in the period considered). However, what happened is something different:
5 the vast majority of the units actually improved their productivity in the period
6 (“efficiency change” >1) but the “frontier shift” was <1: it means that the performance
7 differential is much less dispersed in 2007, but at the same time it happens because
8 the frontier is not improved – the best performers did not improve, or even worsened
9 their efficiency. The summary statistics confirms this idea (look at the really lower
10 mean in 2004, with a much higher dispersion – standard deviation – around it). The
11 result is a “research system” in the region that performs better on average, but
12 without having excellence.

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17 The importance of evaluation and accountability has been growing in these recent
18 years and criteria used are widely acknowledged: publications and the ability to
19 gather financial resources (from abroad or from firms). Since the application of these
20 evaluations for funding allocation is more and more concrete, we believe that the
21 weakest departments raised their attention towards those performances. Thanks to
22 this new attention the weakest departments have increased their efficiency and
23 become much closer to the best performers that, on the contrary, had little margin for
24 further improvements.

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29 This result requires an important policy discussion. Indeed, the objective of the
30 Lombardy Region was to foster the performance of excellent research units. This
31 purpose animated some policy interventions such as the creation of “clusters”, the
32 policies for improving contacts between companies’ demand and research units
33 through vouchers (the idea behind is that the best research units would be able to
34 collect more vouchers), etc. Apparently, the results obtained are in the opposite
35 direction.

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39 This fact raises two reflections. The first is that maybe the universities (and,
40 consequently, the research units) look not at the regional incentives, but at the
41 national ones (as the Ministry is still the main financer of the universities’ activities)
42 and at international ones (the research reputation strongly depends upon the ability
43 to publish in international journals and to attract international grants). If this is the
44 case, a question arises about the opportunity for a regional government to be
45 involved in this sector.

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49 A second (possibly alternative) reflection is that the policies adopted for boosting
50 research productivity were not adequate in terms of policy design. To properly design
51 a policy in this field the necessary first step is to understand what affect the academic
52 productivity. In this context, Faria (2002) suggests that policies for fostering the
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2 overall productivity of the research sector are: (i) competition in the labour market
3 among researchers (e.g., through career or salary incentives) and (ii) increasing
4 research funds. Did the policies of Lombardy Region respect these elements? Are
5 there other elements that affect research productivity? These are interesting starting
6 point for further research in this field.
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11 Our second analysis regarded how five external factors (“external” because they are
12 not under the control of the departments) affect efficiency (section 4.2.). Our
13 empirical analysis suggests that none of these factors (location in metropolitan area,
14 scientific sector, university effect, proportion of tenured academic staff, departments
15 “longevity”) is able to adequately explain efficiency differentials. We consider this
16 result as positive, especially when thinking to the use of efficiency scores for policy
17 purposes (e.g., resources allocation). Indeed, a usual critic to the efficiency analyses
18 is that they provide results which are affected by factors which are not under the
19 control of the units themselves: when this is the case, a procedure of resource
20 allocation following efficiency results would be inequitable. Among others, Marinova
21 & Newman (2008), describing the new funding model for Australian universities’
22 research, pointed out several counterproductive mechanisms that can be created by
23 linking academic performance and resources without taking into account factors
24 affecting efficiency in a proper way. The authors concluded their paper stating that
25 among the “*two necessary pre-conditions for Australia to have a healthy, strong and*
26 *world-class university research sector*” one is that “*the funding model used should*
27 *allow for diversity and flexibility to properly reflect the complexity of academic world*”
28 (p.285).
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31 At the same time, we argue that there are some elements, which actually could
32 influence efficiency and which are related to some “soft” characteristics of the
33 academic units, typically (i) the incentive systems and (ii) the
34 governance/management. For instance, Ramsden (1994) pointed out that the
35 perception of the academic staff about the importance of publications for their career
36 was consistently related to the production of academic articles and books. Rodgers &
37 Neri (2007) suggested that the “departmental environment” is important and they
38 define it through several measures centred on the “human capital” of researchers
39 who work in the department. Unfortunately, QuESTIO dataset does not collect such
40 data: an extension of this dataset along this dimension could help to improve
41 significantly the understanding of this pattern.
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45 However, if the incentive system really matters, another conclusion can be drawn
46 from our study: as we measured a potential “university effect”, and it is not
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2 statistically relevant, then we can conclude that no incentive system works at
3 university level. Different reasons can be proposed to explain this result. In particular,
4 it can be both the cases that (i) the incentive system is designed at an higher level (in
5 Italy, at the central government level), or (ii) that it is designed at a lower
6 (department) level – and given the department-level of our data, we cannot exploit
7 such dimension, which requires individual-level data. The evidence about the
8 process for recruiting academic staff and its career in Italy suggests that, however,
9 no government-level incentive exists – indeed, the career of professors is very poorly
10 related to their scientific production.

11
12 Levin (1991) underlined the importance of incentives to raise the productivity of
13 universities' activities. More specifically, he acknowledged that higher education
14 shows productivity declines due to two main reasons: (i) it is a "stagnant industry", as
15 it is based on labour intensity, and (ii) clear rewards and property rights are absent.
16 Thus, the suggestion provided by the author is to develop a reward system within the
17 university based on clear goals, financial incentives and evaluation procedures.
18 Whether such schemes have been actually implemented in departments analysed in
19 this paper is not clear; probably detailed case studies can help to shed more light on
20 this topic through future research.

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22 The governance/management of the academic departments has not been analysed
23 in our study, as the only information available in this respect (the presence of a
24 quality system or a management control system) is a very indirect measure of the
25 governance process and the data recovery on this topic was quite imprecise. Another
26 way to improve the QuESTIO dataset should be to better investigate this dimension,
27 by including some qualitative descriptions about the way Department managers
28 organise and coordinate the activities and resources, formulate strategies and
29 foresight studies and manage networking activities (see for instance Sala et al.,
30 forthcoming; Salerno et al., 2008). Without knowing the characteristics of the
31 "management style" of each department, it is impossible to derive policy implications
32 from such dimension. At the same time, a possible way to better understand the
33 potential incidence of such phenomenon is to conduct case studies about the
34 successful academic departments (e.g. those with higher efficiency scores or those
35 which highly improved the scores in the last years).

36
37 Finally, a potential candidate to analyse the efficiency differentials is the interaction
38 between research and teaching activities conducted by the departments. Typically,
39 the literature did not paid enough attention to the interaction between teaching and
40 research at department level, mainly because both activities were considered as
41 inputs and outputs (see section 2). In this paper, the focus was exclusively on the
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2 research activities, but it raises also questions about the effects that the
3 (unmeasured) teaching activities play on the research result. This issue is very
4 relevant both in theoretical terms (are there economies of scope, or tradeoffs,
5 between the two activities?) and in empirical ones (which is the optimal allocation of
6 energies between teaching and research?). This interesting issue was at the centre
7 of several contributes since the seminal paper by Cohn et al. (1989), that for the first
8 time addressed and modelled the multi-outputs nature of academic activities.
9 Recently, the theme has been explored by Bonaccorsi & Daraio (2007) for a sample
10 of European universities. In the present paper, we cannot explore this topic because
11 QuESTIO dataset does not record data about the teaching dimension of the
12 departments' activities (as before, it could represent a substantial improvement of the
13 dataset).

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15 Finally, the issue of research quality still remains open. Indeed, our analysis is
16 focused only on a quantitative dimension of research, while quality is important to
17 adequately assess the performance. Typically the lack of data on this respect
18 justifies the scarce attention to this problem. However, the QuESTIO dataset will
19 include in the next years some qualitative indicators, like H and citation indexes. We
20 will devote attention to this topic in future research, also exploring trade-offs between
21 research quantity and quality.

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30 The analyses and the data have allowed an interesting discussion in terms of policy
31 implication but we hope that further research will follow both including new data (e.g.
32 referring to teaching activities and research quality) and considering other
33 geographical regions.
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References

- Abbott, M., Doucouliagos, C., (2003), The Efficiency of Australian Universities: a Data Envelopment Analysis, *Economics of Education Review*, 22(1), 89-97.
- Agasisti, T., (2009), Market Forces and Competition in University Systems: Theoretical Reflections and Empirical Evidence from Italy, *International Review of Applied Economics*, 23(4), 463-483.
- Agasisti, T., Dal Bianco, A., (2006), Data Envelopment Analysis of the Italian University System: Theoretical Issues and Policy Implications, *International Journal of Business Performance Management*, 8(4), 344-367.
- Agasisti, T., Dal Bianco, A., (2009), Reforming the University Sector: Effects on Teaching Efficiency. Evidence from Italy, *Higher Education*, 57(4), 477-498.
- Agasisti, T., Salerno, C., (2007), Assessing the cost efficiency of Italian universities, *Education Economics*, 15(4), 455-471.
- Athanassopoulos, A.D., Shale, E., (1997), Assessing the Comparative Efficiency of Higher Education Institutions in the UK by Means of Data Envelopment Analysis, *Education Economics*, 5(2), 117-134.
- Avkiran, N.K., (2001), Investigating Technical and Scale Efficiencies of Australian Universities Through Data Envelopment Analysis, *Socio-Economic Planning Sciences*, 35(1), 57-80.
- Banker, R. D., Charnes, A., Cooper, W., (1984), Models for Estimation of Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science*, 30, 1078-1092.
- Bonaccorsi, A., Daraio, C., (2007), *Universities and strategic knowledge creation*, Edward Elgar Publisher, Cheltenham, UK.
- Bonaccorsi, A., Daraio, C., Simar, L., (2006), Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data, *Scientometrics*, 66(2), 389-410.
- Brennan, J., Teichler U., (2008), The future of higher education and of higher education Research, *Higher Education*, 56, 259-264.
- Brockett, P.L., Golany, B., Shan Li, (1998), Analysis of intertemporal efficiency trends using rank statistics with an application evaluating the macro economic performance of OECD nations, *Journal of Productivity Analysis*, 11(1), 169-182.

Charnes, A., Cooper, W.W., Rhodes, E. (1978) Measuring the efficiency of decision making units, *European Journal of Operational Research*, 2, 429-444.

Clark, B., (1998), *Creating Entrepreneurial Universities: Organizational Pathways of Transformation*, Issues in Higher Education, Elsevier Science, New York.

Deleted: Clark, B. (1997), The modern integration of research activities with teaching and learning, *Journal of Higher Education* 68(3), 241-255. ¶

Cohn, E., Rhine, S.L.W., Santos, M.C. (1989), Institutions of higher education as multi-product firms: economies of scale and scope, *Review of Economics and Statistics*, 71, 284-290.

Cooke P., Uranga M. G., Etxebarria G. (1997) Regional Innovation Systems: Institutional and organisational dimensions, *Research Policy*, 26, 475-491.

Cooper, W.W., Seiford L.M., Tone K., (2006), *Introduction to Data Envelopment Analysis and Its Uses*, Springer, New York.

Curran, P.J., (2000), Competition in UK Higher Education: competitive advantage in the Research Assessment Exercise and Porter's diamond, *Higher Education Quarterly*, 54(4), 386-410.

Daraio, C., Simar L., (2005), Introducing environmental variables in nonparametric frontier models: a probabilistic approach, *Journal of Productivity Analysis*, 24(1), 93-121.

Etzkowitz, H., (2003), Research groups as 'quasi-firms': the invention of the entrepreneurial university, *Research Policy*, 32(1), 109-121.

Deleted: Elsen, M., Visser-Wijnveen, G.J., van der Rijst, R.M., van Driel, J.H., (2009), How to strengthen the connection between research and teaching in undergraduate university education, *Higher Education Quarterly*, 63(1), 64-85. ¶

Faria, J.R., Scientific, business and political networks in academia, *Research in Economics*, 56(1), 187-198.

Flagg, A.T., Allen, D.O., Field, K., Thurlow, T.W., (2004), "Measuring the Efficiency of British Universities: a Multi-Period Data Envelopment Analysis", *Education Economics*, 12(3), 231-249.

Gimenez, V.M., Martinez, J.L., (2006), Cost efficiency in the university: a departmental evaluation model, *Economics of Education Review*, 25, 543-553.

Hare, P., Wyatt, G., (1992), Economics of academic research and its implications for higher education, *Oxford Review of Economic Policy*, 8(2), 48-66.

Deleted: Hagermann, A., (2009), Towards a holistic framework for driving performance in externally-funded academic research, *Higher Education Quarterly*, 63(2), 196-206. ¶

Hood, C. (1991), A public management for all seasons? *Public Administration*, 69, 3-19.

Deleted: Hicks, D., (2009), Evolving regimes of multi-university research evaluation. *Higher Education*, 57, 393-404 ¶

Hood, C. (1995), The new public management in the 1980s: Variations on a theme. *Accounting Organizations and Society*, 20(2/3), 93-110.

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Johnes, G., Johnes, J., (1993), Measuring the Research Performance of UK Economics Departments: an Application of Data Envelopment Analysis, *Oxford Economic Papers*, 45, pp.332-347.

Johnes, G., Johnes, J., (1995), "Research Funding and Performance in UK University Departments of Economics: A Frontier Analysis", *Economics of Education Review*, 14(3), 301-314.

Johnes, J., (2004), Efficiency Measurement, in Johnes, G., Johnes, J., (eds), *International Handbook on the Economics of Education*, Edward Elgar Publishing Ltd, Cheltenham.

Johnes, J., (2006), Data Envelopment Analysis and its Application to the Measurement of Efficiency in Higher Education, *Economics of Education Review*, n. 25, pp. 273-288.

Kocher, M.G., Luptàcik, M., Sutter, M., (2006), Measuring Productivity of Research in Economics. A Cross-Country Study Using DEA, *Socio-Economic Planning Sciences*, 40, 314-332.

Koksal, G., Nalcaci, B., (2006), The relative efficiency of departments at a Turkish engineering college: a data envelopment analysis, *Higher Education*, 51(1), 173-289.

Kruskal, W.H, Wallis, W.A., (1952), Use of ranks in one-criterion variance analysis, *Journal of the American Statistical Association*, 47(260), 583-621.

Landoni, P., Verganti, R. 2006. Fostering Knowledge and Technology Transfer through evaluation systems at a regional level. *International Journal of Technology Transfer and Commercialisation*, Vol.5, No.4, pp.355-372

Lechner C., Dowling M. (1999) The Evolution of Industrial Districts and Regional Networks: The Case of the Biotechnology Region Munich/Martinsried, *Journal of Management and Governance*, 3, 309–338.

Levin, H.M., (1991), Raising productivity in higher education, *Journal of Higher Education*, 62(3), 242-262.

Madden, G., Savage, S., Kemp, S., (1997), Measuring public sector efficiency: a study of economics departments at Australian universities, *Education Economics*, 5(2), 153-167.

Marinova, D., Newman, P., (2008), The changing research funding regime in Australia and academic productivity, *Mathematics and Computers in Simulation* 78(2-3), 283-291.

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McMillan, M.L., Datta, D., (1998), The Relative Efficiencies of Canadian Universities: A DEA Perspective, *Canadian Public Policy*, 24(4), 485-511.

Moreno, A.A., Tadepali, R., (2002), Assessing Academic Department Efficiency at a Public University, *Managerial and Decision Economics*, 23, 385-397.

Ng, Y.C., Li, S.K., (2000), Measuring the Research Performance of Chinese Higher Education Institutions: An Application of Data Envelopment Analysis, *Education Economics*, 8(2), 139-156.

OECD, (2002), Proposed Standard Practise for Surveys of Research and Experimental Development - Frascati Manual, sixth edition.

OECD. (2003), Education policy analysis. Paris: OECD.

Pastor, J.T., Ruiz, J.L, Sirvent, I., (2002), A Statistical Test for Nested Radial Models, *Operations Research*, vol. 50, n. 4, pp.728-735.

Pesenti, R., Ukovich, W., (1996), Evaluating Academic Activities Using DEA, Internal Report, DEEI, Università di Trieste.

Porter M.E. (1998) Clusters and the New Economics of Competition, Harvard Business School Press.

Ramsden, P., (1994), Describing and explaining research productivity, *Higher Education*, 28(2), 207-226.

Rizzi, D., (1999), L'efficienza dei dipartimenti dell'Università Cà Foscari di Venezia via DEA e DFA (The efficiency of departments at University Cà Foscari through DEA and DFA), Working Paper, Università Cà Foscari di Venezia, Dipartimento di Scienze Economiche.

Rodgers, J. R., Neri, F., (2007), Research Productivity of Australian Academic Economists: Human-Capital and Fixed Effects, *Australian Economic Papers*, 41(6), 67-87.

Deleted: Robertson, J., Bond, C., (2005), The research/teaching relation: A view from the 'edge', *Higher Education*, 50, 509-535.¶

Sala A., Landoni P., Verganti R., (forthcoming) "R&D networks: an evaluation framework" *International Journal of Technology Management*.

Salerno M., Landoni P., Verganti R. "Designing foresight studies for Nanoscience and Nanotechnology (NST) future developments" *Technological Forecasting & Social Change*, 75(8), 1202-1223

Sarkis, J., (2007), Preparing your data for DEA, in Zhu. J., Cook, W.D., (eds.), *Modeling Data Irregularities and Structural Complexities in Data Envelopment Analysis*, Springer, New York.

1
2 Sarrico, C.S., Dyson, R.G., (2004), Restricting virtual weights in data envelopment
3 analysis, European Journal of Operational Research, 159(1), 17-34.

4
5 Sarrico, C.S., Teixeira, P.N., Rosa, M.J., Cardoso, M.F., (2009), Subject mix and
6 productivity in Portuguese universities, 197(2), 287-295.

7
8 Thursby, J.G., (2000), What Do We Say about Ourselves and What Does It Mean?
9 Yet Another Look at Economics Department Research, Journal of Economic
10 Literature, 38, 383-404.

11
12 Warning, S., (2004), Performance Differences in German Higher Education:
13 Empirical Analysis of Strategic Groups, Review of Industrial Organization, 24, 393-
14 408.

15
16 Wilson, P.W, (1995), Detecting influential observations in data envelopment analysis,
17 Journal of Productivity Analysis, 6(1), 27-45.

18
19 Zhu, J., (2003), Quantitative Models for Performance Evaluation and Benchmarking,
20 Kluwer Academic Publisher, Boston, MA.

Deleted: Zamorski, B. (2002),
Research-led teaching and learning in
higher education: A case, Teaching in
Higher Education, 7(4), 411-427.¶

Table 1. Inputs/outputs descriptive statistics

	Average	Std deviation	min	Max	Average difference 2004-2007
Laboratories (m ²)	2,243.83	6,917.93	0.00	60,180.00	80.24
Human resources (n)	105.50	83.30	9.00	445.00	16.19
High Qualified Human resources (n)	98.33	79.66	8.00	434.00	16.00
Other personnel (n)	7.12	6.83	0.00	32.00	-0.30
Revenues from financed activities (€)	486,936.06	557,412.78	0.00	3,039,361.00	142,196.00
Financed activities from abroad (€)	118,587.58	256,766.37	0.00	1,805,922.00	10,896.00
Revenues from orders (€)	451,240.13	764,559.23	0.00	3,333,362.00	86,950.00
Number of publications (n)	32.45	31.91	0.00	188.00	2.87
Doctorates in cooperation with external bodies (n)	2.49	4.04	0.00	22.00	0.63

Table 2. Efficiency scores (DEA on 2007 data) – descriptive statistics

	CRS Efficiency	VRS Efficiency	Scale Efficiency
Mean	0.745	0.786	0.937
St. Deviation	0.241	0.219	0.101
Min	0.173	0.216	0.432
Max	1.000	1.000	1.000
# efficient units	25	29	25

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 3. Malmquist index 2004-2007 – descriptive statistics

Department	Malmquist index	Efficiency change	Frontier shift
Mean	1.060	1.666	0.652
St. dev.	0.492	0.882	0.141
Min	0.072	0.529	0.104
Max	2.534	4.600	1.031
# improving units	35	56	2

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 4. Factors affecting efficiency (Kruskal-Wallis analysis)

Effects of Metropolitan area (Milan)	
H (observed value)	0.007
H (critic value)	3.481
p-value	0.934
Effects of subject mix	
H (observed value)	8.451
H (critic value)	9.488
p-value	0.076
University effects	
H (observed value)	9.426
H (critic value)	14.067
p-value	0.224
Effects of tenured staff proportion	
H (observed value)	0.163
H (critic value)	3.841
p-value	0.687
Effects of departments' age	
H (observed value)	1.172
H (critic value)	3.841
p-value	0.279

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Evaluating the efficiency of research in academic departments: an empirical analysis in an Italian Region

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Abstract.

14 This paper investigates the efficiency of university departments on science, technology and
15 medicine in an Italian Region (Lombardy). The aim of the paper is twofold: (i) to analyze the
16 changes in productivity in recent years (from 2004 and 2007), and (ii) to detect factors that
17 are potentially affecting efficiency. We benefited from a new and unique dataset (called
18 QuESTIO) developed by the Lombardy Regional Government.

19 Using facilities and academic staff as inputs, and research grants and publications as outputs,
20 we modelled the research activity of academic departments. The methodological approach for
21 computing efficiency scores is DEA (Data Envelopment Analysis); Malmquist indexes have
22 been used to measure changes in productivity, while Kruskal-Wallis tests were employed to
23 study the potential determinants of efficiency.

24 We obtained two main results. First, we found that in the period considered, the academic
25 departments improved their efficiency but, at the same time, the efficiency frontier worsened.
26 Second, we highlighted that external and measurable factors (like scientific sector, proportion
27 of tenured staff, location, etc.) have a limited impact in explaining efficiency differentials. Both
28 results are discussed in terms of policy implications.

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Keywords.

30 University research, efficiency, research policies, Data Envelopment Analysis, Malmquist
31 index

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JEL Codes.

33 C14, H41, H52
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1. Introduction and motivation

In recent years, Higher Education Institutions (HEIs) have been increasingly studied. In nowadays “knowledge economy” their importance for economic development, social equity, mobility, social cohesion and integration is widely acknowledged (Brennan & Teichler, 2008). Furthermore, given the difficult situation of public finances, considerations about resources allocation have been raised in many countries, calling for more evaluations and accountability. For these reasons the so called ‘New Public Management’ movement, started at the beginning of the 1980s in the public sector in general, has been also increasingly affecting the universities. New Public Management (Hood, 1991; 1995) represents the request to public organisations to become more managerial, in particular by drawing on practices and models from the private sector. This process has been driven both by universities themselves and by governments through reforming efforts. The results, especially in many countries within Europe, share some common characteristics: i) the introduction of incentives schemes based on financial models for allocating public funds, ii) new or strengthened assessment procedures and evaluation agencies, and iii) more emphasis on universities’ autonomy (OECD, 2003).

In this work we explored how the recent changes in the university system affected the efficiency of university research. In particular we were interested in understanding whether an overall increase in efficiency can be recognised and/or whether differences are present between universities given the previously noted enlarged autonomy. As a matter of facts, normally the majority of the reforming efforts have been directed towards education activities, whilst an increase in efficiency of university research has been assigned to incentive systems and evaluation processes. These are expected to have had an overall positive effect on the system, but at the same time they have left the universities in charge of finding and managing the ways to obtain better results. Given the autonomy of the universities and the decentralisation of responsibilities significant differences in terms of efficiency changes are thus expected between and within universities. Furthermore, the idea that performance differentials in terms of research are key for competition among departments is well-established in the literature (Curran, 2000).

We decided to focus on universities research activities and not on education or knowledge/technology transfer activities. Universities’ education activities constitute the first and original mission of the universities, but at the same time, they are normally carefully regulated by laws and already widely studied in terms of efficiency and quality (e.g. Madden et al., 1997; section 2 [Indicators](#) such as number of degrees awarded, rate of success, years of study, etc. have been widely used both

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2 to evaluate the universities and to introduce new policies. The opposite holds for
3 universities' knowledge/technology transfer activities. First of all, even if some argue
4 for this to be a third mission for academia and call for "entrepreneurial universities"
5 (Clark, 1998; Etzkowitz, 2003), others refuse this perspective and signal the risks of
6 focusing on and expanding the role of these activities. Moreover, the efficiency
7 analysis of these activities is hampered by the difficulties in finding the right
8 indicators. As a matter of facts, there are many different knowledge/technology
9 transfer activities (e.g., spin-off, consultancies, research projects with firms, patents,
10 etc.) and their evaluation can be based only partially on economic values given the
11 not for profit nature of universities (Landoni and Verganti, 2006). Finally, we **decided**
12 **to focus on the research activities because we** share the vision that **they** are the core
13 activities of universities, driving and informing both education activities and
14 knowledge/technology transfer activities. This relationship especially holds for
15 transfer activities because the value of the results transferred heavily rely on the
16 underlying research they are based on.
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24 In this work with the term "research" we adopt the standard definition provided by the
25 OECD: "*Research and development is a term covering three activities: basic*
26 *research, applied research, and experimental development*" (OECD, 2002) but we
27 consider only research activities that are normally carried out within universities.
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30 Furthermore in this work, as it is done in the evaluation systems previously cited, we
31 focus our efficiency analysis on university departments and not on the university as a
32 whole. Universities are composed of different research departments and usually they
33 significantly differ in terms of fields of activities and thus publication outputs, co-
34 authorship behaviors and thus efficiency. We believe that an analysis at the level of
35 the university can put forward mixed results, while an analysis at the level of single
36 departments is more precise and coherent with the objectives of an efficiency
37 analysis. For this reason, in order to obtain a sample of comparable departments we
38 focused our attention only on natural science departments, not considering the arts
39 and humanities ones. The choice of the department level for the analysis is coherent
40 with the focus on research activities: normally education activities are managed by
41 organizational entities inside the university that are transversal to more departments
42 and many transfer activities are centralized in a single organizational unit (i.e. Liason
43 office or Knowledge / Technology transfer office).
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50 Our analyses consider departments located in the Lombardy region (Italy). We have
51 chosen a regional focus in order to have similar contextual variables in terms of
52 policies, economic environment, etc. for the universities included in the analysis.
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Furthermore, Lombardy is one of the more advanced European regions both in terms of (i) economic development and (ii) research activities and universities: more than 9.4 millions of habitants, GDP per capita >34,000 €; 12 universities are located in the Region – out of about 70 in all the country, and more than 230,000 students.

Finally, the regional level is increasingly recognized as a relevant level of analysis in terms of research and innovation activities. Many authors (e.g. Cooke et. al., 1997; Porter, 1998; Lechner e Dowling, 1999) underline that it is at a local level that the majority of the connections between the different innovation actors take place. The localization of knowledge and the role of proximity as a driver of economic development (e.g. clusters) have also highlighted the importance of regional and local government in fostering and strengthening the actors and their relationships.

To summarize, the focus of the paper is on efficiency of research activities in scientific departments in the Lombardy Region (Italy). Our research questions are two:

- did changes in the overall efficiency of departments' research occurred between 2004 and 2007?
- which are the main factors affecting efficiency?

The paper is organized as follows: the next section present the more recent literature on the topic, then the methodology and the data used are introduced, finally results are presented and conclusions are drawn.

2. Background

The international literature about universities' efficiency – through non-parametric techniques – has been developed both at institution-level (Athanasopoulos & Shale, 1997; McMillan & Datta, 1998; Ng & Li, 2000; Avkiran, 2001; Abbott & Doucouliagos, 2003; Flagg, et al, 2004; Warning, 2004) and department-level. The latter is more relevant for the context of the present study.

The contributions by Johnes & Johnes (1993; 1995) highly influenced our methodological approach. In a first paper Johnes & Johnes (1993) measured the research performance of UK economics departments, by using staff numbers as inputs and publication counts and grants as outputs; the same strategy was adopted again for deriving efficiency scores of economics department in a subsequent paper (Johnes & Johnes, 1995). The authors ran several DEA models to test the robustness of results and claim for a possible use of results for policy purposes,

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2 especially for establishing an optimal allocation of resources across departments.
3 These two contributions are the most important as they focus exclusively on the
4 research dimension of the universities' work.

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6 Madden et al. (1997) studied the efficiency of economics departments in 29
7 Australian universities. Inputs were teaching and research staff, outputs were
8 graduates and publications (for teaching and research respectively). As in other
9 studies listed below, here the focus was both on teaching and research performance,
10 even if the analysis were conducted at subunit level (that is at departmental level
11 instead of institutional level). The specific objective of the Madden et al. (1997) study
12 was to verify whether policies promoted by the governments impacted on the
13 productivity; they confirmed that there was actually an increase in productive
14 efficiency.

15
16 Thursby (2000) analyzed the efficiency of the Economics Research Departments in
17 the US. He defined efficiency as follows: "(...) a department is deemed technically
18 efficient if, when compared to departments with similar level of inputs, it could
19 produce greater research outputs without increasing its inputs usage, or equivalently,
20 it is one which, compared to departments with similar levels of outputs, could
21 produce the current levels of outputs with fewer inputs" (p. 400). He used publication,
22 citation data and number of Ph.D.s as outputs, and faculty size, full professors,
23 graduate students, federal grants, library acquisitions and a dummy for private
24 ownership as inputs. He found that the average level of efficiency in US is incredibly
25 high (67% of economics departments appear as efficient). Seen from a European
26 perspective, this result is not so unexpected.

27
28 Moreno & Tadepalli (2002) focused on 42 academic units distributed across 7
29 colleges in the US. They used staff, financial resources and proxies for structures
30 (e.g., building space) as inputs, and number of students, FTE enrolments and grant
31 awards as outputs. In discussing their results, they evidenced that efficiency scores
32 do not illustrate information about effectiveness – that is, they argue that a qualitative
33 dimension is necessary for this purpose. Lastly, as their background is strongly
34 managerial, they also suggest a use of efficiency analysis as a planning tool, not only
35 for evaluating universities' activities.

36
37 Koksal & Nalcaci (2006) derived efficiency scores for 14 university departments at
38 the Middle East Technical University (METU) in Turkey, by using staff salaries, a
39 composite indicator of previous research quality and number of students as inputs,
40 and number of publications, graduates, and teaching indicators as outputs. Thus, in
41 their contribution, the authors focus also on the teaching activity of the departments.
42 They decided to use weights for teaching and research loads as suggested by
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2 university's administrators through a preliminary survey. The paper suggests that the
3 models adopted for computing efficiency can serve to set new targets for inefficient
4 departments.
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6 Gimenez & Martinez (2006) focused on cost efficiency of the departments at the
7 Autonomous University of Barcelona. They computed cost-efficiency scores and
8 separated cost excess into three categories: technical efficiency, fixed factors, scale
9 of size. The units of analysis were 42 departments, and again the focus is on both
10 teaching and research activities. The inputs chosen were: expenditure on temporary
11 hired teaching and research staff, operational expenditures, expenditures on tenure
12 staff. To measure the outputs, they employed the following variables: results of a
13 government evaluation process of research, teaching load (measured through credits
14 granted) and students' opinions. The authors suggest that their analyses can be
15 used to assess the differences between (i) the observed cost of the units and (ii) the
16 cost they would achieve assuming long-term cost minimization. Their result tells that
17 size does not matter in determining efficiency, while higher proportion of non-tenured
18 staff is associated with higher efficiency levels.
19

20 In another exercise presented by Kocher et al. (2006) the analysis is focused on the
21 productivity of research in economics across 21 OECD countries. The focus of the
22 paper is on research and the outputs selected are top publications (and impact
23 factors), while inputs are R&D expenditures, number of universities and total
24 population. This study is quite different, however, with respect to the relevant
25 contributions for the present paper, as the unit of analysis is the country (neither the
26 university nor the department). The results suggest that research productivity can be
27 raised through an increase in the scale of operations.
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29 An interesting issue is to analyze the related literature about the Italian universities'
30 research. To the best of the authors' knowledge, there are only two specific
31 contributes which specifically analyze the efficiency of universities in producing
32 research outputs (Pesenti & Ukovich, 1996; Rizzi, 1999), and just one attempting to
33 focus on teaching production (Agasisti & Dal Bianco, 2009).
34

35 The two contributions at departmental level (Pesenti & Ukovich, 1996; Rizzi, 1999)
36 use a similar set of variables and focus both on teaching and research outputs. The
37 main scope for these contributions is to provide information and suggestion for
38 allocating resources within a university.
39

40 Contributes about the efficiency of Italian higher education has been conducted at
41 institution-level (thus, not considering separately the structures devoted to teaching
42 and research). The reason for this choice can be summarized by the idea that the
43 strategy and the mission of universities is defined at macro(institution) level, then the
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2 balance between teaching and research is decided by the decision centres at
3 institution level (Bonaccorsi & Daraio, 2007, p.22).
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5 Among these contributions at an institutional level Agasisti & Dal Bianco (2006)
6 studied the efficiency of 58 Italian public universities, by using number of staff,
7 financial resources and students as inputs, and graduates and research grants as
8 outputs. They suggest the use of efficiency analysis for policy purposes, especially to
9 evaluate the differences in terms of performance between efficient and inefficient
10 units. Later, Agasisti & Salerno (2007) analysed the cost efficiency of another sample
11 of Italian universities, by adding some qualitative measures for inputs and outputs.
12 They conclude that a redistribution of inputs across universities could lead to an
13 overall improvement of efficiency in the Italian HE sector.
14

15 Bonaccorsi et al. (2006) used a robust non-parametric technique (developed by
16 Daraio & Simar, 2005) to take in account external conditions affecting the productivity
17 of universities. The inputs and outputs adopted are quite similar to previous studies
18 (that is, staff numbers, expenses and spaces as inputs, and publications and
19 graduates as outputs), but they also include some “external” factors: university size,
20 number of departments within the university, percentage of private funding, number
21 of curricula activated. Their conclusions are there economies of scale and scope are
22 not relevant factors in explaining (in)efficiency, but that a strong role is instead played
23 by the external factors – clearly, such result affects the policy considerations.
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28 To sum up, the literature seems to suggest that, to analyse research efficiency of
29 universities – that is, the efficiency in the production of research outputs:
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- 31 • inputs can be classified under three main groups: human resources, financial
32 resources and structures (e.g. facilities, buildings, etc.);
- 33 • outputs can be grouped into publications and grants.

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Clearly, the best indicators to measure these classes of inputs/outputs are
questionable, but the general emerging consensus is on a productive process that
can be described with such indicators. The present paper moves from these
suggestions, and it focuses on the efficiency of research activities in scientific
departments in the Lombardy Region (Italy).

3. Methodology and data

3.1. Methodology

The methodology is articulated accordingly to the two steps adopted to answer the
research questions of the paper: on one hand the efficiency analysis (including

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2 efficiency scores of the departments, changes across time and time trends), on the
3 other hand the effort to identify the determinants of efficiency.
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5 The first choice is about the methodology to compute efficiency, because there are
6 different methods to target the analysis of efficiency among different units Data
7 Envelopment Analysis (DEA) is a frontier, linear programming technique, introduced
8 by the seminal work of Charnes, et al. (1978). It deals with the efficiency problem of
9 complex organizations that produce many outputs using several inputs at a time.
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11 In this paper we have only briefly discussed some characteristics of DEA, referring
12 the interested reader to Johnes (2004); Cooper *et al.*, (2006), and Zhu (2003).
13

14 In a DEA model, the notion of efficiency is that of “technical efficiency”, defined as
15 the relative ability of each Decision Making Unit (DMU) in producing outputs, where
16 the term “relative” means that each organization is compared with any other
17 homogeneous unit. DEA could be represented by a linear programming technique
18 where each DMU tries to maximize the efficiency ratio (output over inputs) choosing
19 the best set of weights. There are two ways to deal with a DEA formulation: (i) input
20 oriented (that is, the ability to minimize inputs when outputs are given), and (ii) output
21 oriented (maximization of outputs given a certain bundle of inputs). In this paper, we
22 adopt this latter approach, as the typical problem for a research unit is to maximize
23 outputs (e.g., publications, grants, etc.) given its inputs (e.g. research staff,
24 laboratories, etc).
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DEA mathematical formulation can deal with both constant returns to scale (CRS) and variable returns (VRS). The seminal work of Charnes et al. (1978) introduced a constant return to scale (CRS) model where DMU dimension has no importance in defining efficiency performance (see equation 2). DMUs face the same efficiency frontier, independently of their relative size. Obviously, one can cast doubts on the comparability of small and large units. Larger units exploit common inputs to produce different outputs, whereas smaller ones benefit from substantial advantages in organizing activities. The BCC model, developed by Banker et al. (1984) introduces in DEA modelling the dimension factor.

Smaller units are associated with increasing economies of scale, and bigger units with decreasing economies of scale. In the middle, there is a “grey area” of constant returns to scale. So, it is also possible to compute the scale efficiency. This is defined as the ratio CRS/VRS efficiencies, and interpreted as the ability of each institution to benefit (in terms of productivity) from its size – in other words, in a VRS formulation, each DMU is compared only with those units having a comparable size.

We also measure changes in efficiency across time, and our relevant period is between 2004 and 2007. For measuring the determinants of the changes in efficiency scores, we use Malmquist index (for more information about this index see

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Johnes, 2004 and Coelli *et. al.*, 2006). Let us consider a DMU, named P that has a change in production position from P_t (in period t) to P_{t+1} (in period t+1). The change in the production frontier could have occurred in a non-neutral way - that is, it could be determined both by efficiency changes and shifts in the efficiency frontier. Thus, for measuring the change in the efficiency score, we have to break down the score in these two different components. Both of the components have a specific mean: the resulting score for the DMU could have positive or negative effects due to the own efficiency change or due to the shift (movement) of the frontier. Thus the resulting efficiency index is composed by two parts. The first component of the equation is the ratio of technical efficiency in time period t+1 on the technical efficiency in the period t. Since it measures the change in technical efficiency, it is equal to 1 if no changes occurred, greater than 1 if the change was positive, and less than 1 if it was negative. The second component measures the shift in the production frontier: if it is equal to 1 it has no effect on the efficiency score, if it is greater than 1 it has a positive effect and if it is less than 1 it has a negative effect. In other words, a shift in a production frontier that makes worse the relative position of the DMU (the other DMUs are performing relative better than before) provides a second component less than 1. The index (Malmquist index) resulting from the combination of these two components will be equal to 1 if there is no net effect of changes in technical efficiency and frontier changes; it will be greater than 1 if the net effect is positive, and less than 1 if it is negative. In our analysis, we name "efficiency change" the first component and "frontier shift" the second one.

Moreover, we would detect the eventual stability of efficiency rankings across the period (again, the relevant period is between 2004 and 2007). In this case, we adopted one of the statistics suggested by Brockett *et al.* (1998). More specifically, we are interested in knowing if the efficiency of departments changed influencing the rankings or not over time. *"Ranking the set of $n \times k$ efficiency ratings and observing the sum of ranks associated with each DMU, one can learn about the relative position of the DMUs vis-avis each other across the whole period"* (Brockett *et al.*, 1998, p. 174). For this purpose, the basis of the analysis is a Kruskal-Wallis test (Kruskal & Wallis, 1952) where the rejection of the null hypothesis leads to the conclusion that, in general, the different DMUs maintain their relative efficiency positions over time" (p. 175).

The second task in our methodology is to study some potential determinants of efficiency. To pursue this objective, we identified some external factors (e.g. "location" effects, "discipline" effects, etc.) and then we compared efficiency scores

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2 across different groups of units. The comparison was made by means of the Kruskal-
3 Wallis test (Kruskal & Wallis, 1952). This test allows the researcher to detect if are
4 there statistical differences across the groups analyzed (e.g., when comparing the
5 efficiency scores of units located in a metropolitan area with those located
6 elsewhere, the test indicates if this location effect generates a statistical difference
7
8 between the average scores of the two groups).

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12 3.2. Data

13 In this paper, we used a unique dataset that consists of input and output variables
14 about research and technology transfer activities in university departments located
15 within the Lombardy Region. This dataset is based on information coming from
16 QuESTIO system, a mapping of Research and Technological Transfer organisations
17 developed in Lombardy Region. The QuESTIO system, launched in 2004 by the
18 Regional Government, was intended to be a transparency and incentive tool for the
19 Research and Technological Transfer market by reducing any information
20 unevenness often binding cooperation among producers and users of knowledge.
21 The system pursues such scopes by collecting, updating and publishing financial,
22 organizational and structural characteristics of research organisations and
23 Knowledge Business Intelligence Services in Lombardy.

24 Since it aims at presenting the most detailed picture of Regional community active in
25 Research and Technological Transfer, the dataset has some specific criteria that are
26 pivotal for our analyses. First, the system is focused on every structure where such
27 activities are carried out, even where that structure is a part of a wider organisation.
28 Second, these structures should have significant management autonomy so that
29 their accountancy shall be determinable. The first criterion enables the regional
30 administration to collect information on every single department, being acknowledged
31 that departments belonging to the same university can differ significantly in terms of
32 performances. As a consequence the university departments, as well as sections
33 and institute of National Research Council or R&D unit belonging to a Company,
34 provide data making solely reference to their specific resources and outputs. The
35 second criterion assures that each structure included in the dataset is responsible (to
36 some extent) for its strategy and performances thus justifying application of DEA
37 technique.

38 University departments are main actors in Lombardy Innovation System; as a matter
39 of fact they are 147 out of 364 structures mapped, which balance the presence of
40 Knowledge Business Intelligence Services, which count for 151. The map is

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2 completed with 13 Hospital and medical research centres, 34 Public Research
3 Organizations and 19 company R&D units.
4

5 In order to better point out the capillarity of these structures within the territory, the
6 geographical analysis shows a concentration in the Province of Milan, and a little less
7 in Bergamo, Brescia, Pavia and Varese, which is explained by the presence of
8 universities in those cities, all of them accredited with their single departments.
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10 We built our dataset by considering those university departments that provided
11 information for the whole period 2004-2007 (units for which there are not missing
12 data), by selecting the following variables:
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15 INPUTS

16 I1. Laboratories

17 This variable considers the areas (measured in square meters) devoted to
18 laboratories belonging to or accessible by the department. This data provides a
19 dimensional data related to the most distinctive and characterizing areas equipped
20 for scientific research.
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23 I.2. High-Qualified Human Resources

24 It refers to persons who perform research and technology transfer activities,
25 regardless of their qualifications. They are mainly full professors, associated
26 professors, permanent researchers, post-Doc scholarships and PhD students. It
27 includes employees dedicated to activities in support of research, like: certification,
28 tests and measurements, patenting and commercialisation, financial assistance,
29 partners search, technologies monitoring, events organisation, editing of technical-
30 scientific "spreading publications".
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33 I.3. Other personnel

34 This variable considers administrative personnel that should ensure the efficient
35 working of human resources devoted to research and technology transfer activities.
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38 OUTPUTS

39 O.1. Revenues from financed activities

40 Accomplished activities financed with regional or national calls for bids. This variable
41 denotes the ability of the department to compete with other research organizations in
42 getting public-funded research, thus measuring the amount of research that meet
43 requirements of national and regional R&I strategies.
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46 O.2. Revenues from financed activities from abroad

47 Accomplished activities financed shows the capacity of drawing on international
48 funding, like the European projects, resulting by working with third countries
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2 organizations. It reflects department down stream internationalization and it is a sign
3 of the research activities that are acknowledged at international level.

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5 O.3. Revenue from orders

6 This variable measures how far research activities carried out in a department are
7 committed directly by companies or other institutions.

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9 O.4. Yearly number of publications

10 This variable reports yearly articles signed by department human resources on the
11 international scientific press. This is the traditional and widespread variable used to
12 measure the output of research activities.

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14 O.5. Doctorates in cooperation with external bodies

15 This variable sheds light on the capability of departments in attracting investments for
16 education finalized to research and to establish cooperation with institutions and
17 companies. Since this variable could be interpreted such as an indicator of
18 technology transfer activities, we investigated if it could alter the efficiency scores
19 and we ran a DEA model without considering it. The results are the same for almost
20 all the DMUs so we decided to keep it in the model.
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26 As discussed in the previous section the choice of input and output variables is
27 coherent with the most recent literature. The final sample contains 75 departments,
28 for 4 years – overall, there are 300 observations. Descriptive statistics are illustrated
29 in Table 1.
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33 <Table 1> around here
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35 **4. Results**

36 In this section, we illustrate the results obtained through the DEA analysis on the
37 university departments in the Lombardy Region.
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41 The results are presented in two main sections. The first is devoted to a description
42 of the efficiency scores with reference to the year 2007 (the last year available,
43 where the results are more stable as previously discussed). In this section one
44 subparagraph analyses the change in efficiency between the first year of our dataset
45 (2004) and the last year (2007) and another one explore the presence of time trends
46 in the efficiency scores. The second section refers to the study of statistical
47 differences among efficiency scores due to “external factors”, such as localization,
48 discipline subject, etc.
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4.1. DEA efficiency scores, year 2007

This section explores the results of the efficiency analyses both looking at a single year (2007) and at differences between years.

4.1.1. DEA efficiency scores, year 2007

Table 2 reports the descriptive statistics about the efficiency scores derived with reference to the year 2007 (the annex reports the specific scores for each department). As explained in the methodological section, we calculated CRS efficiency and VRS efficiency, as well as the “scale” efficiency computed as CRS/VRS scores (it is important to recall here that the model is output-oriented).

<Table 2> around here

The research efficiency of university departments in the Lombardy Region looks quite high (0.75 in terms of CRS efficiency, 0.78 in terms of VRS efficiency); actually, the high average efficiency is coherent with previous results derived across the world in the higher educations sector (Salerno, 2003). What is worth pointing out is a strong heterogeneity across departments – indeed, the standard deviation is >0.2 . A look at the lowest scores suggests that there are very poor performers which shows scores <0.5 .

Data about scale efficiency suggests that all the departments have almost reached their optimal scale of operations (given their present scale), as the scale efficiency score is very high (>0.93) and standard deviation is very low (about 0.1) in this respect.

The picture that emerges from this first analysis of efficiency scores is a sector where there is a number of very efficient units (both assuming constant or variable returns to scale) and a number of departments which experienced low levels of technical efficiency; thus, as the anecdotic evidence suggests, there is quite a strong differentiation among departments in terms of research efficiency.

As the focus of our paper is the efficiency of academic departments in the Lombardy Region, we also checked the robustness of our results by considering revenues from entities located in the Lombardy Region as a separate output (REV_LOMB). The correlation among results obtained by the baseline model and this modified model is very high (>0.97). the VRS efficiency scores for each department comparing the two models (also in this case the reference year is 2007) is available, on request, from the authors.

4.1.2. Efficiency changes between 2004 and 2007 – a Malmquist analysis

Following the methodology described above, we derived the Malmquist index, which allows us to disentangle the efficiency changes due to “pure” efficiency improvement (or worsening) and technological improvement (or worsening). The descriptive statistics about the results are reported in Table 3, while the detailed results are available on request from the authors.

<Table 3> around here

The picture that emerges highlights an interesting phenomenon. It looks like an improvement in productivity did not occur (because the Malmquist index is around 1) but, looking at the decomposition of the index, the reality appears more complex: an efficiency changes happened, it was very positive (the index is >1.6) and involved the major part of the departments (56 out of 70); on the other side, there was a relevant detriment of the technology environment (the “frontier shift” indicator is <0.7). It looks like the academic units improved their technical efficiency (that is, the ability to transform inputs into outputs) but, at the same time, the frontier worsened. In other words, what happened is that the “technological change” (in the Malmquist language) was negative.

What is “technology” in a regional research system, when we define research performance as the ability to attract financial resources and to publish in academic journals? Technology could be defined as the bundle of policies that should help in improving research efficiency, e.g. Information Technologies, research grants, support for publishing research results or to attract financial resources from international grants or companies, etc. Thus, the results contained in Table 3 suggest that, while the majority of the universities improved their efficiency, the system as a whole did not experienced an improvement in terms of technology available. A discussion about the potential responsibilities for such phenomenon will be reported in the last section, which deals with policy implications of our work.

4.1.3. Productivity changes between 2004 and 2007 – an analysis of “rankings stability”

Lastly, we analyzed the stability of rankings across our analysis period (between 2004 and 2007) by means of the H index proposed by Brockett et al. (1998). The index is equal to 177.96, and it must be compared with H^2 that is equal to 102.99. The rejection of the null hypothesis leads to the conclusion that some of the academic departments exhibit consistently better economic performance than others

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2 (as measured by the input-output factors that were included in our model) (see
3 Brockett et al., 1998).

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5 Reading this results together with the Malmquist index, it looks like the academic
6 departments improved their performance, but some units continue to perform better
7 than others. At the same time, the results show that some units are not efficient –
8 that is, the frontier actually worsened.
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10 11 12 13 *4.2. DEA efficiency scores, year 2007 – the external factors affecting efficiency*

14 In this second section, given the evidence on the efficiency results, it is interesting to
15 explore which are the determinants of this efficiency or, in other words, what could
16 actually affect a department's performance.
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18 To answer this question, we tested a number of different factors, by using the
19 Kruskal-Wallis test as methodological approach (see the data section). All the results
20 are listed in Table 4.
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26 27 *4.2.1 First external factor: are departments located in Milan metropolitan area* 28 *(regional capital) more efficient than other departments?* 29

30 We analysed this factor on the assumption that in a metropolitan area the
31 competition among research centres enforces departments' managerial efficiency. In
32 Milan, there is an important concentration of public and private research institutions
33 and the competition for resources is not limited to departments. The high
34 concentration of research facilities may justify a greater effort by departments in
35 fostering a more balanced use in input resources or may impulse an effort in control
36 for managerial quality. Elsewhere, Agasisti (2009) demonstrated that the effect of
37 competition on Italian universities' performance is positive – but, there, output was
38 defined through teaching dimension's measures.
39

40 We ran a Kruskal-Wallis test to verify the statistical difference between the efficiency
41 scores of departments located in Milan versus the other departments. We do not find
42 evidence of difference in efficiency performance between the two groups (indeed, the
43 observed value of the H statistic is nearly 0, and the p-value >0.9). This evidence
44 suggests that there is no "concentration" effect or "location" effect on efficiency
45 performance of university departments or, at least, in the relative rankings. At the
46 same time, this result may suggest i) the existence of no competitive pressure in a
47 high concentration area as Milan, or that ii) we have to look at overall concentration
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2 of research centres, and not only to university departments (e.g., there could be a
3 “university” effect which could dominate a “location” effect, or that iii) there is
4 competition but at the same time more opportunities to find resources (more demand
5 for research, and consequently the amount of resources is enough to guarantee a
6 sufficient level of grants for different departments without the need to compete one
7 against the others).

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12 *4.2.2. Second external factor: can different scientific sectors affect university*
13 *department efficiency?*

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15 As we measured “output” by using i) publication counts and ii) research grants (of
16 different kinds), it is important to recall that there are some differences in the average
17 number and quality of publication across different disciplines (e.g. medicine versus
18 engineering or biology), as well as differences in terms of attractiveness of research
19 funds (e.g., in engineering fields it is simpler to attract grants for applied research
20 than in physics).

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23 The idea that disciplines greatly vary in terms of costs and productivity is not new,
24 and the suggestion to take this factor into account is important to obtain not-biased
25 results (Sarrico & Dyson, 2004). Recently, Sarrico et al. (2009) demonstrated a
26 strong role of “subject mix” (defined as the disciplinary composition of institutions) in
27 explaining the efficiency differentials among Portuguese higher education institutions.
28 The authors acknowledged that “(...) *research production also varies significantly*
29 *from subject to subject, with medical, some natural and technical sciences being*
30 *more prolific in the number of articles than most of the social sciences and*
31 *humanities”* (p.290). Also Ramsden (1994), in his empirical analysis of Australian
32 research departments, adjusted the coefficients on the basis of discipline subjects.

33
34 We find a small, but statistically significant difference among university departments
35 classified by scientific sectors: the observed value of the H statistic is >8.4, near the
36 critical value (9.4), and the p-value is 0.07 (then the effect has statistical significance
37 at the 10% level). However, given the limited power of this effect, it is not easy to
38 determine which sectors outperform the others straightforwardly.

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45 *4.2.3. Third external factor: is there a “university effect”?*

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47 An alternative explanation of efficiency can refer to the existence of a “university
48 effect”, that is if a university is more efficient than others, then its departments could
49 be more productive than those belonging to other universities. This assumption finds
50 its justification in the setting of strategies at university levels, not at subunits levels. In
51 this respect, Bonaccorsi & Daraio (2007, pp. 22-23) pointed out that “(...) *the notion*
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of strategy is much more relevant and interesting if assumed at the overall university level. On the one hand, most strategic decisions are made at university level. (...) The fundamental reason for assuming the university level as the unit of analysis is that at the university level the problem of attribution of inputs (in particular, human resources, funding and physical capital) to specific units of outputs, can be kept under control". Even if these authors recognized that a lower unit of analysis could provide useful information on the actual research process, they suggest that a "university effect" (due to different strategies and characteristics at macro-level) can be detected.

Our tests suggest that such effect is not explaining efficiency differentials for our sample (observed value of the H statistic is 9.4, well below the critical value of 14.06, and the p-value is 0.22).

4.2.4. Fourth external factor: does the number of tenured academic staff influence efficiency?

The proportion of tenured research staff theoretically can affect the efficiency of a department: there is anecdotic evidence that tenured and non-tenured staff face quite different stimulus and incentives. Nevertheless, the direction of this influence is not clear a priori: tenured staff is certainly more expert in attracting research grants and in publishing academic papers, also thanks to reputational advantages; conversely, non-tenured staff can have an incentive to be more productive, for instance as a mean to obtain a tenured position. The promotion system can affect productivity if researchers are satisfied with rules promoting this dimension (a discussion of motivations behind researchers' activity is in Ramsden, 1994, pp.214-215).

A complementary idea behind this question is that the different human capital of researchers (in our paper, indirectly measured via the tenured status) can affect the research productivity of the research groups – and so, of the department. In this respect, an interesting example is the paper by Rodgers & Neri (2007), who specifically attempted to correlate the human capital of researchers with the research productivity of Australian departments of Economics. They have found that human capital differential account for about 50% of the observed differences in research productivity. If human capital is (even indirectly) captured by the tenured status (e.g., researchers with more experience should have reached their tenured position), then we should expect a correlation between the proportion of tenured researchers and the department's results. Ramsden (1994) showed that productivity of professors and readers was much higher than that of lecturers.

Our analysis did not find evidence of a statistical influence of this factor on research efficiency (the value of the H statistic is 0.16 and the related p-value is >0.6).

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4.2.5. Fifth external factor: can departments' "longevity" affect research efficiency?

Finally, we looked at the possible effects due to the longevity of departments. As we measured inputs in terms of numbers of academic staff and laboratories/facilities, it is reasonable that older departments accumulated higher stocks of inputs that could influence their outputs.

A key assumption here is that older departments can favour more cohesion among its members, then facilitating the climate of "collaboration" and "common motivation" that some authors pointed out as a determinant of research productivity (Ramsden, 1994).

Another interesting point of view about this potential phenomenon is that it is related to the "critical mass" dimension. Among the economic aspects of research, Hare & Wyatt (1992) underlined that the ability in producing research relies upon the human capital accumulated by the individual researchers; thus, *"combining this process with the notion that there are economies of scale in research may dispose university departments to feel they need to have at least some critical mass of researchers working in the same area in order to function properly as research units"* (pp. 55-56). Consequently, it could be reasonable to assume that older departments are more likely to have reached such "optimal" scale dimension than the more recently established ones.

The statistical analysis did not provide statistically robust results on this effect, indeed the value of the H statistic is 1.172 – while the critical value is around 3.8, so that the p-value is 0.27).

5. Discussion and policy conclusions

As highlighted discussing the literature on the topic, the analyses presented in this work are innovative in terms of data and methodology. Indeed, in this paper we have investigated the efficiency of university departments on science and technology and medicine in an Italian Region (Lombardy). The aim of the paper was (i) to analyze the changes in productivity in recent years (from 2004 and 2007), and (ii) to detect factors that are potentially affecting efficiency.

Discussing our results about the efficiency change between 2004 and 2007, some questions must be posed: how can a Malmquist index equal to 1 exactly be interpreted? How can we judge a frontier shift that is less than 1? Each academic

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2 unit, on average, is in the 2007 in the same position *relative to the frontier* than in the
3 2004 (indeed, also the H index calculated above suggests small changes in the
4 rankings in the period considered). However, what happened is something different:
5 the vast majority of the units actually improved their productivity in the period
6 (“efficiency change” >1) but the “frontier shift” was <1: it means that the performance
7 differential is much less dispersed in 2007, but at the same time it happens because
8 the frontier is not improved – the best performers did not improve, or even worsened
9 their efficiency. The summary statistics confirms this idea (look at the really lower
10 mean in 2004, with a much higher dispersion – standard deviation – around it). The
11 result is a “research system” in the region that performs better on average, but
12 without having excellence.

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18 The importance of evaluation and accountability has been growing in these recent
19 years and criteria used are widely acknowledged: publications and the ability to
20 gather financial resources (from abroad or from firms). Since the application of these
21 evaluations for funding allocation is more and more concrete, we believe that the
22 weakest departments raised their attention towards those performances. Thanks to
23 this new attention the weakest departments have increased their efficiency and
24 become much closer to the best performers that, on the contrary, had little margin for
25 further improvements.

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29 This result requires an important policy discussion. Indeed, the objective of the
30 Lombardy Region was to foster the performance of excellent research units. This
31 purpose animated some policy interventions such as the creation of “clusters”, the
32 policies for improving contacts between companies’ demand and research units
33 through vouchers (the idea behind is that the best research units would be able to
34 collect more vouchers), etc. Apparently, the results obtained are in the opposite
35 direction.

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39 This fact raises two reflections. The first is that maybe the universities (and,
40 consequently, the research units) look not at the regional incentives, but at the
41 national ones (as the Ministry is still the main financer of the universities’ activities)
42 and at international ones (the research reputation strongly depends upon the ability
43 to publish in international journals and to attract international grants). If this is the
44 case, a question arises about the opportunity for a regional government to be
45 involved in this sector.

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49 A second (possibly alternative) reflection is that the policies adopted for boosting
50 research productivity were not adequate in terms of policy design. To properly design
51 a policy in this field the necessary first step is to understand what affect the academic
52 productivity. In this context, Faria (2002) suggests that policies for fostering the
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2 overall productivity of the research sector are: (i) competition in the labour market
3 among researchers (e.g., through career or salary incentives) and (ii) increasing
4 research funds. Did the policies of Lombardy Region respect these elements? Are
5 there other elements that affect research productivity? These are interesting starting
6 point for further research in this field.
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10 Our second analysis regarded how five external factors (“external” because they are
11 not under the control of the departments) affect efficiency (section 4.2.). Our
12 empirical analysis suggests that none of these factors (location in metropolitan area,
13 scientific sector, university effect, proportion of tenured academic staff, departments
14 “longevity”) is able to adequately explain efficiency differentials. We consider this
15 result as positive, especially when thinking to the use of efficiency scores for policy
16 purposes (e.g., resources allocation). Indeed, a usual critic to the efficiency analyses
17 is that they provide results which are affected by factors which are not under the
18 control of the units themselves: when this is the case, a procedure of resource
19 allocation following efficiency results would be inequitable. Among others, Marinova
20 & Newman (2008), describing the new funding model for Australian universities’
21 research, pointed out several counterproductive mechanisms that can be created by
22 linking academic performance and resources without taking into account factors
23 affecting efficiency in a proper way. The authors concluded their paper stating that
24 among the “*two necessary pre-conditions for Australia to have a healthy, strong and*
25 *world-class university research sector*” one is that “*the funding model used should*
26 *allow for diversity and flexibility to properly reflect the complexity of academic world*”
27 (p.285).
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36 At the same time, we argue that there are some elements, which actually could
37 influence efficiency and which are related to some “soft” characteristics of the
38 academic units, typically (i) the incentive systems and (ii) the
39 governance/management. For instance, Ramsden (1994) pointed out that the
40 perception of the academic staff about the importance of publications for their career
41 was consistently related to the production of academic articles and books. Rodgers &
42 Neri (2007) suggested that the “departmental environment” is important and they
43 define it through several measures centred on the “human capital” of researchers
44 who work in the department. Unfortunately, QuESTIO dataset does not collect such
45 data: an extension of this dataset along this dimension could help to improve
46 significantly the understanding of this pattern.
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51 However, if the incentive system really matters, another conclusion can be drawn
52 from our study: as we measured a potential “university effect”, and it is not
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2 statistically relevant, then we can conclude that no incentive system works at
3 university level. Different reasons can be proposed to explain this result. In particular,
4 it can be both the cases that (i) the incentive system is designed at an higher level (in
5 Italy, at the central government level), or (ii) that it is designed at a lower
6 (department) level – and given the department-level of our data, we cannot exploit
7 such dimension, which requires individual-level data. The evidence about the
8 process for recruiting academic staff and its career in Italy suggests that, however,
9 no government-level incentive exists – indeed, the career of professors is very poorly
10 related to their scientific production.

11 Levin (1991) underlined the importance of incentives to raise the productivity of
12 universities' activities. More specifically, he acknowledged that higher education
13 shows productivity declines due to two main reasons: (i) it is a "stagnant industry", as
14 it is based on labour intensity, and (ii) clear rewards and property rights are absent.
15 Thus, the suggestion provided by the author is to develop a reward system within the
16 university based on clear goals, financial incentives and evaluation procedures.
17 Whether such schemes have been actually implemented in departments analysed in
18 this paper is not clear; probably detailed case studies can help to shed more light on
19 this topic through future research.

20 The governance/management of the academic departments has not been analysed
21 in our study, as the only information available in this respect (the presence of a
22 quality system or a management control system) is a very indirect measure of the
23 governance process and the data recovery on this topic was quite imprecise. Another
24 way to improve the QuESTIO dataset should be to better investigate this dimension,
25 by including some qualitative descriptions about the way Department managers
26 organise and coordinate the activities and resources, formulate strategies and
27 foresight studies and manage networking activities (see for instance Sala et al.,
28 forthcoming; Salerno et al., 2008). Without knowing the characteristics of the
29 "management style" of each department, it is impossible to derive policy implications
30 from such dimension. At the same time, a possible way to better understand the
31 potential incidence of such phenomenon is to conduct case studies about the
32 successful academic departments (e.g. those with higher efficiency scores or those
33 which highly improved the scores in the last years).

34 Finally, a potential candidate to analyse the efficiency differentials is the interaction
35 between research and teaching activities conducted by the departments. Typically,
36 the literature did not paid enough attention to the interaction between teaching and
37 research at department level, mainly because both activities were considered as
38 inputs and outputs (see section 2). In this paper, the focus was exclusively on the

1
2 research activities, but it raises also questions about the effects that the
3 (unmeasured) teaching activities play on the research result. This issue is very
4 relevant both in theoretical terms (are there economies of scope, or tradeoffs,
5 between the two activities?) and in empirical ones (which is the optimal allocation of
6 energies between teaching and research?). This interesting issue was at the centre
7 of several contributes since the seminal paper by Cohn et al. (1989), that for the first
8 time addressed and modelled the multi-outputs nature of academic activities.
9 Recently, the theme has been explored by Bonaccorsi & Daraio (2007) for a sample
10 of European universities. In the present paper, we cannot explore this topic because
11 QuESTIO dataset does not record data about the teaching dimension of the
12 departments' activities (as before, it could represent a substantial improvement of the
13 dataset).

14
15 Finally, the issue of research quality still remains open. Indeed, our analysis is
16 focused only on a quantitative dimension of research, while quality is important to
17 adequately assess the performance. Typically the lack of data on this respect
18 justifies the scarce attention to this problem. However, the QuESTIO dataset will
19 include in the next years some qualitative indicators, like H and citation indexes. We
20 will devote attention to this topic in future research, also exploring trade-offs between
21 research quantity and quality.

22
23 The analyses and the data have allowed an interesting discussion in terms of policy
24 implication but we hope that further research will follow both including new data (e.g.
25 referring to teaching activities and research quality) and considering other
26 geographical regions.

References

Abbott, M., Doucouliagos, C., (2003), The Efficiency of Australian Universities: a Data Envelopment Analysis, *Economics of Education Review*, 22(1), 89-97.

Agasisti, T., (2009), Market Forces and Competition in University Systems: Theoretical Reflections and Empirical Evidence from Italy, *International Review of Applied Economics*, 23(4), 463-483.

Agasisti, T., Dal Bianco, A., (2006), Data Envelopment Analysis of the Italian University System: Theoretical Issues and Policy Implications, *International Journal of Business Performance Management*, 8(4), 344-367.

Agasisti, T., Dal Bianco, A., (2009), Reforming the University Sector: Effects on Teaching Efficiency. Evidence from Italy, *Higher Education*, 57(4), 477-498.

Agasisti, T., Salerno, C., (2007), Assessing the cost efficiency of Italian universities, *Education Economics*, 15(4), 455-471.

Athanassopoulos, A.D., Shale, E., (1997), Assessing the Comparative Efficiency of Higher Education Institutions in the UK by Means of Data Envelopment Analysis, *Education Economics*, 5(2), 117-134.

Avkiran, N.K., (2001), Investigating Technical and Scale Efficiencies of Australian Universities Through Data Envelopment Analysis, *Socio-Economic Planning Sciences*, 35(1), 57-80.

Banker, R. D., Charnes, A., Cooper, W., (1984), Models for Estimation of Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science*, 30, 1078-1092.

Bonaccorsi, A., Daraio, C., (2007), *Universities and strategic knowledge creation*, Edward Elgar Publisher, Cheltenham, UK.

Bonaccorsi, A., Daraio, C., Simar, L., (2006), Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data, *Scientometrics*, 66(2), 389-410.

Brennan, J., Teichler U., (2008), The future of higher education and of higher education Research, *Higher Education*, 56, 259–264.

Brockett, P.L., Golany, B., Shan Li, (1998), Analysis of intertemporal efficiency trends using rank statistics with an application evaluating the macro economic performance of OECD nations, *Journal of Productivity Analysis*, 11(1), 169-182.

1
2 Charnes, A., Cooper, W.W., Rhodes, E. (1978) Measuring the efficiency of decision
3 making units, *European Journal of Operational Research*, 2, 429-444.

4
5 Clark, B., (1998), *Creating Entrepreneurial Universities: Organizational Pathways of*
6 *Transformation, Issues in Higher Education*, Elsevier Science, New York.

7
8 Cohn, E., Rhine, S.L.W., Santos, M.C. (1989), Institutions of higher education as
9 multi-product firms: economies of scale and scope, *Review of Economics and*
10 *Statistics*, 71, 284-290.

11
12 Cooke P., Uranga M. G., Etxebarria G. (1997) *Regional Innovation Systems:*
13 *Institutional and organisational dimensions*, *Research Policy*, 26, 475-491.

14
15 Cooper, W.W., Seiford L.M., Tone K., (2006), *Introduction to Data Envelopment*
16 *Analysis and Its Uses*, Springer, New York.

17
18 Curran, P.J., (2000), Competition in UK Higher Education: competitive advantage in
19 the Research Assessment Exercise and Porter's diamond, *Higher Education*
20 *Quarterly*, 54(4), 386-410.

21
22 Daraio, C., Simar L., (2005), Introducing environmental variables in nonparametric
23 frontier models: a probabilistic approach, *Journal of Productivity Analysis*, 24(1), 93-
24 121.

25
26 Etkowitz, H., (2003), Research groups as 'quasi-firms': the invention of the
27 entrepreneurial university, *Research Policy*, 32(1), 109-121.

28
29 Faria, J.R., Scientific, business and political networks in academia, *Research in*
30 *Economics*, 56(1), 187-198.

31
32 Flagg, A.T., Allen, D.O., Field, K., Thurlow, T.W., (2004), "Measuring the Efficiency of
33 British Universities: a Multi-Period Data Envelopment Analysis", *Education*
34 *Economics*, 12(3), 231-249.

35
36 Gimenez, V.M., Martinez, J.L., (2006), Cost efficiency in the university: a
37 departmental evaluation model, *Economics of Education Review*, 25, 543-553.

38
39 Hare, P., Wyatt, G., (1992), Economics of academic research and its implications for
40 higher education, *Oxford Review of Economic Policy*, 8(2), 48-66.

41
42 Hood, C. (1991), A public management for all seasons? *Public Administration*, 69, 3-
43 19.

44
45 Hood, C. (1995), The new public management in the 1980s: Variations on a theme.
46 *Accounting Organizations and Society*, 20(2/3), 93-110.

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Johnes, G., Johnes, J., (1993), Measuring the Research Performance of UK Economics Departments: an Application of Data Envelopment Analysis, Oxford Economic Papers, 45, pp.332-347.

Johnes, G., Johnes, J., (1995), "Research Funding and Performance in UK University Departments of Economics: A Frontier Analysis", Economics of Education Review, 14(3), 301-314.

Johnes, J., (2004), Efficiency Measurement, in Johnes, G., Johnes, J., (eds), International Handbook on the Economics of Education, Edward Elgar Publishing Ltd, Cheltenham.

Johnes, J., (2006), Data Envelopment Analysis and its Application to the Measurement of Efficiency in Higher Education, Economics of Education Review, n. 25, pp. 273-288.

Kocher, M.G., Luptàcik, M., Sutter, M., (2006), Measuring Productivity of Research in Economics. A Cross-Country Study Using DEA, Socio-Economic Planning Sciences, 40, 314-332.

Koksal, G., Nalcaci, B., (2006), The relative efficiency of departments at a Turkish engineering college: a data envelopment analysis, Higher Education, 51(1), 173-289.

Kruskal, W.H, Wallis, W.A., (1952), Use of ranks in one-criterion variance analysis, Journal of the American Statistical Association, 47(260), 583-621.

Landoni, P., Verganti, R. 2006. Fostering Knowledge and Technology Transfer through evaluation systems at a regional level. International Journal of Technology Transfer and Commercialisation, Vol.5, No.4, pp.355-372

Lechner C., Dowling M. (1999) The Evolution of Industrial Districts and Regional Networks: The Case of the Biotechnology Region Munich/Martinsried, Journal of Management and Governance, 3, 309–338.

Levin, H.M., (1991), Raising productivity in higher education, Journal of Higher Education, 62(3), 242-262.

Madden, G., Savage, S., Kemp, S., (1997), Measuring public sector efficiency: a study of economics departments at Australian universities, Education Economics, 5(2), 153-167.

Marinova, D., Newman, P., (2008), The changing research funding regime in Australia and academic productivity, Mathematics and Computers in Simulation 78(2-3), 283-291.

1
2 McMillan, M.L., Datta, D., (1998), The Relative Efficiencies of Canadian Universities:
3 A DEA Perspective, Canadian Public Policy, 24(4), 485-511.

4
5 Moreno, A.A., Tadepali, R., (2002), Assessing Academic Department Efficiency at a
6 Public University, Managerial and Decision Economics, 23, 385-397.

7
8 Ng, Y.C., Li, S.K., (2000), Measuring the Research Performance of Chinese Higher
9 Education Institutions: An Application of Data Envelopment Analysis, Education
10 Economics, 8(2), 139-156.

11
12 OECD, (2002), Proposed Standard Practise for Surveys of Research and
13 Experimental Development - Frascati Manual, sixth edition.

14
15 OECD. (2003), Education policy analysis. Paris: OECD.

16
17 Pastor, J.T., Ruiz, J.L, Sirvent, I., (2002), A Statistical Test for Nested Radial Models,
18 Operations Research, vol. 50, n. 4, pp.728-735.

19
20 Pesenti, R., Ukovich, W., (1996), Evaluating Academic Activities Using DEA, Internal
21 Report, DEEI, Università di Trieste.

22
23 Porter M.E. (1998) Clusters and the New Economics of Competition, Harvard
24 Business School Press.

25
26 Ramsden, P., (1994), Describing and explaining research productivity, Higher
27 Education, 28(2), 207-226.

28
29 Rizzi, D., (1999), L'efficienza dei dipartimenti dell'Università Cà Foscari di Venezia
30 via DEA e DFA (The efficiency of departments at University Cà Foscari through DEA
31 and DFA), Working Paper, Università Cà Foscari di Venezia, Dipartimento di Scienze
32 Economiche.

33
34 Rodgers, J. R., Neri, F., (2007), Research Productivity of Australian Academic
35 Economists: Human-Capital and Fixed Effects, Australian Economic Papers, 41(6),
36 67-87.

37
38 Sala A., Landoni P., Verganti R., (forthcoming) "R&D networks: an evaluation
39 framework" International Journal of Technology Management.

40
41 Salerno M., Landoni P., Verganti R. "Designing foresight studies for Nanoscience
42 and Nanotechnology (NST) future developments" Technological Forecasting & Social
43 Change, 75(8), 1202-1223

44
45 Sarkis, J., (2007), Preparing your data for DEA, in Zhu. J., Cook, W.D., (eds.),
46 Modeling Data Irregularities and Structural Complexities in Data Envelopment
47 Analysis, Springer, New York.

1
2 Sarrico, C.S., Dyson, R.G., (2004), Restricting virtual weights in data envelopment
3 analysis, *European Journal of Operational Research*, 159(1), 17-34.
4

5 Sarrico, C.S., Teixeira, P.N., Rosa, M.J., Cardoso, M.F., (2009), Subject mix and
6 productivity in Portuguese universities, 197(2), 287-295.
7

8
9 Thursby, J.G., (2000), What Do We Say about Ourselves and What Does It Mean?
10 Yet Another Look at Economics Department Research, *Journal of Economic*
11 *Literature*, 38, 383-404.
12

13 Warning, S., (2004), Performance Differences in German Higher Education:
14 Empirical Analysis of Strategic Groups, *Review of Industrial Organization*, 24, 393-
15 408.
16

17
18 Wilson, P.W, (1995), Detecting influential observations in data envelopment analysis,
19 *Journal of Productivity Analysis*, 6(1), 27-45.
20

21 Zhu, J., (2003), *Quantitative Models for Performance Evaluation and Benchmarking*,
22 Kluwer Academic Publisher, Boston, MA.
23
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Table 1. Inputs/outputs descriptive statistics

	Average	Std deviation	min	Max	Average difference 2004-2007
Laboratories (m ²)	2,243.83	6,917.93	0.00	60,180.00	80.24
Human resources (n)	105.50	83.30	9.00	445.00	16.19
High Qualified Human resources (n)	98.33	79.66	8.00	434.00	16.00
Other personnel (n)	7.12	6.83	0.00	32.00	-0.30
Revenues from financed activities (€)	486,936.06	557,412.78	0.00	3,039,361.00	142,196.00
Financed activities from abroad (€)	118,587.58	256,766.37	0.00	1,805,922.00	10,896.00
Revenues from orders (€)	451,240.13	764,559.23	0.00	3,333,362.00	86,950.00
Number of publications (n)	32.45	31.91	0.00	188.00	2.87
Doctorates in cooperation with external bodies (n)	2.49	4.04	0.00	22.00	0.63

Table 2. Efficiency scores (DEA on 2007 data) – descriptive statistics

	CRS Efficiency	VRS Efficiency	Scale Efficiency
Mean	0.745	0.786	0.937
St. Deviation	0.241	0.219	0.101
Min	0.173	0.216	0.432
Max	1.000	1.000	1.000
# efficient units	25	29	25

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 3. Malmquist index 2004-2007 – descriptive statistics

Department	Malmquist index	Efficiency change	Frontier shift
Mean	1.060	1.666	0.652
St. dev.	0.492	0.882	0.141
Min	0.072	0.529	0.104
Max	2.534	4.600	1.031
# improving units	35	56	2

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 4. Factors affecting efficiency (Kruskal-Wallis analysis)

Effects of Metropolitan area (Milan)	
H (observed value)	0.007
H (critic value)	3.481
p-value	0.934
Effects of subject mix	
H (observed value)	8.451
H (critic value)	9.488
p-value	0.076
University effects	
H (observed value)	9.426
H (critic value)	14.067
p-value	0.224
Effects of tenured staff proportion	
H (observed value)	0.163
H (critic value)	3.841
p-value	0.687
Effects of departments' age	
H (observed value)	1.172
H (critic value)	3.841
p-value	0.279

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33 **Abstract.**

34 This paper investigates the efficiency of university departments on science,
35 technology and medicine in an Italian Region (Lombardy). The aim of the paper is
36 twofold: (i) to analyse the changes in productivity in recent years (from 2004 and
37 2007); and (ii) to detect factors that are potentially affecting efficiency. The research
38 benefited from a new and unique dataset (called QuESTIO) developed by the
39 Lombardy Regional Government. Using facilities and academic staff as inputs and
40 research grants and publications as outputs, the research activity of academic
41 departments was modelled. The methodological approach for computing efficiency
42 scores is Data Envelopment Analysis (DEA). Malmquist indexes have been used to
43 measure changes in productivity, while Kruskal-Wallis tests were employed to study
44 the potential determinants of efficiency. The main results were, first, that in the period
45 considered, the academic departments improved their efficiency but, at the same time,
46 the efficiency frontier worsened. Second, external and measurable factors (such as,
47 scientific sector, proportion of tenured staff, location) have a limited impact in
48 explaining efficiency differentials. Policy implications of the results are discussed.
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53 **Keywords.**

54 University research, efficiency, research policies, Data Envelopment Analysis,
55 Malmquist index, higher education policy.
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58 **JEL Codes.**

59 **C14, H41, H52**
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1. Introduction and motivation

In recent years, higher education institutions have been increasingly studied. In the “knowledge economy” their importance for economic development, social equity, mobility, social cohesion and integration is widely acknowledged (Brennan & Teichler, 2008). Furthermore, given the difficult situation of public finances, considerations about resources allocation have been raised in many countries, calling for more evaluations and accountability. For these reasons the so-called ‘New Public Management’ movement, started at the beginning of the 1980s in the public sector in general, has also increasingly been affecting the universities. New Public Management (Hood, 1991; 1995) represents the request to public organisations to become more managerial, in particular by drawing on practices and models from the private sector. This process has been driven both by universities themselves and by governments through reforming efforts. The results, especially in many countries within Europe, share some common characteristics: first, the introduction of incentives schemes based on financial models for allocating public funds; second, new or strengthened assessment procedures and evaluation agencies; third, more emphasis on universities’ autonomy (OECD, 2003).

This work explores how the recent changes in the university system affected the efficiency of university research. In particular, the research sought to understand whether an overall increase in efficiency can be recognised or whether differences are present between universities given the previously-noted increased autonomy. Normally, the majority of the reforming efforts have been directed towards education activities, whilst an increase in efficiency of university research has been assigned to incentive systems and evaluation processes. These are expected to have had an overall positive effect on the system but, at the same time, they have left the universities in charge of finding and managing the ways to obtain better results. Given the autonomy of the universities and the decentralisation of responsibilities, significant efficiency changes are thus expected between and within universities. Furthermore, the idea that differentials in research performance are key for competition among departments is well established in the literature (Curran, 2000).

The research focused on universities research activities and not on education or knowledge/technology transfer activities. Universities’ education activities constitute the first and original mission of the universities but, at the same time, they are normally carefully regulated by laws and their efficiency and quality are already

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3 widely studied (Madden *et al.*, 1997). Indicators such as number of degrees awarded,
4 rate of success, years of study, have been widely used both to evaluate the universities
5 and to introduce new policies. The opposite holds for universities'
6 knowledge/technology transfer activities. Even if some argue for this to be a third
7 mission for academia and call for "entrepreneurial universities" (Clark, 1998;
8 Etzkowitz, 2003), others refuse this perspective and signal the risks of focusing on
9 and expanding the role of these activities. Moreover, the efficiency analysis of these
10 activities is hampered by the difficulties in finding the right indicators. There are
11 many different knowledge/technology transfer activities (for example, spin-off,
12 consultancies, research projects with firms, patents) and their evaluation can be based
13 only partially on economic values given the not-for-profit nature of (most)
14 universities (Landoni and Verganti, 2006). Finally, the focus of the study is on the
15 research activities as they are the core activities of universities; driving and informing
16 both education activities and knowledge/technology transfer activities. This
17 relationship especially holds for transfer activities because the value of the results
18 transferred relies heavily on the underlying research on which they are based.
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33 This paper adopts the standard definition of 'research' provided by the Organisation
34 for Economic Co-operation and Development (OECD): "Research and development
35 is a term covering three activities: basic research, applied research, and experimental
36 development" (OECD, 2002). However, only research activities that are normally
37 carried out within universities are considered.
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42 Furthermore, the focus of the efficiency analysis is on university departments and not
43 on the university as a whole. Universities are composed of different research
44 departments and their publication outputs, co-authorship behaviours and thus
45 efficiency usually differ significantly. An analysis at the level of the university can
46 put forward mixed results, while an analysis at the level of single departments is more
47 precise and coherent with the objectives of an efficiency analysis. For this reason, to
48 obtain a sample of comparable departments the research focused on natural science
49 departments. The choice of the department level for the analysis is coherent with the
50 focus on research activities: normally education activities are managed by
51 organisational entities inside the university that are transversal to more departments
52 and many transfer activities are centralised in a single organisational unit (such as a
53 liaison office or a knowledge/technology transfer office).
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3 The research considers departments located in the Lombardy region (Italy). A
4 regional focus has been adopted to ensure similar contextual variables, such as
5 policies and economic environment, for the universities included in the analysis.
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7 Furthermore, Lombardy is one of the more advanced European regions both for (i)
8 economic development and (ii) research activities and universities: more than 9.4
9 million habitants, GDP per capita >€34,000; 12 universities are located in the Region
10 (out of about 70 in all the country) with more than 230,000 students. Finally, the
11 regional level is increasingly recognised as a relevant level when analysing research
12 and innovation activities. Many authors (Cooke *et al.*, 1997; Porter, 1998; Lechner &
13 Dowling, 1999) underline that it is at a local level that the majority of the connections
14 between the different innovation actors take place. The localisation of knowledge and
15 the role of proximity as a driver of economic development (for example, clusters)
16 have also highlighted the importance of regional and local government in fostering
17 and strengthening the actors and their relationships.
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30 To summarise, the focus of the paper is on efficiency of research activities in
31 scientific departments in the Lombardy Region (Italy). The research questions are:

- 32 • did changes in the overall efficiency of departments' research occur between
33 2004 and 2007?
- 34 • Which are the main factors affecting efficiency?
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40 The next section presents recent literature on the topic, then the methodology and the
41 data used are introduced, finally results are presented and conclusions are drawn.
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49 **Background**

50 The international literature about universities' efficiency (through non-parametric
51 techniques) has been developed both at institution-level (Athanasopoulos & Shale,
52 1997; McMillan & Datta, 1998; Ng & Li, 2000; Avkiran, 2001; Abbott &
53 Doucouliagos, 2003; Flagg, et al, 2004; Warning, 2004) and department-level. The
54 latter is more relevant for the context of the present study.
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58 The contributions by Johnes & Johnes (1993; 1995) had a major influence on the
59 methodological approach. Johnes & Johnes (1993) measured the research
60 performance of UK economics departments by using staff numbers as inputs and

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3 publication counts and grants as outputs; the same strategy was adopted again for
4 deriving efficiency scores of economics department in a subsequent paper (Johnes &
5 Johnes, 1995). The authors ran several Data Envelopment Analysis (DEA) models to
6 test the robustness of results and claim for a possible use of results for policy
7 purposes, especially for establishing an optimal allocation of resources across
8 departments. These two contributions are the most important as they focus
9 exclusively on the research dimension of the universities' work.

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16 Madden *et al.* (1997) studied the efficiency of economics departments in 29
17 Australian universities. Inputs were teaching and research staff, outputs were
18 graduates and publications (for teaching and research respectively). As in other
19 studies listed below, here the focus was both on teaching and research performance,
20 even if the analysis were conducted at sub-unit level (that is at departmental level
21 instead of institutional level). The specific objective of the Madden *et al.* (1997) study
22 was to verify whether policies promoted by governments impacted on productivity;
23 they confirmed that there was actually an increase in productive efficiency.
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30 Thursby (2000, p. 400) analysed the efficiency of the Economics Research
31 Departments in the United States. He defined efficiency as follows:

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33 a department is deemed technically efficient if, when compared to departments
34 with similar level of inputs, it could produce greater research outputs without
35 increasing its inputs usage, or equivalently, it is one which, compared to
36 departments with similar levels of outputs, could produce the current levels of
37 outputs with fewer inputs.
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44 Thursby used publication, citation data and number of Ph.D.s as outputs and faculty
45 size [WHAT DO YOU MEAN BY FACULTY SIZE?], full professors, graduate
46 students, federal grants, library acquisitions and a dummy for private ownership as
47 inputs. He found that the average level of efficiency in the United States is high (67%
48 of economics departments appear as efficient). Seen from a European perspective, this
49 result is not so unexpected [WHY?].
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55 Moreno & Tadeballi (2002) focused on 42 academic units distributed across 7
56 colleges in the United States. They used staff, financial resources and proxies for
57 structures (for example, building space) as inputs and number of students, FTE
58 enrolments and grant awards as outputs. In discussing their results, they showed that
59 efficiency scores do not illustrate information about effectiveness: that is, they argued
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3 that a qualitative dimension is necessary for this purpose. Lastly, as their background
4 is strongly managerial, they also suggested a use of efficiency analysis as a planning
5 tool, not only for evaluating universities' activities.
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9 Koksall & Nalcaci (2006) derived efficiency scores for 14 university departments at
10 the Middle East Technical University (METU) in Turkey, by using staff salaries, a
11 composite indicator of previous research quality and number of students as inputs and
12 number of publications, graduates and teaching indicators as outputs. Thus, in their
13 contribution, the authors focused also on the teaching activity of the departments.
14 They decided to use weights for teaching and research loads as suggested by
15 university's administrators through a preliminary survey. The paper suggests that the
16 models adopted for computing efficiency can serve to set new targets for inefficient
17 departments.
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20 Gimenez & Martinez (2006) focused on cost efficiency of the departments at the
21 Autonomous University of Barcelona. They computed cost-efficiency scores and
22 separated cost excess into three categories: technical efficiency, fixed factors, **scale of**
23 **size** [WHAT IS THIS? DO YOU MEAN NUMBER OF ACADEMICS IN THE
24 **DEPARTMENT?].** The units of analysis were 42 departments and again the focus is
25 on both teaching and research activities. The inputs chosen were: expenditure on
26 temporary hired teaching and research staff, operational expenditures, expenditures on
27 tenure staff. To measure the outputs, they employed the following variables: results of
28 a government evaluation process of research, teaching load (measured through credits
29 granted) and students' opinions. The authors suggested that their analyses can be used
30 to assess the differences between (i) the observed cost of the units and (ii) the cost
31 they would achieve assuming long-term cost minimisation. Their result tells that size
32 does not matter in determining efficiency, while higher proportion of non-tenured
33 staff is associated with higher efficiency levels.
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37 In another exercise presented by Kocher *et al.* (2006) the analysis focused on the
38 productivity of research in economics across 21 OECD countries. The focus of the
39 paper is on research and the outputs selected are top publications (and impact factors),
40 while inputs are expenditure on research and development, number of universities and
41 total population. This study is quite different, however, with respect to the relevant
42 contributions for the present paper, as the unit of analysis is the country (neither the
43 university nor the department). The results suggest that research productivity can be
44 raised through an increase in the scale of operations.
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3 An interesting issue is to analyse the related literature about the Italian universities'
4 research. To the best of the authors' knowledge, there are only two specific
5 contributes that specifically analyse the efficiency of universities in producing
6 research outputs (Pesenti & Ukovich, 1996; Rizzi, 1999) and just one attempting to
7 focus on teaching production (Agasisti & Dal Bianco, 2009).

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12 The two contributions at departmental level (Pesenti & Ukovich, 1996; Rizzi, 1999)
13 use a similar set of variables and focus both on teaching and research outputs. The
14 main scope for these contributions is to provide information and suggestions for
15 allocating resources within a university.

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20 Contributions about the efficiency of Italian higher education has been conducted at
21 institution-level (thus, not considering separately the structures devoted to teaching
22 and research). ~~The reason for this choice can be summarised by the idea that the
23 strategy and the mission of universities is defined at macro (institution) level, then the
24 balance between teaching and research is decided by the decision centres at institution
25 level (Bonaccorsi & Daraio, 2007, p. 22).~~ This is because the strategy and the mission
26 of universities and the balance between teaching and research are defined at
27 institutional level (Bonaccorsi & Daraio, 2007, p. 22).

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33 Among these contributions at an institutional level Agasisti & Dal Bianco (2006)
34 studied the efficiency of 58 Italian public universities, by using, as inputs, number of
35 staff, financial resources and students and, as outputs, graduates and research grants.
36 They suggested the use of efficiency analysis for policy purposes, especially to
37 evaluate the differences in performance between efficient and inefficient units. Later,
38 Agasisti & Salerno (2007) analysed the cost efficiency of another sample of Italian
39 universities, by adding some qualitative measures for inputs and outputs. They
40 concluded that a redistribution of inputs across universities could lead to an overall
41 improvement of efficiency in the Italian higher education sector.

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Bonaccorsi *et al.* (2006) used a robust non-parametric technique (developed by
Daraio & Simar, 2005) to take in account external conditions affecting the
productivity of universities. The inputs and outputs adopted are quite similar to
previous studies (that is, staff numbers, expenses and spaces as inputs and
publications and graduates as outputs) but they also included some "external" factors:
university size, number of departments within the university, percentage of private
funding, number of curricula activated. They concluded that economies of scale and
scope are not relevant factors in explaining (in)efficiency. However, a strong role is

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3 played by the external factors: clearly, such result affects the policy considerations.
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10 To sum up, the literature seems to suggest that, to analyse research efficiency of
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12 universities, that is, the efficiency in the production of research outputs:
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- 14 • inputs can be classified under three main groups: human resources, financial
15 resources and structures (e.g., facilities, buildings);
- 16
17 • outputs can be grouped into publications and grants.
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19 The best indicators to measure these classes of inputs/outputs are questionable but the
20 general emerging consensus is on a productive process that can be described with
21 such indicators WHAT DOES THIS MEAN?. The present paper moves from these
22 suggestions and it focuses on the efficiency of research activities in scientific
23 departments in the Lombardy Region (Italy). [what struck me was inconsistency in
24 the research about economies of scale!]
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31 32 Methodology and data

33 34 Methodology

35 The methodology is articulated accordingly to the two steps adopted to answer the
36 research questions of the paper: on one hand the efficiency analysis (including
37 efficiency scores of the departments, changes across time and time trends), on the
38 other hand the effort to identify the determinants of efficiency.
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43 ~~The first choice is about the methodology to compute efficiency, because there are~~
44 ~~different methods to target the analysis of efficiency among different units. Data~~
45 ~~Envelopment Analysis (DEA) is a frontier, linear programming technique, introduced~~
46 ~~by the seminal work of Charnes *et al.* (1978). It deals with the efficiency problem of~~
47 ~~complex organisations that produce many outputs using several inputs at a time. Data~~
48 ~~Envelopment Analysis (DEA) (Charnes *et al.*, 1978) was the methodology used to~~
49 ~~analyse efficiency. It deals with the efficiency problem of complex organisations that~~
50 ~~produce many outputs using several inputs at a time.~~
51 Data
52 Envelopment Analysis (DEA) (Charnes *et al.*, 1978) was the methodology used to
53 analyse efficiency. It deals with the efficiency problem of complex organisations that
54 produce many outputs using several inputs at a time.
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57 This paper only briefly discusses some characteristics of DEA, referring the interested
58 reader to Johnes (2004), Cooper *et al.*, (2006) and Zhu (2003).
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3 In a DEA model, the notion of efficiency is that of “technical efficiency”, defined as
4 the relative ability of each decision making unit (DMU) in producing outputs, where
5 the term “relative” means that each organisation is compared with any other
6 homogeneous unit. DEA could be represented by a linear programming technique
7 where each DMU tries to maximise the efficiency ratio (output over inputs) choosing
8 the best set of weights. There are two ways to deal with a DEA formulation: (i) input
9 oriented (that is, the ability to minimise inputs when outputs are given) and (ii) output
10 oriented (maximisation of outputs given a certain bundle of inputs). The latter
11 approach is used in this paper, as the typical problem for a research unit is to
12 maximise outputs (publications, grants) given its inputs (research staff, laboratories).
13 DEA mathematical formulation can deal with both constant returns to scale (CRS)
14 and variable returns to scale (VRS). The seminal work of Charnes *et al.* (1978)
15 introduced a constant-return-to-scale (CRS) model where DMU dimension has no
16 importance in defining efficiency performance (see equation 2). DMUs face the same
17 efficiency frontier, independently of their relative size. One can cast doubts on the
18 comparability of small and large units. Larger units exploit common inputs to produce
19 different outputs, whereas smaller ones benefit from substantial advantages in
20 organising activities. The BCC [WHAT DOES BCC STAND FOR?] model,
21 developed by Banker *et al.* (1984) introduces in DEA modelling the dimension factor.
22 [WHAT DOES THIS MEAN?]

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Smaller units are associated with increasing economies of scale and bigger units with
decreasing economies of scale. In the middle, there is a “grey area” of constant
returns to scale. So, it is also possible to compute the scale efficiency. This is defined
as the ratio CRS/VRS efficiencies and interpreted as the ability of each institution to
benefit in terms of PLEASE REPHRASE TO AVOID “in terms of” WHICH FAILS
TO EXPLAIN THE RELATIONSHIP productivity from its size: in other words, in a
VRS formulation, each DMU is compared only with those units having a comparable
size.

IN THE FOLLOWING PLEASE AMEND TO REMOVE THE
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We also measure changes in efficiency across time and our relevant period is between
2004 and 2007. For measuring the determinants of the changes in efficiency scores,
we use Malmquist index (for more information about this index see Johnes (2004) and

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3 Coelli *et al.*, (2006)). Let us consider a DMU, named P that has a change in
4 production position from P_t (in period t) to P_{t+1} (in period t+1). The change in the
5 production frontier could have occurred in a non-neutral way; that is, it could be
6 determined both by efficiency changes and shifts in the efficiency frontier. Thus, for
7 measuring the change in the efficiency score, we have to break down the score in
8 these two different components. Both of the components have a specific mean: the
9 resulting score for the DMU could have positive or negative effects due to the own
10 efficiency change or due to the shift (movement) of the frontier. Thus the resulting
11 efficiency index is composed of two parts. The first component of the equation is the
12 ratio of technical efficiency in time period t+1 on the technical efficiency in the
13 period t. Since it measures the change in technical efficiency, it is equal to 1 if no
14 changes occurred, greater than 1 if the change was positive and less than 1 if it was
15 negative. The second component measures the shift in the production frontier: if it is
16 equal to 1 it has no effect on the efficiency score, if it is greater than 1 it has a positive
17 effect and if it is less than 1 it has a negative effect. In other words, a shift in a
18 production frontier that makes worse the relative position of the DMU (the other
19 DMUs are performing relative better than before) provides a second component less
20 than 1. The index (Malmquist index) resulting from the combination of these two
21 components will be equal to 1 if there is no net effect of changes in technical
22 efficiency and frontier changes; it will be greater than 1 if the net effect is positive
23 and less than 1 if it is negative. In our analysis, we name “efficiency change” the first
24 component and “frontier shift” the second one. I THINK A CONCRETE EXAMPLE
25 IS NECESSARY HERE TO GUIDE THE READER.

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44 Moreover, we would detect the eventual stability of efficiency rankings across the
45 period (again, the relevant period is between 2004 and 2007). In this case, we adopted
46 one of the statistics suggested by Brockett *et al.* (1998). More specifically, we are
47 interested in knowing if the efficiency of departments changed influencing the
48 rankings or not over time. “Ranking the set of $n \times k$ [WHAT IS THIS?] efficiency
49 ratings and observing the sum of ranks associated with each DMU, one can learn
50 about the relative position of the DMUs *vis-à-vis* each other across the whole period”
51 (Brockett *et al.*, 1998, p. 174). For this purpose, the basis of the analysis is a Kruskal-
52 Wallis test (Kruskal & Wallis, 1952, p. 175) where “the rejection of the null
53 hypothesis leads to the conclusion that, in general, the different DMUs maintain their
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3 relative efficiency positions over time”. **AGAIN A CONCRETE EXAMPLE**
4 **WOULD HELP HERE.**
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9 The second task in **our** methodology is to study some potential determinants of
10 efficiency. To pursue this objective, **we** identified some external factors (for example,
11 location effects, discipline effects) and then **we** compared efficiency scores across
12 different groups of units. The comparison was made by means of the Kruskal-Wallis
13 test (Kruskal & Wallis, 1952). This test allows the researcher to detect if are there
14 statistical differences across the groups analysed (for example, when comparing the
15 efficiency scores of units located in a metropolitan area with those located elsewhere,
16 the test indicates if this location effect generates a statistical difference between the
17 average scores of the two groups).
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25 26 *Data*

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28 The research used a unique dataset that consists of input and output variables about
29 research and technology transfer activities in university departments located within
30 the Lombardy Region. This dataset is based on information coming from QuESTIO
31 system, a mapping of research and technological transfer organisations developed in
32 the Lombardy region. The QuESTIO system, launched in 2004 by the regional
33 government, was intended to be a transparency and incentive tool for the research and
34 technological transfer market by reducing any information unevenness often binding
35 cooperation among producers and users of knowledge. The system pursues **such**
36 **scopes [??]** by collecting, updating and publishing financial, organisational and
37 structural characteristics of research organisations and knowledge business
38 intelligence services in Lombardy.
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48 Since it aims at presenting the most detailed picture of regional community active in
49 research and technological transfer, the dataset has some specific criteria that are
50 pivotal for the analyses. First, the system is focused on every structure where such
51 activities are carried out, even where that structure is a part of a wider organisation.
52 Second, these structures should have significant management autonomy so that their
53 accountancy shall be determinable. The first criterion enables the regional
54 administration to collect information on every single department, being acknowledged
55 that the performance of departments belonging to the same university can differ
56 significantly. As a consequence the university departments, as well as sections and
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3 institutes of the National Research Council or a research and development unit
4 belonging to a company, provide data that refers solely to their specific resources and
5 outputs. The second criterion assures that each structure included in the dataset is
6 responsible (to some extent) for its strategy and performances thus justifying
7 application of the DEA technique.
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11 ~~University departments are main actors in Lombardy innovation system; they are 147~~
12 ~~out of 364 structures mapped, which balance the presence of Knowledge Business~~
13 ~~Intelligence Services, which count for 151. The map is completed with 13 Hospital~~
14 ~~and medical research centres, 34 Public Research Organisations and 19 company~~
15 ~~R&D units.~~
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21 The Lombardy innovation system maps 364 structures of which 147 are university
22 departments, 151 are knowledge business intelligence services, 13 are hospital and
23 medical research centres, 34 are public research organisations and 19 are company
24 research and development units.
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30 In order to better point out the capillarity of these structures within the territory, the
31 geographical analysis shows a concentration in the Province of Milan and a little less
32 in Bergamo, Brescia, Pavia and Varese, which is explained by the presence of
33 universities in those cities, all of them accredited with their single departments. [??]
34
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36 We built our dataset by considering those university departments that provided
37 information for the whole period 2004–2007 (units for which there are not missing
38 data), by selecting the following variables:
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43 44 Inputs

45 I1 Laboratories: the areas (measured in square meters) devoted to laboratories
46 belonging to or accessible by the department. This data provides a dimensional data
47 related to the most distinctive and characterising areas equipped for scientific
48 research. [Not clear what this means]
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53 I2 Highly-qualified human resources: persons who perform research and technology
54 transfer activities, regardless of their qualifications. They are mainly full professors,
55 associated professors, permanent researchers, post-Doc post-doctoral scholarships and
56 PhD students. It includes employees dedicated to activities in support of research,
57 such as, certification, tests and measurements, patenting and commercialisation,
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3 financial assistance, partners search, technologies monitoring, events organisation,
4 editing of technical-scientific “spreading publications”.

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7 I3 Other personnel: administrative personnel that should ensure the efficient working
8 of human resources devoted to research and technology transfer activities.
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10 11 12 Outputs

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14 O1 Revenues from financed activities: activities financed with regional or national
15 calls for bids. This variable denotes the ability of the department to compete with
16 other research organisations in getting public-funded research, thus measuring the
17 amount of research that meet requirements of national and regional R&I [in full]
18 strategies.
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22 O2 Revenues from financed activities from abroad: accomplished activities financed
23 [do you mean internationally funded activities?] that show the capacity to draw on
24 international funding, such as European projects, resulting by working with third
25 countries organisations [not clear what this is referring to?]. It reflects department
26 down stream internationalisation [not clear what this means] and it is a sign of the
27 research activities that are acknowledged at international level.
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30 O3 Revenue from orders: measures how far research activities carried out in a
31 department are committed directly by companies [not clear what this means] or other
32 institutions.
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35 O4 Yearly number of publications: yearly articles signed by department human
36 resources on the international scientific press [not clear what this means, do you mean
37 publication in international journals?]. This is the traditional and widespread variable
38 used to measure the output of research activities.
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41 O5 Doctorates in cooperation with external bodies: sheds light on the capability of
42 departments in attracting investments for education finalised to research [not clear
43 what this means] and to establish cooperation with institutions and companies. Since
44 this variable could be interpreted such as an indicator of technology transfer activities,
45 we investigated if it could alter the efficiency scores and we ran a DEA model without
46 considering it. The results are the same for almost all the DMUs so we decided to
47 keep it in the model. [NOT SURE WHETHER YOU ARE SAYING IT WOULDN'T
48 MATTER IF IT WASN'T IN THE MODEL?]
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As discussed in the previous section the choice of input and output variables is ~~coherent~~ **compatible?** with the most recent literature. The final sample contains 75 departments, for 4 years; overall, there are 300 observations, **revealing considerable variation** (Table 1).

<Table 1> about here

Results THIS RESULTS SECTION NEEDS THE RESULTS REPORTED TO BE DISCUSSED AND EXPLAINED BUILDING A PICTURE RATHER THAN LEAVING THE DISCUSSION UNTIL A FINAL SECTION AND THESE RESULTS STANDING IN A KIND OF VACUUM. SEE JOURNAL STYLE. THIS WILL ALSO HELP REDUCE REPETITION AND REDUCE THE WORD COUNT

This section illustrates the results obtained through the DEA analysis of the university departments in the Lombardy Region.

The results are presented in two main sections. The first is devoted to a description of the efficiency scores with reference to the year 2007 (the last year available, where the results are more stable, as previously discussed). ~~In this section one sub-paragraph~~ **It** analyses the change in efficiency between the first year of the dataset (2004) and the last year (2007) ~~and another one explore~~ **as well as** the presence of time trends in the efficiency scores. The second section ~~refers to the study of~~ **examines** statistical differences in efficiency scores due to external factors, such as localisation and discipline subject.

~~DEA efficiency scores, year 2007~~

~~This section explores the results of the efficiency analyses both looking at a single year (2007) and at differences between years.~~ **REPETITIVE**

DEA efficiency scores, year 2007

~~Table 2 reports the descriptive statistics about the efficiency scores derived with reference to the year 2007 (the annex reports the specific scores for each department).~~ **NOT JOURNAL STYLE. INSTEAD SAY WHAT THE DATA SHOWS AND REFER TO 'EVIDENCE' (VIZ TABLE) IN PARENTHESES.** As explained in the

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3 methodological section, we calculated CRS efficiency and VRS efficiency, as well as
4 the “scale” efficiency computed as CRS/VRS scores (it is important to recall here that
5 the model is output-oriented). AVOID TOO MUCH REPETITION AS ARTICLE
6 TOO LONG.
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12 <Table 2> about here
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16 The research efficiency of university departments in the Lombardy region looks quite
17 [?? IS IT OR ISN'T IT HIGH, THIS IS TOO VAGUE] high (0.75 in terms of
18 PLEASE REPHRASE TO AVOID “in terms of” CRS efficiency, 0.78 in terms of
19 PLEASE REPHRASE TO AVOID “in terms of” VRS efficiency); actually, the high
20 average efficiency is coherent compatible? with previous results derived across the
21 world in the higher educations sector (Salerno, 2003). BUT WHAT IS THIS
22 TELLING US? What is worth pointing out is a strong heterogeneity across
23 departments: indeed, the standard deviation is >0.2. A look at the lowest scores
24 suggests that there are very poor performers which shows scores [??] <0.5.
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31 Data about scale efficiency suggests that all the departments have almost reached
32 their optimal scale of operations (given their present scale), as the scale efficiency
33 score is very high (>0.93) and standard deviation is very low (about 0.1) in this
34 respect.
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39 The picture that emerges from this first analysis of efficiency scores is a sector where
40 there is a number of very efficient units (both assuming constant or variable returns to
41 scale) and a number of departments that experienced low levels of technical
42 efficiency; thus, as the anecdotic anecdotal evidence suggests, there is quite a strong
43 differentiation among departments in terms of PLEASE REPHRASE TO AVOID “in
44 terms of” research efficiency.
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50 As the focus of our paper is the efficiency of academic departments in the Lombardy
51 region, we also checked the robustness of our results by considering revenues from
52 entities located in the Lombardy region as a separate output (REV_LOMB). The
53 correlation among results obtained by the baseline model and this modified model is
54 very high (>0.97). WHICH MEANS WHAT? The VRS efficiency scores for each
55 department comparing the two models (also in this case the reference year is 2007) is
56 available, on request, from the authors. NEED TO SAY WHAT THE ESSENCE OF
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THIS EVIDENCE IS AND DROP THIS REFERENCE IN THE TEXT TO SEPARATE DATA BEING AVAILABLE.

Efficiency changes between 2004 and 2007 – a Malmquist analysis

Following the methodology described above, we derived the Malmquist index, which allows us to disentangle the efficiency changes due to “pure” efficiency improvement (or worsening) and technological improvement (or worsening). The descriptive statistics about the results are reported in Table 3, while the detailed results are available on request from the authors.

<Table 3> about here

The picture that emerges highlights an interesting phenomenon. It looks like an improvement in productivity did not occur (because the Malmquist index is around 1) but, looking at the decomposition of the index, the reality appears more complex: an efficiency changes happened, it was very positive (the index is >1.6) and involved the majority of the departments (56 out of 70); conversely, there was a relevant detriment of the technology environment [MEANING NOT CLEAR] (the “frontier shift” indicator is <0.7). It looks like the academic units improved their technical efficiency (that is, the ability to transform inputs into outputs) but, at the same time, the frontier worsened. In other words, what happened is that the “technological change” (in the Malmquist language) was negative. WHICH MEANS WHAT?

What is “technology” in a regional research system, when we define research performance as the ability to attract financial resources and to publish in academic journals? Technology could be defined as the bundle of policies that should help in improving research efficiency, for example, information technologies, research grants, support for publishing research results or to attract financial resources from international grants or companies. Thus, the results (Table 3) suggest that, while the majority of the universities improved their efficiency, the system as a whole did not experience an improvement in terms of PLEASE REPHRASE TO AVOID “in terms of” technology available. A discussion about the potential responsibilities for such phenomenon will be reported in the last section, which deals with policy implications of the study.

Productivity changes between 2004 and 2007: an analysis of “rankings stability”

The stability of rankings across the analysis period (between 2004 and 2007) were analysed by means of the H index proposed by Brockett *et al.* (1998). The index is equal to 177.96 and it must be compared with H^2 that is equal to 102.99. The rejection of the null hypothesis leads to the conclusion that some of the academic departments exhibit consistently better economic performance than others (as measured by the input-output factors that were included in our model) (see Brockett *et al.*, 1998).

Reading this results together with the Malmquist index, it looks like the academic departments improved their performance but some units continue to perform better than others. At the same time, the results show that some units are not efficient, that is, the frontier actually worsened.

DEA efficiency scores, year 2007: the external factors affecting efficiency

~~This section, given the evidence on the efficiency results, it is interesting to explore which are the determinants of this efficiency or, in other words, what could actually affect a department's performance.~~

~~To answer this question, we tested a number of different factors, by using the Kruskal-Wallis test as methodological approach (see the data section). All the results are listed in Table 4.~~

This section explores what affects a department's performance. Several factors were tested using the Kruskal-Wallis test, which showed.... WHAT? (Table 4)

<Table 4> about here

4.2.1 First external factor: are departments located in Milan metropolitan area (regional capital) more efficient than other departments?

We analysed this factor on the assumption that in a metropolitan area the competition among research centres enforces departments' managerial efficiency. In Milan, there is an important concentration of public and private research institutions and the competition for resources is not limited to departments. The high concentration of research facilities may justify a greater effort by departments in fostering a more balanced use in input resources or may impulse an effort in control for managerial quality. Elsewhere, Agasisti (2009) demonstrated that the effect of competition on Italian universities' performance is positive – but, there, output was defined through teaching dimension's measures.

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3 We ran a Kruskal-Wallis test to verify the statistical difference between the efficiency
4 scores of departments located in Milan versus the other departments. We do not find
5 evidence of difference in efficiency performance between the two groups (indeed, the
6 observed value of the H statistic is nearly 0 and the p-value >0.9). This evidence
7 suggests that there is no “concentration” effect or “location” effect on efficiency
8 performance of university departments or, at least, in the relative rankings. At the
9 same time, this result may suggest i) the existence of no competitive pressure in a
10 high concentration area as Milan, or that ii) we have to look at overall concentration
11 of research centres and not only to university departments (e.g., there could be a
12 “university” effect which could dominate a “location” effect, or that iii) there is
13 competition but at the same time more opportunities to find resources (more demand
14 for research and consequently the amount of resources is enough to guarantee a
15 sufficient level of grants for different departments without the need to compete one
16 against the others).

30 4.2.2. Second external factor: can different scientific sectors affect university 31 department efficiency?

32 As we measured “output” by using i) publication counts and ii) research grants (of
33 different kinds), it is important to recall that there are some differences in the average
34 number and quality of publication across different disciplines (e.g. medicine versus
35 engineering or biology), as well as differences in terms of PLEASE REPHRASE TO
36 AVOID “in terms of” attractiveness of research funds (e.g., in engineering fields it is
37 simpler to attract grants for applied research than in physics).

38 The idea that disciplines greatly vary in terms of PLEASE REPHRASE TO AVOID
39 “in terms of” costs and productivity is not new and the suggestion to take this factor
40 into account is important to obtain not-biased results (Sarrico & Dyson, 2004).
41 Recently, Sarrico et al. (2009) demonstrated a strong role of “subject mix” (defined as
42 the disciplinary composition of institutions) in explaining the efficiency differentials
43 among Portuguese higher education institutions. The authors acknowledged that “(...) *research production also varies significantly from subject to subject, with medical,*
44 *some natural and technical sciences being more prolific in the number of articles than*
45 *most of the social sciences and humanities”* (p.290). Also Ramsden (1994), in his
46 empirical analysis of Australian research departments, adjusted the coefficients on the
47 basis of discipline subjects.

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3 We find a small but statistically significant difference among university departments
4 classified by scientific sectors: the observed value of the H statistic is >8.4, near the
5 critical value (9.4) and the p-value is 0.07 (then the effect has statistical significance
6 at the 10% level **WHY CHOOSE 10%? WHY NOT SAY NOT SIGNICANT (AT**
7 **5%, WHICH TENDS TO BE THE NORM?)**). However, given the limited power of
8 this effect, it is not easy to determine which sectors outperform the others
9 straightforwardly.
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17 4.2.3. *Third external factor: is there a “university effect”?*

18 An alternative explanation of efficiency can refer to the existence of a “university
19 effect”, that is if a university is more efficient than others, then its departments could
20 be more productive than those belonging to other universities. This assumption finds
21 its justification in the setting of strategies at university levels, not at subunits levels. In
22 this respect, Bonaccorsi & Daraio (2007, pp. 22–23) pointed out that:
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28 the notion of strategy is much more relevant and interesting if assumed at the
29 overall university level. On the one hand, most strategic decisions are made at
30 university level.... The fundamental reason for assuming the university level
31 as the unit of analysis is that at the university level the problem of attribution
32 of inputs (in particular, human resources, funding and physical capital) to
33 specific units of outputs, can be kept under control.
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39 Even if these authors recognised that a lower unit of analysis could provide useful
40 information on the actual research process, they suggest that a “university effect” (due
41 to different strategies and characteristics at macro-level) can be detected.
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44 Our tests suggest that such effect is not explaining efficiency differentials for our
45 sample (observed value of the H statistic is 9.4, well below the critical value of 14.06
46 and the p-value is 0.22).
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51 4.2.4. *Fourth external factor: does the number of tenured academic staff influence* 52 *efficiency?*

53 The proportion of tenured research staff theoretically can affect the efficiency of a
54 department: there is anecdotic evidence that tenured and non-tenured staff face quite
55 different stimulus and incentives. Nevertheless, the direction of this influence is not
56 clear a priori: tenured staff is certainly more expert in attracting research grants and in
57 publishing academic papers, also thanks to reputational advantages; conversely, non-
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3 tenured staff can have an incentive to be more productive, for instance as a mean to
4 obtain a tenured position. The promotion system can affect productivity if researchers
5 are satisfied with rules promoting this dimension.
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9 A complementary idea behind this question is that the different human capital of
10 researchers (in our paper, indirectly measured via the tenured status) can affect the
11 research productivity of the research groups and, so, of the department. In this respect,
12 an interesting example is the paper by Rodgers & Neri (2007), who specifically
13 attempted to correlate the human capital of researchers with the research productivity
14 of Australian departments of Economics. They have found that human capital
15 differential account for about 50% of the observed differences in research
16 productivity. If human capital is (even indirectly) captured by the tenured status (e.g.,
17 researchers with more experience should have reached their tenured position), then
18 we should expect a correlation between the proportion of tenured researchers and the
19 department's results. Ramsden (1994) showed that productivity of professors and
20 readers was much higher than that of lecturers.
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24 Our analysis did not find evidence of a statistical influence of this factor on research
25 efficiency (the value of the H statistic is 0.16 and the related p-value is >0.6).
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30 31 32 33 34 35 4.2.5. *Fifth external factor: can departments' "longevity" affect research efficiency?*

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37 Finally, we looked at the possible effects due to the longevity of departments. As we
38 measured inputs in terms of PLEASE REPHRASE TO AVOID "in terms of"
39 numbers of academic staff and laboratories/facilities, it is reasonable that older
40 departments accumulated higher stocks of inputs that could influence their outputs.
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44 A key assumption here is that older departments can favour more cohesion among its
45 members, facilitating the climate of collaboration and common motivation which
46 enhances research productivity.
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50 Another interesting point of view about this potential phenomenon is that it is related
51 to the "critical mass" dimension. Among the economic aspects of research, Hare &
52 Wyatt (1992) underlined that the ability in producing research relies upon the human
53 capital accumulated by the individual researchers; thus:
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57 combining this process with the notion that there are economies of scale in
58 research may dispose university departments to feel they need to have at least
59 some critical mass of researchers working in the same area in order to function
60 properly as research units. (Wyatt, 1992, pp. 55–56)

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Consequently, it could be reasonable to assume that older departments are more likely to have reached such “optimal” scale dimension than the more recently established ones.

The statistical analysis did not provide statistically robust results on this effect, indeed the value of the H statistic is 1.172, while the critical value is around 3.8, so that the p-value is 0.27).

5. Discussion and policy conclusions IT WOULD PROBABLY BE BETTER TO INCLUDE MUCH OF THIS DISCUSSION IN THE PRESENTATION OF RESULTS TO (A) AVOID REPETITION AND (B) TO PROVIDE A CLEARER STORY AS TO WHAT HE RESULTS MEAN.

As highlighted discussing the literature on the topic, the analyses presented in this work are innovative in terms of PLEASE REPHRASE TO AVOID “in terms of” data and methodology. Indeed, in this paper we have investigated the efficiency of university departments on science and technology and medicine in an Italian region (Lombardy). The aim of the paper was (i) to analyse the changes in productivity in recent years (from 2004 and 2007) and (ii) to detect factors that are potentially affecting efficiency.

Discussing our results about the efficiency change between 2004 and 2007, some questions must be posed: how can a Malmquist index equal to 1 exactly be interpreted? How can we judge a frontier shift that is less than 1? Each academic unit, on average, is in the 2007 in the same position *relative to the frontier* than in the 2004 (indeed, also the H index calculated above suggests small changes in the rankings in the period considered). However, what happened is something different: the vast majority of the units actually improved their productivity in the period (“efficiency change” >1) but the “frontier shift” was <1: it means that the performance differential is much less dispersed in 2007 but at the same time it happens because the frontier is not improved – the best performers did not improve, or even worsened their efficiency. The summary statistics confirms this idea (look at the really lower mean in 2004, with a much higher dispersion – standard deviation – around it). The result is a “research system” in the region that performs better on average but without having excellence.

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3 The importance of evaluation and accountability has been growing in these recent
4 years and criteria used are widely acknowledged: publications and the ability to
5 gather financial resources (from abroad or from firms). Since the application of these
6 evaluations for funding allocation is more and more concrete, we believe that the
7 weakest departments raised their attention towards those performances. Thanks to this
8 new attention the weakest departments have increased their efficiency and become
9 much closer to the best performers that, on the contrary, had little margin for further
10 improvements.
11

12 This result requires an important policy discussion. Indeed, the objective of the
13 Lombardy Region was to foster the performance of excellent research units. This
14 purpose animated some policy interventions such as the creation of “clusters”, the
15 policies for improving contacts between companies’ demand and research units
16 through vouchers (the idea behind is that the best research units would be able to
17 collect more vouchers), etc. Apparently, the results obtained are in the opposite
18 direction.
19

20 This fact raises two reflections. The first is that maybe the universities (and,
21 consequently, the research units) look not at the regional incentives but at the national
22 ones (as the Ministry is still the main financer of the universities’ activities) and at
23 international ones (the research reputation strongly depends upon the ability to
24 publish in international journals and to attract international grants). If this is the case,
25 a question arises about the opportunity for a regional government to be involved in
26 this sector.
27

28 A second (possibly alternative) reflection is that the policies adopted for boosting
29 research productivity were not adequate in terms of PLEASE REPHRASE TO
30 AVOID “in terms of” policy design. To properly design a policy in this field the
31 necessary first step is to understand what affect the academic productivity. In this
32 context, Faria (2002) suggests that policies for fostering the overall productivity of the
33 research sector are: (i) competition in the labour market among researchers (e.g.,
34 through career or salary incentives) and (ii) increasing research funds. Did the policies
35 of Lombardy Region respect these elements? Are there other elements that affect
36 research productivity? These are interesting starting point for further research in this
37 field.
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Our second analysis regarded how five external factors (“external” because they are not under the control of the departments) affect efficiency (section 4.2.). **Our** empirical analysis suggests that none of these factors (location in metropolitan area, scientific sector, university effect, proportion of tenured academic staff, departments “longevity”) is able to adequately explain efficiency differentials. **We** consider this result as positive, especially when thinking to the use of efficiency scores for policy purposes (e.g., resources allocation). Indeed, a usual critic to the efficiency analyses is that they provide results which are affected by factors which are not under the control of the units themselves: when this is the case, a procedure of resource allocation following efficiency results would be inequitable. Among others, Marinova & Newman (2008), describing the new funding model for Australian universities’ research, pointed out several counterproductive mechanisms that can be created by linking academic performance and resources without taking into account factors affecting efficiency in a proper way. The authors concluded their paper stating that among the “*two necessary pre-conditions for Australia to have a healthy, strong and world-class university research sector*” one is that “*the funding model used should allow for diversity and flexibility to properly reflect the complexity of academic world*” (p.285).

At the same time, **we** argue that there are some elements, which actually could influence efficiency and which are related to some “soft” characteristics of the academic units, typically (i) the incentive systems and (ii) the governance/management. For instance, Ramsden (1994) pointed out that the perception of the academic staff about the importance of publications for their career was consistently related to the production of academic articles and books. Rodgers & Neri (2007) suggested that the “departmental environment” is important and they define it through several measures centred on the “human capital” of researchers who work in the department. Unfortunately, QuESTIO dataset does not collect such data: an extension of this dataset along this dimension could help to improve significantly the understanding of this pattern.

However, if the incentive system really matters, another conclusion can be drawn from **our** study: as **we** measured a potential “university effect”, and it is not statistically relevant, then **we** can conclude that no incentive system works at university level. Different reasons can be proposed to explain this result. In particular, it can be both the cases that (i) the incentive system is designed at an higher level (in

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3 Italy, at the central government level), or (ii) that it is designed at a lower
4 (department) level – and given the department-level of our data, we cannot exploit
5 such dimension, which requires individual-level data. The evidence about the process
6 for recruiting academic staff and its career in Italy suggests that, however, no
7 government-level incentive exists – indeed, the career of professors is very poorly
8 related to their scientific production.
9

10 Levin (1991) underlined the importance of incentives to raise the productivity of
11 universities' activities. More specifically, he acknowledged that higher education
12 shows productivity declines due to two main reasons: (i) it is a “stagnant industry”, as
13 it is based on labour intensity; (ii) clear rewards and property rights are absent. Thus,
14 the suggestion provided by the author is to develop a reward system within the
15 university based on clear goals, financial incentives and evaluation procedures.
16 Whether such schemes have been actually implemented in departments analysed in
17 this paper is not clear; probably detailed case studies can help to shed more light on
18 this topic through future research.
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20 The governance/management of the academic departments has not been analysed in
21 our study, as the only information available in this respect (the presence of a quality
22 system or a management control system) is a very indirect measure of the governance
23 process and the data recovery on this topic was quite imprecise. Another way to
24 improve the QuESTIO dataset should be to better investigate this dimension, by
25 including some qualitative descriptions about the way Department managers organise
26 and coordinate the activities and resources, formulate strategies and foresight studies
27 and manage networking activities (see for instance Sala *et al.*, forthcoming; Salerno *et*
28 *al.*, 2008). Without knowing the characteristics of the “management style” of each
29 department, it is impossible to derive policy implications from such dimension. At the
30 same time, a possible way to better understand the potential incidence of such
31 phenomenon is to conduct case studies about the successful academic departments
32 (for example, those with higher efficiency scores or those which highly improved the
33 scores in the last years).
34

35 Finally, a potential candidate to analyse the efficiency differentials is the interaction
36 between research and teaching activities conducted by the departments. Typically, the
37 literature did not paid enough attention to the interaction between teaching and
38 research at department level, mainly because both activities were considered as inputs
39 and outputs (see section 2). In this paper, the focus was exclusively on the research
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3 activities but it raises also questions about the effects that the (unmeasured) teaching
4 activities play on the research result. This issue is very relevant both in theoretical
5 terms (are there economies of scope, or tradeoffs, between the two activities?) and in
6 empirical ones (which is the optimal allocation of energies between teaching and
7 research?). This interesting issue was at the centre of several contributes since the
8 seminal paper by Cohn et al. (1989), that for the first time addressed and modelled the
9 multi-outputs nature of academic activities. Recently, the theme has been explored by
10 Bonaccorsi & Daraio (2007) for a sample of European universities. In the present
11 paper, we cannot explore this topic because QuESTIO dataset does not record data
12 about the teaching dimension of the departments' activities (as before, it could
13 represent a substantial improvement of the dataset).

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16 Finally, the issue of research quality still remains open. Indeed, our analysis is
17 focused only on a quantitative dimension of research, while quality is important to
18 adequately assess the performance. Typically the lack of data on this respect justifies
19 the scarce attention to this problem. However, the QuESTIO dataset will include in
20 the next years some qualitative indicators, like H and citation indexes. We will devote
21 attention to this topic in future research, also exploring trade-offs between research
22 quantity and quality.

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25 The analyses and the data have allowed an interesting discussion in terms of PLEASE
26 REPHRASE TO AVOID "in terms of" policy implication but we hope that further
27 research will follow both including new data (e.g. referring to teaching activities and
28 research quality) and considering other geographical regions.
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59
60

References PLEASE REDO TO FIT JOURNAL STYLE. Note dash – not hyphen - to identify page numbers

Abbott, M., Doucouliagos, C., (2003), The Efficiency of Australian Universities: a Data Envelopment Analysis, *Economics of Education Review*, 22(1), 89-97.

Agasisti, T., (2009), Market Forces and Competition in University Systems: Theoretical Reflections and Empirical Evidence from Italy, *International Review of Applied Economics*, 23(4), 463-483.

Agasisti, T., Dal Bianco, A., (2006), Data Envelopment Analysis of the Italian University System: Theoretical Issues and Policy Implications, *International Journal of Business Performance Management*, 8(4), 344-367.

Agasisti, T., Dal Bianco, A., (2009), Reforming the University Sector: Effects on Teaching Efficiency. Evidence from Italy, *Higher Education*, 57(4), 477-498.

Agasisti, T., Salerno, C., (2007), Assessing the cost efficiency of Italian universities, *Education Economics*, 15(4), 455-471.

Athanassopoulos, A.D., Shale, E., (1997), Assessing the Comparative Efficiency of Higher Education Institutions in the UK by Means of Data Envelopment Analysis, *Education Economics*, 5(2), 117-134.

Avkiran, N.K., (2001), Investigating Technical and Scale Efficiencies of Australian Universities Through Data Envelopment Analysis, *Socio-Economic Planning Sciences*, 35(1), 57-80.

Banker, R. D., Charnes, A., Cooper, W., (1984), Models for Estimation of Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science*, 30, 1078-1092.

Bonaccorsi, A., Daraio, C., (2007), *Universities and strategic knowledge creation*, Edward Elgar Publisher, Cheltenham, UK.

Bonaccorsi, A., Daraio, C., Simar, L., (2006), Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data, *Scientometrics*, 66(2), 389-410.

Brennan, J., Teichler U., (2008), The future of higher education and of higher education Research, *Higher Education*, 56, 259–264.

1
2
3 Brockett, P.L., Golany, B., Shan Li, (1998), Analysis of intertemporal efficiency
4 trends using rank statistics with an application evaluating the macro economic
5 performance of OECD nations, *Journal of Productivity Analysis*, 11(1), 169-182.
6
7

8
9 Charnes, A., Cooper, W.W., Rhodes, E. (1978) Measuring the efficiency of decision
10 making units, *European Journal of Operational Research*, 2, 429-444.
11

12
13 Clark, B., (1998), *Creating Entrepreneurial Universities: Organisational Pathways of*
14 *Transformation*, Issues in Higher Education, Elsevier Science, New York.
15

16
17 Cohn, E., Rhine, S.L.W., Santos, M.C. (1989), Institutions of higher education as
18 multi-product firms: economies of scale and scope, *Review of Economics and*
19 *Statistics*, 71, 284-290.
20
21

22
23 Cooke P., Uranga M. G., Etxebarria G. (1997) Regional Innovation Systems:
24 Institutional and organisational dimensions, *Research Policy*, 26, 475-491.
25

26
27 Cooper, W.W., Seiford L.M., Tone K., (2006), *Introduction to Data Envelopment*
28 *Analysis and Its Uses*, Springer, New York.
29

30
31 Curran, P.J., (2000), Competition in UK Higher Education: competitive advantage in
32 the Research Assessment Exercise and Porter's diamond, *Higher Education Quarterly*,
33 54(4), 386-410.
34
35

36
37 Daraio, C., Simar L., (2005), Introducing environmental variables in nonparametric
38 frontier models: a probabilistic approach, *Journal of Productivity Analysis*, 24(1), 93-
39 121.
40
41

42
43 Etzkowitz, H., (2003), Research groups as 'quasi-firms': the invention of the
44 entrepreneurial university, *Research Policy*, 32(1), 109-121.
45
46

47
48 Faria, J.R., Scientific, business and political networks in academia, *Research in*
49 *Economics*, 56(1), 187-198.
50

51
52 Flagg, A.T., Allen, D.O., Field, K., Thurlow, T.W., (2004), "Measuring the Efficiency
53 of British Universities: a Multi-Period Data Envelopment Analysis", *Education*
54 *Economics*, 12(3), 231-249.
55

56
57 Gimenez, V.M., Martinez, J.L., (2006), Cost efficiency in the university: a
58 departmental evaluation model, *Economics of Education Review*, 25, 543-553.
59
60

1
2
3 Hare, P., Wyatt, G., (1992), Economics of academic research and its implications for
4 higher education, *Oxford Review of Economic Policy*, 8(2), 48-66.

5
6
7 Hood, C. (1991), A public management for all seasons? *Public Administration*, 69, 3–
8 19.

9
10
11 Hood, C. (1995), The new public management in the 1980s: Variations on a theme.
12 *Accounting Organizations and Society*, 20(2/3), 93–110.

13
14
15 Johnes, G., Johnes, J., (1993), Measuring the Research Performance of UK
16 Economics Departments: an Application of Data Envelopment Analysis, *Oxford*
17 *Economic Papers*, 45, pp.332-347.

18
19
20 Johnes, G., Johnes, J., (1995), “Research Funding and Performance in UK University
21 Departments of Economics: A Frontier Analysis”, *Economics of Education Review*,
22 14(3), 301-314.

23
24
25 Johnes, J., (2004), Efficiency Measurement, in Johnes, G., Johnes, J., (eds),
26 *International Handbook on the Economics of Education*, Edward Elgar Publishing
27 Ltd, Cheltenham.

28
29
30 Johnes, J., (2006), Data Envelopment Analysis and its Application to the
31 Measurement of Efficiency in Higher Education, *Economics of Education Review*, n.
32 25, pp. 273-288.

33
34
35 Kocher, M.G., Luptàcik, M., Sutter, M., (2006), Measuring Productivity of Research
36 in Economics. A Cross-Country Study Using DEA, *Socio-Economic Planning*
37 *Sciences*, 40, 314-332.

38
39
40 Koksal, G., Nalcaci, B., (2006), The relative efficiency of departments at a Turkish
41 engineering college: a data envelopment analysis, *Higher Education*, 51(1), 173-289.

42
43
44 Kruskal, W.H, Wallis, W.A., (1952), Use of ranks in one-criterion variance analysis,
45 *Journal of the American Statistical Association*, 47(260), 583-621.

46
47
48 Landoni, P., Verganti, R. 2006. Fostering Knowledge and Technology Transfer
49 through evaluation systems at a regional level. *International Journal of Technology*
50 *Transfer and Commercialisation*, Vol.5, No.4, pp.355-372

1
2
3 Lechner C., Dowling M. (1999) The Evolution of Industrial Districts and Regional
4 Networks: The Case of the Biotechnology Region Munich/Martinsried, *Journal of*
5 *Management and Governance*, 3, 309–338.

6
7
8
9 Levin, H.M., (1991), Raising productivity in higher education, *Journal of Higher*
10 *Education*, 62(3), 242-262.

11
12
13 Madden, G., Savage, S., Kemp, S., (1997), Measuring public sector efficiency: a
14 study of economics departments at Australian universities, *Education Economics*,
15 5(2), 153-167.

16
17
18
19 Marinova, D., Newman, P., (2008), The changing research funding regime in
20 Australia and academic productivity, *Mathematics and Computers in Simulation*
21 78(2-3), 283-291.

22
23
24
25 McMillan, M.L., Datta, D., (1998), The Relative Efficiencies of Canadian
26 Universities: A DEA Perspective, *Canadian Public Policy*, 24(4), 485-511.

27
28
29 Moreno, A.A., Tadepali, R., (2002), Assessing Academic Department Efficiency at a
30 Public University, *Managerial and Decision Economics*, 23, 385-397.

31
32
33 Ng, Y.C., Li, S.K., (2000), Measuring the Research Performance of Chinese Higher
34 Education Institutions: An Application of Data Envelopment Analysis, *Education*
35 *Economics*, 8(2), 139–156.

36
37
38
39 Organisation for Economic Co-operation and Development (OECD), (2002),
40 Proposed Standard Practise for Surveys of Research and Experimental Development -
41 Frascati Manual, sixth edition.

42
43
44
45 Organisation for Economic Co-operation and Development (OECD), (2003),
46 Education policy analysis. Paris: OECD.

47
48
49 Pastor, J.T., Ruiz, J.L., Sirvent, I., (2002), A Statistical Test for Nested Radial Models,
50 *Operations Research*, vol. 50, n. 4, pp.728-735.

51
52
53 Pesenti, R., Ukovich, W., (1996), Evaluating Academic Activities Using DEA,
54 Internal Report, DEEI, Università di Trieste.

55
56
57 Porter M.E. (1998) *Clusters and the New Economics of Competition*, Harvard
58 Business School Press.

1
2
3 Rizzi, D., (1999), L'efficienza dei dipartimenti dell'Università Cà Foscari di Venezia
4 via DEA e DFA (The efficiency of departments at University Cà Foscari through
5 DEA and DFA), Working Paper, Università Cà Foscari di Venezia, Dipartimento di
6 Scienze Economiche.
7
8
9

10
11 Rodgers, J. R., Neri, F., (2007), Research Productivity of Australian Academic
12 Economists: Human-Capital and Fixed Effects, Australian Economic Papers, 41(6),
13 67-87.
14
15

16
17 Sala A., Landoni P., Verganti R., (forthcoming) "R&D networks: an evaluation
18 framework" International Journal of Technology Management.
19

20
21 Salerno M., Landoni P., Verganti R. "Designing foresight studies for Nanoscience
22 and Nanotechnology (NST) future developments" Technological Forecasting &
23 Social Change, 75(8), 1202-1223
24
25

26
27 Sarkis, J., (2007), Preparing your data for DEA, in Zhu. J., Cook, W.D., (eds.),
28 Modeling Data Irregularities and Structural Complexities in Data Envelopment
29 Analysis, Springer, New York.
30
31

32
33 Sarrico, C.S., Dyson, R.G., (2004), Restricting virtual weights in data envelopment
34 analysis, European Journal of Operational Research, 159(1), 17-34.
35

36
37 Sarrico, C.S., Teixeira, P.N., Rosa, M.J., Cardoso, M.F., (2009), Subject mix and
38 productivity in Portuguese universities, 197(2), 287-295.
39

40
41 Thursby, J.G., (2000), What Do We Say about Ourselves and What Does It Mean?
42 Yet Another Look at Economics Department Research, Journal of Economic
43 Literature, 38, 383-404.
44
45

46
47 Warning, S., (2004), Performance Differences in German Higher Education:
48 Empirical Analysis of Strategic Groups, Review of Industrial Organization, 24, 393-
49 408.
50

51
52 Wilson, P.W, (1995), Detecting influential observations in data envelopment analysis,
53 Journal of Productivity Analysis, 6(1), 27-45.
54
55

56
57 Zhu, J., (2003), Quantitative Models for Performance Evaluation and Benchmarking,
58 Kluwer Academic Publisher, Boston, MA.
59
60

Table 1. Inputs/outputs descriptive statistics

	<i>Average (Mean?)</i>	<i>Standard deviation</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Average difference 2004–2007</i>
Laboratories (m ²)	2,243.83	6,917.93	0.00	60180.00	80.24
Human resources (n)	105.50	83.30	9.00	445.00	16.19
High Qualified Human resources (n)	98.33	79.66	8.00	434.00	16.00
Other personnel (n)	7.12	6.83	0.00	32.00	-0.30
Revenues from financed activities (€)	486936.06	557412.78	0.00	3039361.00	142196.00
Financed activities from abroad (€)	118587.58	256766.37	0.00	1805922.00	10896.00
Revenues from orders (€)	451240.13	764559.23	0.00	3333362.00	86950.00
Number of publications (n)	32.45	31.91	0.00	188.00	2.87
Doctorates in cooperation with external bodies (n)	2.49	4.04	0.00	22.00	0.63

Table 2. Efficiency scores (DEA on 2007 data) – descriptive statistics

	<i>CRS Efficiency</i>	<i>VRS Efficiency</i>	<i>Scale Efficiency</i>
Mean	0.745	0.786	0.937
St. Deviation	0.241	0.219	0.101
Min	0.173	0.216	0.432
Max	1.000	1.000	1.000
# efficient units	25	29	25

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 3. Malmquist index 2004-2007 – descriptive statistics

<i>Department</i>	<i>Malmquist index</i>	<i>Efficiency change</i>	<i>Frontier shift</i>
Mean	1.060	1.666	0.652
St. dev.	0.492	0.882	0.141
Min	0.072	0.529	0.104
Max	2.534	4.600	1.031
# improving units	35	56	2

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 4. Factors affecting efficiency (Kruskal-Wallis analysis)

<i>Effects of Metropolitan area (Milan)</i>	
H (observed value)	0.007
H (critic value)	3.481
p-value	0.934
<i>Effects of subject mix</i>	
H (observed value)	8.451
H (critic value)	9.488
p-value	0.076
<i>University effects</i>	
H (observed value)	9.426
H (critic value)	14.067
p-value	0.224
<i>Effects of tenured staff proportion</i>	
H (observed value)	0.163
H (critic value)	3.841
p-value	0.687
<i>Effects of departments' age</i>	
H (observed value)	1.172
H (critic value)	3.841
p-value	0.279

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3 **Evaluating the efficiency of research in academic departments: an empirical**
4 **analysis in an Italian Region**
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12 **completing. The tense keeps changing and for reference to published work I have**
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33 **Abstract.**

34 This paper investigates the efficiency of university departments on science,
35 technology and medicine in an Italian Region (Lombardy). The aim of the paper is
36 twofold: (i) to analyse the changes in productivity in recent years (from 2004 to and
37 2007); and (ii) to detect factors that are potentially affecting efficiency. The research
38 benefited from a new and unique dataset (called QuESTIO) developed by the
39 Lombardy Regional Government. Using facilities and academic staff as inputs and
40 research grants and publications as outputs, the research activity of academic
41 departments was modelled. The methodological approach for computing efficiency
42 scores is Data Envelopment Analysis (DEA). Malmquist indexes have been used to
43 measure changes in productivity, while Kruskal-Wallis tests were employed to study
44 the potential determinants of efficiency. **The main results were that in the period**
45 **considered, the academic departments improved their efficiency but, at the same time,**
46 **the efficiency frontier worsened. ~~Second,~~ Moreover, external and measurable factors**
47 **(such as, scientific sector, proportion of tenured staff, location) have a limited impact**
48 **in explaining efficiency differentials. Policy implications of the results are discussed.**
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53 **Keywords.**

54 University research, efficiency, research policies, Data Envelopment Analysis,
55 Malmquist index, higher education policy.
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58 **JEL Codes.**

59 **C14, H41, H52**
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1. Introduction and motivation

In recent years, higher education institutions have been increasingly studied. In the “knowledge economy” their importance for economic development, social equity, mobility, social cohesion and integration is widely acknowledged (Brennan & Teichler, 2008). Furthermore, given the difficult situation of public finances, considerations about resources allocation have been raised in many countries, calling for more evaluations and accountability. For these reasons the so-called ‘New Public Management’ movement, started at the beginning of the 1980s in the public sector in general, has also increasingly been affecting the universities. New Public Management (Hood, 1991; 1995) represents the request to public organisations to become more managerial, in particular by drawing on practices and models from the private sector. This process has been driven both by universities themselves and by governments through reforming efforts. The results, especially in many countries within Europe, share some common characteristics: first, the introduction of incentives schemes based on financial models for allocating public funds; second, new or strengthened assessment procedures and evaluation agencies; third, more emphasis on universities’ autonomy (OECD, 2003).

This work explores how the recent changes in the university system affected the efficiency of university research. In particular, the research sought to understand whether an overall increase in efficiency can be recognised or whether differences are present between universities given the previously-noted increased autonomy. Normally, the majority of the reforming efforts have been directed towards education activities, whilst an increase in efficiency of university research has been assigned to incentive systems and evaluation processes. These are expected to have had an overall positive effect on the system but, at the same time, they have left the universities in charge of finding and managing the ways to obtain better results. Given the autonomy of the universities and the decentralisation of responsibilities, significant efficiency changes are thus expected between and within universities. Furthermore, the idea that differentials in research performance are key for competition among departments is well established in the literature (Curran, 2000).

The research focused on universities research activities and not on education or knowledge/technology transfer activities. Universities’ education activities constitute the first and original mission of the universities but, at the same time, they are normally carefully regulated by laws and their efficiency and quality are already

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3 widely studied (Madden *et al.*, 1997). Indicators such as number of degrees awarded,
4 rate of success, years of study, have been widely used both to evaluate the universities
5 and to introduce new policies. The opposite holds for universities'
6 knowledge/technology transfer activities. Even if some argue for this to be a third
7 mission for academia and call for "entrepreneurial universities" (Clark, 1998;
8 Etzkowitz, 2003), others refuse this perspective and signal the risks of focusing on
9 and expanding the role of these activities. Moreover, the efficiency analysis of these
10 activities is hampered by the difficulties in finding the right indicators. There are
11 many different knowledge/technology transfer activities (for example, spin-off,
12 consultancies, research projects with firms, patents) and their evaluation can be based
13 only partially on economic values given the not-for-profit nature of (most)
14 universities (Landoni and Verganti, 2006). Finally, the focus of the study is on the
15 research activities as they are the core activities of universities; driving and informing
16 both education activities and knowledge/technology transfer activities. This
17 relationship especially holds for transfer activities because the value of the results
18 transferred relies heavily on the underlying research on which they are based.
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33 This paper adopts the standard definition of 'research' provided by the Organisation
34 for Economic Co-operation and Development (OECD): "Research and development
35 is a term covering three activities: basic research, applied research, and experimental
36 development" (OECD, 2002). However, only research activities that are normally
37 carried out within universities are considered.
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42 Furthermore, the focus of the efficiency analysis is on university departments and not
43 on the university as a whole. Universities are composed of different research
44 departments and their publication outputs, co-authorship behaviours and thus
45 efficiency usually differ significantly. An analysis at the level of the university can
46 put forward mixed results, while an analysis at the level of single departments is more
47 precise and coherent with the objectives of an efficiency analysis. For this reason, to
48 obtain a sample of comparable departments the research focused on natural science
49 departments. The choice of the department level for the analysis is coherent with the
50 focus on research activities: normally education activities are managed by
51 organisational entities inside the university that are transversal to more departments
52 and many transfer activities are centralised in a single organisational unit (such as a
53 liaison office or a knowledge/technology transfer office).
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3 The research considers departments located in the Lombardy region (Italy). A
4 regional focus has been adopted to ensure similar contextual variables, such as
5 policies and economic environment, for the universities included in the analysis.
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7 Furthermore, Lombardy is one of the more advanced European regions both for (i)
8 economic development and (ii) research activities and universities: more than 9.4
9 million habitants, GDP per capita >€34,000; 12 universities are located in the Region
10 (out of about 70 in all the country) with more than 230,000 students. Finally, the
11 regional level is increasingly recognised as a relevant level when analysing research
12 and innovation activities. Many authors (Cooke *et al.*, 1997; Porter, 1998; Lechner &
13 Dowling, 1999) underline that it is at a local level that the majority of the connections
14 between the different innovation actors take place. The localisation of knowledge and
15 the role of proximity as a driver of economic development (for example, clusters)
16 have also highlighted the importance of regional and local government in fostering
17 and strengthening the actors and their relationships.
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21 To summarise, the focus of the paper is on efficiency of research activities in
22 scientific departments in the Lombardy Region (Italy). The research questions are:
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- 24 • did changes in the overall efficiency of departments' research occur between
25 2004 and 2007?
 - 26 • Which are the main factors affecting efficiency?
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31 The next section presents recent literature on the topic, then the methodology and the
32 data used are introduced, finally results are presented and discussed. ~~and conclusions~~
33 ~~are drawn.~~
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49 **Background**

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51 The international literature about universities' efficiency (through non-parametric
52 techniques) has been developed both at institution-level (Athanasopoulos & Shale,
53 1997; McMillan & Datta, 1998; Ng & Li, 2000; Avkiran, 2001; Abbott &
54 Doucouliagos, 2003; Flagg, et al, 2004; Warning, 2004) and department-level. The
55 latter is more relevant for the context of the present study.
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59 The contributions by Johnes & Johnes (1993; 1995) had a major influence on the
60 methodological approach. Johnes & Johnes (1993) measured the research

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3 performance of UK economics departments by using staff numbers as inputs and
4 publication counts and grants as outputs; the same strategy was adopted again for
5 deriving efficiency scores of economics department in a subsequent paper (Johnes &
6 Johnes, 1995). The authors ran several Data Envelopment Analysis (DEA) models to
7 test the robustness of results and claim for a possible use of results for policy
8 purposes, especially for establishing an optimal allocation of resources across
9 departments. These two contributions are the most important as they focus
10 exclusively on the research dimension of the universities' work.

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Madden *et al.* (1997) studied the efficiency of economics departments in 29
Australian universities. Inputs were teaching and research staff, outputs were
graduates and publications (for teaching and research respectively). As in other
studies listed below, here the focus was both on teaching and research performance,
even if the analysis were conducted at sub-unit level (that is at departmental level
instead of institutional level). The specific objective of the Madden *et al.* (1997) study
was to verify whether policies promoted by governments impacted on productivity;
they confirmed that there was actually an increase in productive efficiency.

Thursby (2000, p. 400) analysed the efficiency of the Economics Research
Departments in the United States. He defined efficiency as follows:

a department is deemed technically efficient if, when compared to departments
with similar level of inputs, it could produce greater research outputs without
increasing its inputs usage, or equivalently, it is one which, compared to
departments with similar levels of outputs, could produce the current levels of
outputs with fewer inputs.

Thursby used publication, citation data and number of Ph.D.s as outputs and **the
number of researchers and professors** **faculty size** [WHAT DO YOU MEAN BY
FACULTY SIZE?], ~~full professors~~, graduate students, federal grants, library
acquisitions and a dummy for private ownership as inputs. He found that the average
level of efficiency in the United States is high (67% of economics departments appear
as efficient). ~~Seen from a European perspective, this result is not so unexpected~~
[WHY?].

Moreno & Tadepalli (2002) focused on 42 academic units distributed across 7
colleges in the United States. They used staff, financial resources and proxies for
structures (for example, building space) as inputs and number of students, FTE

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3 enrolments and grant awards as outputs. In discussing their results, they showed that
4 efficiency scores do not illustrate information about effectiveness: that is, they argued
5 that a qualitative dimension is necessary for this purpose. Lastly, as their background
6 is strongly managerial, they also suggested a use of efficiency analysis as a planning
7 tool, not only for evaluating universities' activities.
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11 Koksas & Nalcaci (2006) derived efficiency scores for 14 university departments at
12 the Middle East Technical University (METU) in Turkey, by using staff salaries, a
13 composite indicator of previous research quality and number of students as inputs and
14 number of publications, graduates and teaching indicators as outputs. Thus, in their
15 contribution, the authors focused also on the teaching activity of the departments.
16 They decided to use weights for teaching and research loads as suggested by
17 university's administrators through a preliminary survey. The paper suggests that the
18 models adopted for computing efficiency can serve to set new targets for inefficient
19 departments.
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23 Gimenez & Martinez (2006) focused on cost efficiency of the departments at the
24 Autonomous University of Barcelona. They computed cost-efficiency scores and
25 separated cost excess into three categories: technical efficiency, fixed factors, and
26 "scale effects" (due to the number of academics in the department). **scale of size**
27 **[WHAT IS THIS? DO YOU MEAN NUMBER OF ACADEMICS IN THE**
28 **DEPARTMENT?]**. The units of analysis were 42 departments and again the focus is
29 on both teaching and research activities. The inputs chosen were: expenditure on
30 temporary hired teaching and research staff, operational expenditures, expenditures on
31 tenure staff. To measure the outputs, they employed the following variables: results of
32 a government evaluation process of research, teaching load (measured through credits
33 granted) and students' opinions. The authors suggested that their analyses can be used
34 to assess the differences between (i) the observed cost of the units and (ii) the cost
35 they would achieve assuming long-term cost minimisation. Their result tells that size
36 does not matter in determining efficiency, while higher proportion of non-tenured
37 staff is associated with higher efficiency levels.
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41 In another exercise presented by Kocher *et al.* (2006) the analysis focused on the
42 productivity of research in economics across 21 OECD countries. The focus of the
43 paper is **was** on research and the outputs selected are top publications (and impact
44 factors), while inputs are expenditure on research and development, number of
45 universities and total population. This study is **was** quite different, however, with
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4 respect to the relevant contributions for the present paper, as the unit of analysis is the
5 country (neither the university nor the department). The results suggest that research
6 productivity can be raised through an increase in the scale of operations.
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9 An interesting issue is to analyse the related literature about the Italian universities'
10 research. To the best of the authors' knowledge, there ~~were~~ ~~are~~ only two specific
11 contributors that specifically analyse the efficiency of universities in producing
12 research outputs (Pesenti & Ukovich, 1996; Rizzi, 1999) and just one attempting to
13 focus on teaching production (Agasisti & Dal Bianco, 2009).
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16 The two contributions at departmental level (Pesenti & Ukovich, 1996; Rizzi, 1999)
17 ~~use~~ ~~used~~ a similar set of variables and focus both on teaching and research outputs.
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19 The main scope for these contributions ~~is~~ ~~was~~ to provide information and suggestions
20 for allocating resources within a university.
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23 Contributions about the efficiency of Italian higher education have been conducted at
24 institution-level (thus, not considering separately the structures devoted to teaching
25 and research). ~~The reason for this choice can be summarised by the idea that the~~
26 ~~strategy and the mission of universities is defined at macro (institution) level, then the~~
27 ~~balance between teaching and research is decided by the decision centres at institution~~
28 ~~level (Bonaccorsi & Daraio, 2007, p. 22).~~ This is because the strategy and the mission
29 of universities and the balance between teaching and research are defined at
30 institutional level (Bonaccorsi & Daraio, 2007, p. 22).
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33 Among these contributions at an institutional level Agasisti & Dal Bianco (2006)
34 studied the efficiency of 58 Italian public universities, by using, as inputs, number of
35 staff, financial resources and students and, as outputs, graduates and research grants.
36 They suggested the use of efficiency analysis for policy purposes, especially to
37 evaluate the differences in performance between efficient and inefficient units. Later,
38 Agasisti & Salerno (2007) analysed the cost efficiency of another sample of Italian
39 universities, by adding some qualitative measures for inputs and outputs. They
40 concluded that a redistribution of inputs across universities could lead to an overall
41 improvement of efficiency in the Italian higher education sector.
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44 Bonaccorsi *et al.* (2006) used a robust non-parametric technique (developed by
45 Daraio & Simar, 2005) to take in account external conditions affecting the
46 productivity of universities. The inputs and outputs adopted are quite similar to
47 previous studies (that is, staff numbers, expenses and spaces as inputs and
48 publications and graduates as outputs) but they also included some "external" factors:
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3 university size, number of departments within the university, percentage of private
4 funding, number of curricula activated. They concluded that economies of scale and
5 scope are not relevant factors in explaining (in)efficiency. However, a strong role is
6 played by the external factors: clearly, such result affects the policy considerations.
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11 CLAUSE]
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16 To sum up, the literature seems to suggest that, to analyse research efficiency of
17 universities, that is, the efficiency in the production of research outputs:

- 18 • inputs can be classified under three main groups: human resources, financial
19 resources and structures (e.g., facilities, buildings);
- 20 • outputs can be grouped into publications and grants.

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23 The best indicators to measure these classes of inputs/outputs are questionable but the
24 general emerging consensus is on a productive process that can be described with
25 such indicators. WHAT DOES THIS MEAN?. The present paper moves from these
26 suggestions and it focuses on the efficiency of research activities in scientific
27 departments in the Lombardy Region (Italy). [what struck me was inconsistency in
28 the research about economies of scale!]
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37 Methodology and data

38 Methodology

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40 The methodology is articulated accordingly to the two steps adopted to answer the
41 research questions of the paper: on one hand the efficiency analysis (including
42 efficiency scores of the departments, changes across time and time trends), on the
43 other hand the effort to identify the determinants of efficiency.
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49 The first choice is about the methodology to compute efficiency, because there are
50 different methods to target the analysis of efficiency among different units. Data
51 Envelopment Analysis (DEA) is a frontier, linear programming technique, introduced
52 by the seminal work of Charnes *et al.* (1978). It deals with the efficiency problem of
53 complex organisations that produce many outputs using several inputs at a time. Data
54 Envelopment Analysis (DEA) (Charnes *et al.*, 1978) was the methodology used to
55 analyse efficiency. It deals with the efficiency problem of complex organisations that
56 produce many outputs using several inputs at a time.
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3 This paper only briefly discusses some characteristics of DEA, referring the interested
4 reader to Johnes (2004), Cooper *et al.*, (2006) and Zhu (2003).

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6 In a DEA model, the notion of efficiency is that of “technical efficiency”, defined as
7 the relative ability of each decision making unit (DMU) in producing outputs, where
8 the term “relative” means that each organisation is compared with any other
9 homogeneous unit. DEA could be represented by a linear programming technique
10 where each DMU tries to maximise the efficiency ratio (output over inputs) choosing
11 the best set of weights. There are two ways to deal with a DEA formulation: (i) input
12 oriented (that is, the ability to minimise inputs when outputs are given) and (ii) output
13 oriented (maximisation of outputs given a certain bundle of inputs). The latter
14 approach is used in this paper, as the typical problem for a research unit is to
15 maximise outputs (publications, grants) given its inputs (research staff, laboratories).
16 DEA mathematical formulation can deal with both constant returns to scale (CRS)
17 and variable returns to scale (VRS). The seminal work of Charnes *et al.* (1978)
18 introduced a constant-return-to-scale (CRS) model where DMU dimension has no
19 importance in defining efficiency performance (see equation 2). DMUs face the same
20 efficiency frontier, independently of their relative size. One can cast doubts on the
21 comparability of small and large units. Larger units exploit common inputs to produce
22 different outputs, whereas smaller ones benefit from substantial advantages in
23 organising activities. The BCC [WHAT DOES BCC STAND FOR?] A further model,
24 developed by Banker *et al.* (1984) introduces in DEA modelling the dimension factor,
25 by comparing units according to their dimension – that is, by considering that the
26 unit’s dimension can affect efficiency (VRS efficiency). [WHAT DOES THIS
27 MEAN?]

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Smaller units are associated with increasing economies of scale and bigger units with
decreasing economies of scale. In the middle, there is a “grey area” of constant
returns to scale. So, it is also possible to compute the scale efficiency. This is defined
as the ratio CRS/VRS efficiencies and interpreted as the ability of each institution to
benefit in terms of ~~PLEASE REPHRASE TO AVOID “in terms of” WHICH FAILS
TO EXPLAIN THE RELATIONSHIP~~ productivity from its size: operate at its
optimal scale dimension; in other words, in a VRS formulation, each DMU is
compared only with those units having a comparable size.

IN THE FOLLOWING PLEASE AMEND TO REMOVE THE PERSONALISATION AS HIGHLIGHTED IN CYAN.

~~We~~ It is also possible to measure changes in efficiency across time ~~and our~~ (the relevant period here is between 2004 and 2007). For measuring the determinants of the changes in efficiency scores, ~~we use~~ Malmquist index has been used (for more information about this index see Johnes (2004) and Coelli *et al.*, (2006)). ~~Let us~~ Considering a DMU, named P that has a change in production position from P_t (in period t) to P_{t+1} (in period t+1), the change in the production frontier could have occurred in a non-neutral way; that is, it could be determined both by efficiency changes and shifts in the efficiency frontier. Thus, for measuring the change in the efficiency score, ~~we have~~ it is possible to break down the score in these two different components. Both of the components have a specific mean: the resulting score for the DMU could have positive or negative effects due to the own efficiency change or due to the shift (movement) of the frontier. Thus the resulting efficiency index is composed of two parts. The first component of the equation is the ratio of technical efficiency in time period t+1 on the technical efficiency in the period t. Since it measures the change in technical efficiency, it is equal to 1 if no changes occurred, greater than 1 if the change was positive and less than 1 if it was negative. The second component measures the shift in the production frontier: if it is equal to 1 it has no effect on the efficiency score, if it is greater than 1 it has a positive effect and if it is less than 1 it has a negative effect. In other words, a shift in a production frontier that makes worse the relative position of the DMU (the other DMUs are performing relative better than before) provides a second component less than 1. The index (Malmquist index) resulting from the combination of these two components will be equal to 1 if there is no net effect of changes in technical efficiency and frontier changes; it will be greater than 1 if the net effect is positive and less than 1 if it is negative. ~~In our the analysis, we name “efficiency change” is the first component and “frontier shift” the second one. I THINK A CONCRETE EXAMPLE IS NECESSARY HERE TO GUIDE THE READER.~~

~~Moreover, we would detect the eventual stability of efficiency rankings across the period (again, the relevant period is between 2004 and 2007). In this case, we adopted one of the statistics suggested by Brockett *et al.* (1998). More specifically, we are interested in knowing if the efficiency of departments changed influencing the rankings or not over time. “Ranking the set of $n \times k$ [WHAT IS THIS?] efficiency~~

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3 ratings and observing the sum of ranks associated with each DMU, one can learn
4 about the relative position of the DMUs *vis à vis* each other across the whole period”
5 (Brockett *et al.*, 1998, p. 174). For this purpose, the basis of the analysis is a Kruskal-
6 Wallis test (Kruskal & Wallis, 1952, p. 175) where “the rejection of the null
7 hypothesis leads to the conclusion that, in general, the different DMUs maintain their
8 relative efficiency positions over time”. ~~AGAIN A CONCRETE EXAMPLE~~
9 ~~WOULD HELP HERE.~~
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17 The second task in ~~our~~ the methodology is to study some potential determinants of
18 efficiency. To pursue this objective, ~~we identified~~ some external factors (for example,
19 location effects, discipline effects) ~~were identified~~ and then ~~we compared~~ efficiency
20 scores were compared across different groups of units. The comparison was made by
21 means of the Kruskal-Wallis test (Kruskal & Wallis, 1952). This test allows the
22 researcher to detect if are there statistical differences across the groups analysed (for
23 example, when comparing the efficiency scores of units located in a metropolitan area
24 with those located elsewhere, the test indicates if this location effect generates a
25 statistical difference between the average scores of the two groups).
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34 35 *Data*

36 The research used a unique dataset that consists of input and output variables about
37 research and technology transfer activities in university departments located within
38 the Lombardy Region. This dataset is based on information coming from QuESTIO
39 system, a mapping of research and technological transfer organisations developed in
40 the Lombardy region. The QuESTIO system, launched in 2004 by the regional
41 government, was intended to be a transparency and incentive tool for the research and
42 technological transfer market by reducing any information unevenness often binding
43 cooperation among producers and users of knowledge. The system ~~pursues such~~
44 ~~scopes [??]~~ ~~by~~ ~~collects, updated and publishes~~ financial, organisational and structural
45 characteristics of research organisations and knowledge business intelligence services
46 in Lombardy.
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56 Since it aims at presenting the most detailed picture of regional community active in
57 research and technological transfer, the dataset has some specific criteria that are
58 pivotal for the analyses. First, the system is focused on every structure where such
59 activities are carried out, even where that structure is a part of a wider organisation.
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Second, these structures should have significant management autonomy so that their accountancy shall be determinable. The first criterion enables the regional administration to collect information on every single department, being acknowledged that the performance of departments belonging to the same university can differ significantly. As a consequence the university departments, as well as sections and institutes of the National Research Council or a research and development unit belonging to a company, provide data that refers solely to their specific resources and outputs. The second criterion assures that each structure included in the dataset is responsible (to some extent) for its strategy and performances thus justifying application of the DEA technique.

~~University departments are main actors in Lombardy innovation system; they are 147 out of 364 structures mapped, which balance the presence of Knowledge Business Intelligence Services, which count for 151. The map is completed with 13 Hospital and medical research centres, 34 Public Research Organisations and 19 company R&D units.~~

The Lombardy innovation system maps 364 structures of which 147 are university departments, 151 are knowledge business intelligence services, 13 are hospital and medical research centres, 34 are public research organisations and 19 are company research and development units.

~~In order to better point out the capillarity of these structures within the territory, the geographical analysis shows a concentration in the Province of Milan and a little less in Bergamo, Brescia, Pavia and Varese, which is explained by the presence of universities in those cities, all of them accredited with their single departments. [??]~~

~~We built our~~ The dataset was built by considering those university departments that provided information for the whole period 2004–2007 (units for which there are not missing data), by selecting the following variables:

Inputs

I1 Laboratories: the areas (measured in square meters) devoted to laboratories belonging to or accessible by the department. ~~This data provides a dimensional data related to the most distinctive and characterising areas equipped for scientific research. [Not clear what this means]~~

I2 Highly-qualified human resources: persons who perform research and technology transfer activities, regardless of their qualifications. They are mainly full professors, associated professors, permanent researchers, ~~post-Doc~~ ~~post-doctoral~~ scholarships and PhD students. It includes employees dedicated to activities in support of research, such as, certification, tests and measurements, patenting and commercialisation, financial assistance, partners search, technologies monitoring, events organisation, editing of technical-scientific “spreading publications”.

I3 Other personnel: administrative personnel that should ensure the efficient working of human resources devoted to research and technology transfer activities.

Outputs

O1 Revenues from financed activities: activities financed with regional or national calls for bids. This variable denotes the ability of the department to compete with other research organisations in getting public-funded research, thus measuring the amount of research that meet requirements of national and regional **Research and Innovation R&I** ~~[in full]~~ strategies.

O2 Revenues from financed activities from abroad: **internationally funded activities** ~~accomplished activities financed~~ ~~[do you mean internationally funded activities?]~~ that show the capacity to draw on international funding, such as European projects, ~~resulting by working with third countries organisations~~ ~~[not clear what this is referring to?]~~. It reflects department ~~down stream internationalisation~~ ~~[not clear what this means]~~ and it is a sign of the research activities that are acknowledged at international level.

O3 Revenue from orders: measures how far research activities carried out in a department **are funded by companies** ~~are committed directly by companies~~ ~~[not clear what this means]~~ or other institutions.

O4 Yearly number of publications: **yearly publications in academic international journals** ~~articles signed by department human resources on the international scientific press~~ ~~[not clear what this means, do you mean publication in international journals?]~~.

This is the traditional and widespread variable used to measure the output of research activities.

O5 Doctorates in cooperation with external bodies: sheds light on the capability of departments in attracting **funds for doctoral students** ~~investments for education finalised to research~~ ~~[not clear what this means]~~ and to establish cooperation with

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3 institutions and companies. Since this variable could be interpreted such as an
4 indicator of technology transfer activities, ~~we~~ it was investigated if it could alter the
5 efficiency scores and ~~we ran a~~ DEA model ~~has been estimated~~ without considering it.
6
7 The results are the same for almost all the DMUs so ~~we~~ decided to keep it in the
8 model. ~~[NOT SURE WHETHER YOU ARE SAYING IT WOULDN'T MATTER IF~~
9 ~~IT WASN'T IN THE MODEL?]~~
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16 As discussed in the previous section the choice of input and output variables is
17 ~~coherent~~ compatible with the most recent literature. The final sample contains 75
18 departments, for 4 years; overall, there are 300 observations, revealing considerable
19 variation (Table 1).
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25 <Table 1> about here
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28 Results and discussion

29
30 THIS RESULTS SECTION NEEDS THE RESULTS REPORTED TO BE
31 DISCUSSED AND EXPLAINED BUILDING A PICTURE RATHER THAN
32 LEAVING THE DISCUSSION UNTIL A FINAL SECTION AND THESE
33 RESULTS STANDING IN A KIND OF VACUUM. SEE JOURNAL STYLE. THIS
34 WILL ALSO HELP REDUCE REPETITION AND REDUCE THE WORD COUNT
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40 This section illustrates and discusses the results obtained through the DEA analysis of
41 the university departments in the Lombardy Region.
42

43 The results are presented in two main sections. The first is devoted to a description of
44 the efficiency scores with reference to the year 2007 (the last year available, where
45 the results are more stable, as previously discussed). ~~In this section one sub-paragraph~~
46 It analyses the change in efficiency between the first year of the dataset (2004) and
47 the last year (2007) ~~and another one explore~~ as well as the presence of time trends in
48 the efficiency scores. The second section ~~refers to the study of~~ examines statistical
49 differences in efficiency scores due to external factors, such as localisation and
50 discipline subject.
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60 ~~DEA efficiency scores, year 2007~~

This section explores the results of the efficiency analyses both looking at a single year (2007) and at differences between years. REPETITIVE

DEA efficiency scores, year 2007

Table 2 reports the descriptive statistics about the efficiency scores derived with reference to the year 2007 (the annex reports the specific scores for each department). NOT JOURNAL STYLE. INSTEAD SAY WHAT THE DATA SHOWS AND REFER TO 'EVIDENCE' (VIZ TABLE) IN PARENTHESES. As explained in the methodological section, we calculated CRS efficiency and VRS efficiency, as well as the "scale" efficiency computed as CRS/VRS scores (it is important to recall here that the model is output oriented). AVOID TOO MUCH REPETITION AS ARTICLE TOO LONG.

<Table 2> about here

The research efficiency of university departments in the Lombardy region looks quite [?? IS IT OR ISN'T IT HIGH, THIS IS TOO VAGUE] is high (CRS efficiency = 0.75, VRS efficiency = 0.78 (0.75 in terms of PLEASE REPHRASE TO AVOID "in terms of" CRS efficiency, 0.78 in terms of PLEASE REPHRASE TO AVOID "in terms of" VRS efficiency); actually, the high average efficiency is coherent compatible? with previous results derived across the world in the higher educations sector (Salerno, 2003). BUT WHAT IS THIS TELLING US? What is worth pointing out is a strong heterogeneity across departments: indeed, the standard deviation is >0.2. A look at the lowest scores suggests that there are very poor performers which shows scores [??] <0.5.

Data about scale efficiency suggests that all the departments have almost reached their optimal scale of operations (given their present scale), as the scale efficiency score is very high (>0.93) and standard deviation is very low (about 0.1) in this respect.

The picture that emerges from this first analysis of efficiency scores is a sector where there is a number of very efficient units (both assuming constant or variable returns to scale) and a number of departments that experienced low levels of technical efficiency; thus, as the anecdotic anecdotal evidence suggests, there is quite a strong

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3 differentiation among departments ~~in terms of~~ PLEASE REPHRASE TO AVOID “in
4 ~~terms of”~~ research efficiency.
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7 As the focus of ~~our~~ the paper is the efficiency of academic departments in the
8 Lombardy region, ~~we also checked the robustness of~~ ~~our~~ the results’ robustness was
9 checked by considering revenues from entities located in the Lombardy region as a
10 separate output (REV_LOMB). The correlation among results obtained by the
11 baseline model and this modified model is very high (>0.97), suggesting that both
12 models report a similar picture. WHICH MEANS WHAT? The VRS efficiency
13 scores for each department comparing the two models (also in this case the reference
14 year is 2007) is available, on request, from the authors. NEED TO SAY WHAT THE
15 ESSENCE OF THIS EVIDENCE IS AND DROP THIS REFERENCE IN THE
16 TEXT TO SEPARATE DATA BEING AVAILABLE.
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26 *Efficiency changes between 2004 and 2007 – a Malmquist analysis*

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28 Following the methodology described above, ~~we derived the~~ the Malmquist index has
29 been calculated, which allows us to disentangle the efficiency changes due to “pure”
30 efficiency improvement (or worsening) and technological improvement (or
31 worsening). The descriptive statistics about the results are reported in Table 3. ~~while~~
32 the detailed results are available on request from the authors.
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39 <Table 3> about here
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42 The picture that emerges highlights an interesting phenomenon. It looks like an
43 improvement in productivity did not occur (because the Malmquist index is around 1)
44 but, looking at the decomposition of the index, the reality appears more complex: an
45 efficiency changes happened, it was very positive (the index is >1.6) and involved the
46 majority of the departments (56 out of 70); conversely, there was a worsening of the
47 technology frontier (the “frontier shift” indicator is <0.7).
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53 ~~relevant detriment of the technology environment~~ [MEANING NOT CLEAR] It
54 looks like the academic units improved their technical efficiency (that is, the ability to
55 transform inputs into outputs) but, at the same time, the frontier worsened. In other
56 words, what happened is that the “technological change” (in the Malmquist language)
57 was negative. WHICH MEANS WHAT?
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3 What is “technology” in a regional research system, when ~~we define~~ research
4 performance is defined as the ability to attract financial resources and to publish in
5 academic journals? Technology could be defined as the bundle of policies that should
6 help in improving research efficiency, for example, information technologies,
7 research grants, support for publishing research results or to attract financial resources
8 from international grants or companies. This fact raises two reflections. The first is
9 that maybe the universities (and, consequently, the research units) look not at the
10 regional incentives but at the national ones (as the Ministry is still the main financier
11 of the universities’ activities) and at international ones (the research reputation
12 strongly depends upon the ability to publish in international journals and to attract
13 international grants). If this is the case, a question arises about the opportunity for a
14 regional government to be involved in this sector. A second (possibly alternative)
15 reflection is that the policies adopted for boosting research productivity were not
16 adequately designed ~~in terms of~~ ~~PLEASE REPHRASE TO AVOID “in terms of”~~
17 ~~policy design~~. To properly design a policy in this field the necessary first step is to
18 understand what affect the academic productivity. In this context, Faria (2002)
19 suggests that policies for fostering the overall productivity of the research sector are:
20 (i) competition in the labour market among researchers (e.g., through career or salary
21 incentives) and (ii) increasing research funds. Did the policies of Lombardy Region
22 respect these elements? Are there other elements that affect research productivity?
23 These are interesting starting point for further research in this field.
24
25 Thus, the results (Table 3) suggest that, while the majority of the universities
26 improved their efficiency, the system as a whole did not experience an improvement
27 of ~~in terms of~~ ~~PLEASE REPHRASE TO AVOID “in terms of”~~ technology available.
28 A discussion about the potential responsibilities for such phenomenon will be
29 reported in the last section, which deals with policy implications of the study. As a
30 result, however, each academic unit, on average, is in the 2007 in the same position
31 *relative to the frontier* than in the 2004. The vast majority of the units actually
32 improved their productivity in the period (“efficiency change” >1) but the “frontier
33 shift” was <1: it means that the performance differential is much less dispersed in
34 2007 but at the same time it happens because the frontier is not improved – the best
35 performers did not improve, or even worsened their efficiency. The result is a
36 “research system” in the region that performs better on average but without having
37 excellence.

Productivity changes between 2004 and 2007: an analysis of “rankings stability”

The stability of rankings across the analysis period (between 2004 and 2007) were analysed by means of the H index proposed by Brockett *et al.* (1998). The index is equal to 177.96 and it must be compared with H^2 that is equal to 102.99. The rejection of the null hypothesis leads to the conclusion that some of the academic departments exhibit consistently better economic performance than others (as measured by the input-output factors that were included in our model) (see Brockett *et al.*, 1998).

Reading this results together with the Malmquist index, it looks like the academic departments improved their performance but some units continue to perform better than others. At the same time, the results show that some units are not efficient, that is, the frontier actually worsened.

DEA efficiency scores, year 2007: the external factors affecting efficiency

This section, given the evidence on the efficiency results, it is interesting to explore which are the determinants of this efficiency or, in other words, what could actually affect a department's performance.

To answer this question, we tested a number of different factors, by using the Kruskal Wallis test as methodological approach (see the data section). All the results are listed in Table 4.

This section explores what affects a department's performance. Several factors were tested using the Kruskal-Wallis test, which showed..... WHAT? (Table 4)

<Table 4> about here

4.2.1 First external factor: are departments located in Milan metropolitan area (regional capital) more efficient than other departments?

We analysed this factor on the The assumption was that in a metropolitan area the competition among research centres enforces departments' managerial efficiency. In Milan, there is an important concentration of public and private research institutions and the competition for resources is not limited to departments. The high concentration of research facilities may justify a greater effort by departments in fostering a more balanced use in input resources or may impulse an effort in control

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3 for managerial quality. Elsewhere, Agasisti (2009) demonstrated that the effect of
4 competition on Italian universities' performance is positive – but, there, output was
5 defined through teaching dimension's measures.
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8 ~~We ran a Kruskal-Wallis test to verify the statistical difference between the efficiency~~
9 ~~scores of departments located in Milan versus the other departments. We do not find~~
10 ~~There is no evidence of difference in efficiency performance between the two groups~~
11 ~~(indeed, the observed value of the H statistic is nearly 0 and the p-value >0.9). This~~
12 evidence suggests that there is no “concentration” effect or “location” effect on
13 efficiency performance of university departments or, at least, in the relative rankings.
14 At the same time, this result may suggest i) the existence of no competitive pressure
15 in a high concentration area as Milan, or that ii) ~~we~~ have to look at overall
16 concentration of research centres and not only to university departments (e.g., there
17 could be a “university” effect which could dominate a “location” effect, or that iii)
18 there is competition but at the same time more opportunities to find resources (more
19 demand for research and consequently the amount of resources is enough to guarantee
20 a sufficient level of grants for different departments without the need to compete one
21 against the others).

32 33 34 35 4.2.2. *Second external factor: can different scientific sectors affect university* 36 *department efficiency?* 37

38 As ~~we~~ measured “output” is measured by using i) publication counts and ii) research
39 grants (of different kinds), it is important to recall that there are some differences in
40 the average number and quality of publication across different disciplines (e.g.
41 medicine versus engineering or biology), as well as differences in terms of ~~PLEASE~~
42 ~~REPHRASE TO AVOID “in terms of”~~ in the attractiveness of research funds (e.g., in
43 engineering fields it is simpler to attract grants for applied research than in physics).
44

45 The idea that disciplines greatly vary in terms of ~~PLEASE REPHRASE TO AVOID~~
46 ~~“in terms of”~~ in costs and productivity is not new and the suggestion to take this
47 factor into account is important to obtain not-biased results (Sarrico & Dyson, 2004).
48 Recently, Sarrico et al. (2009) demonstrated a strong role of “subject mix” (defined as
49 the disciplinary composition of institutions) in explaining the efficiency differentials
50 among Portuguese higher education institutions. The authors acknowledged that “(...) *research production also varies significantly from subject to subject, with medical,*
51 *some natural and technical sciences being more prolific in the number of articles than*
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most of the social sciences and humanities” (p.290). Also Ramsden (1994), in his empirical analysis of Australian research departments, adjusted the coefficients on the basis of discipline subjects.

~~We It was not found a small but statistically significant difference among university departments classified by scientific sectors: the observed value of the H statistic is >8.4, near the critical value (9.4) and the p-value is 0.07 (then the effect has statistical significance at the 10% level WHY CHOOSE 10%? WHY NOT SAY NOT SIGNICANT (AT 5%, WHICH TENDS TO BE THE NORM?)). However, given the limited power of this effect, it is not easy to determine which sectors outperform the others straightforwardly.~~

4.2.3. *Third external factor: is there a “university effect”?*

An alternative explanation of efficiency can refer to the existence of a “university effect”, that is if a university is more efficient than others, then its departments could be more productive than those belonging to other universities. This assumption finds its justification in the setting of strategies at university levels, not at subunits levels. In this respect, Bonaccorsi & Daraio (2007, pp. 22–23) pointed out that:

“the notion of strategy is much more relevant and interesting if assumed at the overall university level. On the one hand, most strategic decisions are made at university level.... The fundamental reason for assuming the university level as the unit of analysis is that at the university level the problem of attribution of inputs (in particular, human resources, funding and physical capital) to specific units of outputs, can be kept under control”.

Even if these authors recognised that a lower unit of analysis could provide useful information on the actual research process, they suggest that a “university effect” (due to different strategies and characteristics at macro-level) can be detected.

~~Our~~ The tests suggest that such effect is not explaining efficiency differentials for ~~the our~~ sample (observed value of the H statistic is 9.4, well below the critical value of 14.06 and the p-value is 0.22).

4.2.4. *Fourth external factor: does the number of tenured academic staff influence efficiency?*

The proportion of tenured research staff theoretically can affect the efficiency of a department: there is anecdotic evidence that tenured and non-tenured staff face quite

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3 different stimulus and incentives. Nevertheless, the direction of this influence is not
4 clear a priori: tenured staff is certainly more expert in attracting research grants and in
5 publishing academic papers, also thanks to reputational advantages; conversely, non-
6 tenured staff can have an incentive to be more productive, for instance as a mean to
7 obtain a tenured position. The promotion system can affect productivity if researchers
8 are satisfied with rules promoting this dimension.

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10 A complementary idea behind this question is that the different human capital of
11 researchers (in ~~our~~ the paper, indirectly measured via the tenured status) can affect the
12 research productivity of the research groups and, so, of the department. In this respect,
13 an interesting example is the paper by Rodgers & Neri (2007), who specifically
14 attempted to correlate the human capital of researchers with the research productivity
15 of Australian departments of Economics. They have found that human capital
16 differential account for about 50% of the observed differences in research
17 productivity. If human capital is (even indirectly) captured by the tenured status (e.g.,
18 researchers with more experience should have reached their tenured position), then
19 ~~we it should be~~ expected a correlation between the proportion of tenured researchers
20 and the department's results. Ramsden (1994) showed that productivity of professors
21 and readers was much higher than that of lecturers.

22
23 ~~Our~~ The analysis did not find evidence of a statistical influence of this factor on
24 research efficiency (the value of the H statistic is 0.16 and the related p-value is >0.6).

4.2.5. Fifth external factor: can departments' "longevity" affect research efficiency?

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42 Finally, ~~we~~ it was looked at the possible effects due to the longevity of departments.
43 As ~~we measured~~ inputs were measured as ~~in terms of~~ ~~PLEASE REPHRASE TO~~
44 ~~AVOID "in terms of"~~ numbers of academic staff and laboratories/facilities, it is
45 reasonable that older departments accumulated higher stocks of inputs that could
46 influence their outputs.

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48 A key assumption here is that older departments can favour more cohesion among its
49 members, facilitating the climate of collaboration and common motivation which
50 enhances research productivity.

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52 Another interesting point of view about this potential phenomenon is that it is related
53 to the "critical mass" dimension. Among the economic aspects of research, Hare &
54 Wyatt (1992) underlined that the ability in producing research relies upon the human
55 capital accumulated by the individual researchers; thus:

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3 “combining this process with the notion that there are economies of scale in
4 research may dispose university departments to feel they need to have at least
5 some critical mass of researchers working in the same area in order to function
6 properly as research units”. (Hare & Wyatt, 1992, pp. 55–56)
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10 Consequently, it could be reasonable to assume that older departments are more likely
11 to have reached such “optimal” scale dimension than the more recently established
12 ones.
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15 The statistical analysis did not provide statistically robust results on this effect, indeed
16 the value of the H statistic is 1.172, while the critical value is around 3.8, so that the
17 p-value is 0.27).
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22 To sum up, the empirical analysis suggests that none of these factors (location in
23 metropolitan area, scientific sector, university effect, proportion of tenured academic
24 staff, departments “longevity”) is able to adequately explain efficiency differentials.
25 ~~We consider~~ This result should be considered as positive, especially when thinking to
26 the use of efficiency scores for policy purposes (e.g., resources allocation). Indeed, a
27 usual critic to the efficiency analyses is that they provide results which are affected by
28 factors which are not under the control of the units themselves: when this is the case,
29 a procedure of resource allocation following efficiency results would be inequitable.
30 At the same time, ~~we argue~~ it could be possible that there are some elements, which
31 actually could influence efficiency and which are related to some “soft”
32 characteristics of the academic units, typically (i) the incentive systems and (ii) the
33 governance/management. For instance, Ramsden (1994) pointed out that the
34 perception of the academic staff about the importance of publications for their career
35 was consistently related to the production of academic articles and books. Rodgers &
36 Neri (2007) suggested that the “departmental environment” is important and they
37 define it through several measures centred on the “human capital” of researchers who
38 work in the department. Unfortunately, QuESTIO dataset does not collect such data:
39 an extension of this dataset along this dimension could help to improve significantly
40 the understanding of this pattern.
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56 The governance/management of the academic departments has not been analysed in
57 the ~~our~~ study, as the only information available in this respect (the presence of a
58 quality system or a management control system) is a very indirect measure of the
59 governance process and the data recovery on this topic was quite imprecise. Another
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3 way to improve the QuESTIO dataset should be to better investigate this dimension,
4 by including some qualitative descriptions about the way Department managers
5 organise and coordinate the activities and resources, formulate strategies and foresight
6 studies and manage networking activities (see for instance Sala *et al.*, forthcoming;
7 Salerno *et al.*, 2008). Without knowing the characteristics of the “management style”
8 of each department, it is impossible to derive policy implications from such
9 dimension. At the same time, a possible way to better understand the potential
10 incidence of such phenomenon is to conduct case studies about the successful
11 academic departments (for example, those with higher efficiency scores or those
12 which highly improved the scores in the last years).

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21 Finally, a potential candidate to analyse the efficiency differentials is the interaction
22 between research and teaching activities conducted by the departments. Typically, the
23 literature did not paid enough attention to the interaction between teaching and
24 research at department level, mainly because both activities were considered as inputs
25 and outputs (see section 2). In this paper, the focus was exclusively on the research
26 activities but it raises also questions about the effects that the (unmeasured) teaching
27 activities play on the research result. This issue is very relevant both in theoretical
28 terms (are there economies of scope, or tradeoffs, between the two activities?) and in
29 empirical ones (which is the optimal allocation of energies between teaching and
30 research?). This interesting issue was at the centre of several contributes since the
31 seminal paper by Cohn et al. (1989), that for the first time addressed and modelled the
32 multi-outputs nature of academic activities. Recently, the theme has been explored by
33 Bonaccorsi & Daraio (2007) for a sample of European universities. In the present
34 paper, ~~we cannot explore~~ this topic has not been explored because QuESTIO dataset
35 does not record data about the teaching dimension of the departments’ activities (as
36 before, it could represent a substantial improvement of the dataset).

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49 Finally, the issue of research quality still remains open. Indeed, ~~our~~ the analysis is
50 focused only on a quantitative dimension of research, while quality is important to
51 adequately assess the performance. Typically the lack of data on this respect justifies
52 the scarce attention to this problem. However, the QuESTIO dataset will include in
53 the next years some qualitative indicators, like H and citation indexes. ~~We~~ It will be
54 devoted attention to this topic in future research, also exploring trade-offs between
55 research quantity and quality.
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5. Concluding remarks

~~IT WOULD PROBABLY BE BETTER TO INCLUDE MUCH OF THIS DISCUSSION IN THE PRESENTATION OF RESULTS TO (A) AVOID REPETITION AND (B) TO PROVIDE A CLEARER STORY AS TO WHAT THE RESULTS MEAN.~~

~~As highlighted discussing the literature on the topic, the analyses presented in this work are innovative for the in terms of PLEASE REPHRASE TO AVOID “in terms of” data and the methodology. Indeed, in this paper we have investigated the efficiency of university departments on science and technology and medicine in an Italian region (Lombardy). The aim of the paper was (i) to analyse the changes in productivity in recent years (from 2004 and 2007) and (ii) to detect factors that are potentially affecting efficiency.~~

~~Discussing our results about the efficiency change between 2004 and 2007, some questions must be posed: how can a Malmquist index equal to 1 exactly be interpreted? How can we judge a frontier shift that is less than 1? Each academic unit, on average, is in the 2007 in the same position *relative to the frontier* than in the 2004 (indeed, also the H index calculated above suggests small changes in the rankings in the period considered). However, what happened is something different: the vast majority of the units actually improved their productivity in the period (“efficiency change” >1) but the “frontier shift” was <1: it means that the performance differential is much less dispersed in 2007 but at the same time it happens because the frontier is not improved — the best performers did not improve, or even worsened their efficiency. The summary statistics confirms this idea (look at the really lower mean in 2004, with a much higher dispersion — standard deviation — around it). The result is a “research system” in the region that performs better on average but without having excellence.~~

~~The importance of evaluation and accountability has been growing in these recent years and criteria used are widely acknowledged: publications and the ability to gather financial resources (from abroad or from firms). Since the application of these evaluations for funding allocation is more and more concrete, we believe that the weakest departments raised their attention towards those performances. Thanks to this new attention the weakest departments have increased their efficiency and become~~

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3 much closer to the best performers that, on the contrary, had little margin for further
4 improvements.
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7 This result requires an important policy discussion. Indeed, the objective of the
8 Lombardy Region was to foster the performance of excellent research units. This
9 purpose animated some policy interventions such as the creation of “clusters”, the
10 policies for improving contacts between companies’ demand and research units
11 through vouchers (the idea behind is that the best research units would be able to
12 collect more vouchers), etc. Apparently, the results obtained are in the opposite
13 direction.
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17 This fact raises two reflections. The first is that maybe the universities (and,
18 consequently, the research units) look not at the regional incentives but at the national
19 ones (as the Ministry is still the main financier of the universities’ activities) and at
20 international ones (the research reputation strongly depends upon the ability to
21 publish in international journals and to attract international grants). If this is the case,
22 a question arises about the opportunity for a regional government to be involved in
23 this sector.
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27 A second (possibly alternative) reflection is that the policies adopted for boosting
28 research productivity were not adequate in terms of **PLEASE REPHRASE TO**
29 **AVOID “in terms of”** policy design. To properly design a policy in this field the
30 necessary first step is to understand what affect the academic productivity. In this
31 context, Faria (2002) suggests that policies for fostering the overall productivity of the
32 research sector are: (i) competition in the labour market among researchers (e.g.,
33 through career or salary incentives) and (ii) increasing research funds. Did the policies
34 of Lombardy Region respect these elements? Are there other elements that affect
35 research productivity? These are interesting starting point for further research in this
36 field.
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40 Our second analysis regarded how five external factors (“external” because they are
41 not under the control of the departments) affect efficiency (section 4.2.). Our
42 empirical analysis suggests that none of these factors (location in metropolitan area,
43 scientific sector, university effect, proportion of tenured academic staff, departments
44 “longevity”) is able to adequately explain efficiency differentials. We consider this
45 result as positive, especially when thinking to the use of efficiency scores for policy
46 purposes (e.g., resources allocation). Indeed, a usual critic to the efficiency analyses is
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3 that they provide results which are affected by factors which are not under the control
4 of the units themselves: when this is the case, a procedure of resource allocation
5 following efficiency results would be inequitable. Among others, Marinova &
6 Newman (2008), describing the new funding model for Australian universities'
7 research, pointed out several counterproductive mechanisms that can be created by
8 linking academic performance and resources without taking into account factors
9 affecting efficiency in a proper way. The authors concluded their paper stating that
10 among the "two necessary pre-conditions for Australia to have a healthy, strong and
11 world-class university research sector" one is that "the funding model used should
12 allow for diversity and flexibility to properly reflect the complexity of academic
13 world" (p.285).

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15 At the same time, we argue that there are some elements, which actually could
16 influence efficiency and which are related to some "soft" characteristics of the
17 academic units, typically (i) the incentive systems and (ii) the
18 governance/management. For instance, Ramsden (1994) pointed out that the
19 perception of the academic staff about the importance of publications for their career
20 was consistently related to the production of academic articles and books. Rodgers &
21 Neri (2007) suggested that the "departmental environment" is important and they
22 define it through several measures centred on the "human capital" of researchers who
23 work in the department. Unfortunately, QuESTIO dataset does not collect such data:
24 an extension of this dataset along this dimension could help to improve significantly
25 the understanding of this pattern.

26
27 However, if the incentive system really matters, another conclusion can be drawn
28 from our study: as we measured a potential "university effect", and it is not
29 statistically relevant, then we can conclude that no incentive system works at
30 university level. Different reasons can be proposed to explain this result. In particular,
31 it can be both the cases that (i) the incentive system is designed at an higher level (in
32 Italy, at the central government level), or (ii) that it is designed at a lower
33 (department) level — and given the department level of our data, we cannot exploit
34 such dimension, which requires individual level data. The evidence about the process
35 for recruiting academic staff and its career in Italy suggests that, however, no
36 government-level incentive exists — indeed, the career of professors is very poorly
37 related to their scientific production.

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3 Levin (1991) underlined the importance of incentives to raise the productivity of
4 universities' activities. More specifically, he acknowledged that higher education
5 shows productivity declines due to two main reasons: (i) it is a "stagnant industry", as
6 it is based on labour intensity; (ii) clear rewards and property rights are absent. Thus,
7 the suggestion provided by the author is to develop a reward system within the
8 university based on clear goals, financial incentives and evaluation procedures.
9 Whether such schemes have been actually implemented in departments analysed in
10 this paper is not clear; probably detailed case studies can help to shed more light on
11 this topic through future research.

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The governance/management of the academic departments has not been analysed in
our study, as the only information available in this respect (the presence of a quality
system or a management control system) is a very indirect measure of the governance
process and the data recovery on this topic was quite imprecise. Another way to
improve the QuESTIO dataset should be to better investigate this dimension, by
including some qualitative descriptions about the way Department managers organise
and coordinate the activities and resources, formulate strategies and foresight studies
and manage networking activities (see for instance Sala *et al.*, forthcoming; Salerno *et al.*, 2008). Without knowing the characteristics of the "management style" of each
department, it is impossible to derive policy implications from such dimension. At the
same time, a possible way to better understand the potential incidence of such
phenomenon is to conduct case studies about the successful academic departments
(for example, those with higher efficiency scores or those which highly improved the
scores in the last years).

Finally, a potential candidate to analyse the efficiency differentials is the interaction
between research and teaching activities conducted by the departments. Typically, the
literature did not paid enough attention to the interaction between teaching and
research at department level, mainly because both activities were considered as inputs
and outputs (see section 2). In this paper, the focus was exclusively on the research
activities but it raises also questions about the effects that the (unmeasured) teaching
activities play on the research result. This issue is very relevant both in theoretical
terms (are there economies of scope, or tradeoffs, between the two activities?) and in
empirical ones (which is the optimal allocation of energies between teaching and
research?). This interesting issue was at the centre of several contributes since the
seminal paper by Cohn *et al.* (1989), that for the first time addressed and modelled the

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3 multi-outputs nature of academic activities. Recently, the theme has been explored by
4 Bonaccorsi & Daraio (2007) for a sample of European universities. In the present
5 paper, we cannot explore this topic because QuESTIO dataset does not record data
6 about the teaching dimension of the departments' activities (as before, it could
7 represent a substantial improvement of the dataset).
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11 Finally, the issue of research quality still remains open. Indeed, our analysis is
12 focused only on a quantitative dimension of research, while quality is important to
13 adequately assess the performance. Typically the lack of data on this respect justifies
14 the scarce attention to this problem. However, the QuESTIO dataset will include in
15 the next years some qualitative indicators, like H and citation indexes. We will devote
16 attention to this topic in future research, also exploring trade-offs between research
17 quantity and quality.
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26 The analyses and the data have allowed an interesting discussion in terms of PLEASE
27 REPHRASE TO AVOID "in terms of" policy implication but we hope that further
28 research will follow both including new data (e.g. referring to teaching activities and
29 research quality) and considering other geographical regions.
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References

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Abbott, M., Doucouliagos, C., (2003), The Efficiency of Australian Universities: a Data Envelopment Analysis, *Economics of Education Review*, 22(1), pp. 89–97

Agasisti, T., (2009), Market Forces and Competition in University Systems: Theoretical Reflections and Empirical Evidence from Italy, *International Review of Applied Economics*, 23(4), pp. 463–483.

Agasisti, T., Dal Bianco, A., (2006), Data Envelopment Analysis of the Italian University System: Theoretical Issues and Policy Implications, *International Journal of Business Performance Management*, 8(4), pp. 344–367.

Agasisti, T., Dal Bianco, A., (2009), Reforming the University Sector: Effects on Teaching Efficiency. Evidence from Italy, *Higher Education*, 57(4), pp. 477–498.

Agasisti, T., Salerno, C., (2007), Assessing the cost efficiency of Italian universities, *Education Economics*, 15(4), pp. 455–471.

Athanassopoulos, A.D., Shale, E., (1997), Assessing the Comparative Efficiency of Higher Education Institutions in the UK by Means of Data Envelopment Analysis, *Education Economics*, 5(2), pp. 117–134.

Avkiran, N.K., (2001), Investigating Technical and Scale Efficiencies of Australian Universities Through Data Envelopment Analysis, *Socio-Economic Planning Sciences*, 35(1), pp. 57–80.

Banker, R. D., Charnes, A., Cooper, W., (1984), Models for Estimation of Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science*, 30, pp. 1078–1092.

Bonaccorsi, A., Daraio, C., (2007), *Universities and strategic knowledge creation*, (Cheltenham, Edward Elgar Publisher).

Bonaccorsi, A., Daraio, C., Simar, L., (2006), Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data, *Scientometrics*, 66(2), pp. 389–410.

Brennan, J., Teichler U., (2008), The future of higher education and of higher education Research, *Higher Education*, 56, pp. 259–264.

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~~Brockett, P.L., Golany, B., Shan Li, (1998), Analysis of intertemporal efficiency trends using rank statistics with an application evaluating the macro economic performance of OECD nations, *Journal of Productivity Analysis*, 11(1), 169–182.~~

Charnes, A., Cooper, W.W., Rhodes, E. (1978) Measuring the efficiency of decision making units, *European Journal of Operational Research*, 2, pp. 429–444.

Clark, B., (1998), *Creating Entrepreneurial Universities: Organizational Pathways of Transformation, Issues in Higher Education* (Elsevier Science, New York).

Cohn, E., Rhine, S.L.W., Santos, M.C. (1989), Institutions of higher education as multi-product firms: economies of scale and scope, *Review of Economics and Statistics*, 71, pp. 284–290.

Cooke P., Uranga M. G., Etxebarria G. (1997) Regional Innovation Systems: Institutional and organisational dimensions, *Research Policy*, 26, pp. 475–491.

Cooper, W.W., Seiford L.M., Tone K., (2006), *Introduction to Data Envelopment Analysis and Its Uses* (Springer, New York).

Curran, P.J., (2000), Competition in UK Higher Education: competitive advantage in the Research Assessment Exercise and Porter's diamond, *Higher Education Quarterly*, 54(4), pp. 386–410.

Daraio, C., Simar L., (2005), Introducing environmental variables in nonparametric frontier models: a probabilistic approach, *Journal of Productivity Analysis*, 24(1), pp. 93–121.

Etzkowitz, H., (2003), Research groups as 'quasi-firms': the invention of the entrepreneurial university, *Research Policy*, 32(1), pp. 109–121.

~~Faria, J.R., Scientific, business and political networks in academia, *Research in Economics*, 56(1), 187–198.~~

Flagg, A.T., Allen, D.O., Field, K., Thurlow, T.W., (2004), Measuring the Efficiency of British Universities: a Multi-Period Data Envelopment Analysis, *Education Economics*, 12(3), pp. 231–249.

Gimenez, V.M., Martinez, J.L., (2006), Cost efficiency in the university: a departmental evaluation model, *Economics of Education Review*, 25, pp. 543–553.

1
2
3 Hare, P., Wyatt, G., (1992), Economics of academic research and its implications for
4 higher education, *Oxford Review of Economic Policy*, 8(2), pp. 48–66.

5
6
7 Hood, C. (1991), A public management for all seasons? *Public Administration*, 69,
8 pp. 3–19.

9
10
11 Hood, C. (1995), The new public management in the 1980s: Variations on a theme.
12 *Accounting Organizations and Society*, 20(2/3), pp. 93–110.

13
14
15 Johnes, G., Johnes, J., (1993), Measuring the Research Performance of UK
16 Economics Departments: an Application of Data Envelopment Analysis, *Oxford*
17 *Economic Papers*, 45, pp. 332–347.

18
19
20 Johnes, G., Johnes, J., (1995), Research Funding and Performance in UK University
21 Departments of Economics: A Frontier Analysis, *Economics of Education Review*,
22 14(3), pp. 301–314.

23
24
25 Johnes, J., (2004), *Efficiency Measurement*, in Johnes, G., Johnes, J., (eds),
26 International Handbook on the Economics of Education (Edward Elgar Publishing
27 Ltd, Cheltenham).

28
29
30 ~~Johnes, J., (2006), Data Envelopment Analysis and its Application to the~~
31 ~~Measurement of Efficiency in Higher Education, *Economics of Education Review*, n.~~
32 ~~25, pp. 273–288.~~

33
34
35
36
37
38
39 Kocher, M.G., Luptàcik, M., Sutter, M., (2006), Measuring Productivity of Research
40 in Economics. A Cross-Country Study Using DEA, *Socio-Economic Planning*
41 *Sciences*, 40, pp. 314–332.

42
43
44
45
46
47
48
49 Koksai, G., Nalcaci, B., (2006), The relative efficiency of departments at a Turkish
50 engineering college: a data envelopment analysis, *Higher Education*, 51(1), pp. 173–
51 289.

52
53
54
55
56
57
58
59
60 Kruskal, W.H, Wallis, W.A., (1952), Use of ranks in one-criterion variance analysis,
Journal of the American Statistical Association, 47(260), pp. 583–621.

Landoni, P., Verganti, R., (2006), Fostering Knowledge and Technology Transfer
through evaluation systems at a regional level, *International Journal of Technology*
Transfer and Commercialisation, 5(4), pp. 355–372.

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60

Lechner C., Dowling M. (1999) The Evolution of Industrial Districts and Regional Networks: The Case of the Biotechnology Region Munich/Martinsried, *Journal of Management and Governance*, 3, pp. 309–338.

Levin, H.M., (1991), Raising productivity in higher education, *Journal of Higher Education*, 62(3), pp. 242–262.

Madden, G., Savage, S., Kemp, S., (1997), Measuring public sector efficiency: a study of economics departments at Australian universities, *Education Economics*, 5(2), pp. 153–167.

Marinova, D., Newman, P., (2008), The changing research funding regime in Australia and academic productivity, *Mathematics and Computers in Simulation* 78(2-3), pp. 283–291.

McMillan, M.L., Datta, D., (1998), The Relative Efficiencies of Canadian Universities: A DEA Perspective, *Canadian Public Policy*, 24(4), pp. 485–511.

Moreno, A.A., Tadepali, R., (2002), Assessing Academic Department Efficiency at a Public University, *Managerial and Decision Economics*, 23, pp. 385–397.

Ng, Y.C., Li, S.K., (2000), Measuring the Research Performance of Chinese Higher Education Institutions: An Application of Data Envelopment Analysis, *Education Economics*, 8(2), pp. 139–156.

Organisation for Economic Co-operation and Development (OECD), (2002), *Proposed Standard Practise for Surveys of Research and Experimental Development - Frascati Manual, sixth edition* (Paris, OECD).

Organisation for Economic Co-operation and Development (OECD), (2003), *Education policy analysis* (Paris, OECD).

~~Pastor, J.T., Ruiz, J.L., Sirvent, I., (2002), A Statistical Test for Nested Radial Models, *Operations Research*, vol. 50, n. 4, pp.728–735.~~

Pesenti, R., Ukovich, W., (1996), *Evaluating Academic Activities Using DEA*, Internal Report (Trieste, DEEI, Università di Trieste).

Porter M.E. (1998) *Clusters and the New Economics of Competition*, (Boston, Harvard Business School Press).

1
2
3 Ramsden, P., (1994), Describing and explaining research productivity, *Higher*
4 *Education*, 28(2), pp. 207–226.

7 Rizzi, D., (1999), L'efficienza dei dipartimenti dell'Università Cà Foscari di Venezia
8 via DEA e DFA (The efficiency of departments at University Cà Foscari through
9 DEA and DFA), *Working Paper, Università Cà Foscari di Venezia, Dipartimento di*
12 *Scienze Economiche*.

15 Rodgers, J. R., Neri, F., (2007), Research Productivity of Australian Academic
16 Economists: Human-Capital and Fixed Effects, *Australian Economic Papers*, 41(6),
17 pp. 67–87.

20 Sala A., Landoni P., Verganti R., (forthcoming) “R&D networks: an evaluation
21 framework” *International Journal of Technology Management*.

24 Salerno M., Landoni P., Verganti R. (2008), Designing foresight studies for
25 Nanoscience and Nanotechnology (NST) future developments, *Technological*
26 *Forecasting & Social Change*, 75(8), pp. 1202–1223.

30 Sarkis, J., (2007), ~~Preparing your data for DEA, in Zhu. J., Cook, W.D., (eds.),~~
31 ~~Modeling Data Irregularities and Structural Complexities in Data Envelopment~~
32 ~~Analysis, Springer, New York.~~

36 Sarrico, C.S., Dyson, R.G., (2004), Restricting virtual weights in data envelopment
37 analysis, *European Journal of Operational Research*, 159(1), pp. 17–34.

40 Sarrico, C.S., Teixeira, P.N., Rosa, M.J., Cardoso, M.F., (2009), Subject mix and
41 productivity in Portuguese universities, *European Journal of Operational Research*,
42 197(2), pp. 287–295.

46 Thursby, J.G., (2000), What Do We Say about Ourselves and What Does It Mean?
47 Yet Another Look at Economics Department Research, *Journal of Economic*
48 *Literature*, 38, pp. 383–404.

52 Warning, S., (2004), Performance Differences in German Higher Education:
53 Empirical Analysis of Strategic Groups, *Review of Industrial Organization*, 24, pp.
54 393–408.

57 Wilson, P.W., (1995), ~~Detecting influential observations in data envelopment analysis,~~
58 ~~Journal of Productivity Analysis~~, 6(1), 27–45.

Zhu, J., (2003), *Quantitative Models for Performance Evaluation and Benchmarking*,
(Kluwer Academic Publisher, Boston, MA).

For Review Only

Table 1. Inputs/outputs descriptive statistics

	<i>Average (Mean?) Mean</i>	<i>Standard deviation</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Average difference 2004–2007</i>
Laboratories (m ²)	2,243.83	6,917.93	0.00	60180.00	80.24
Human resources (n)	105.50	83.30	9.00	445.00	16.19
High Qualified Human resources (n)	98.33	79.66	8.00	434.00	16.00
Other personnel (n)	7.12	6.83	0.00	32.00	-0.30
Revenues from financed activities (€)	486936.06	557412.78	0.00	3039361.00	142196.00
Financed activities from abroad (€)	118587.58	256766.37	0.00	1805922.00	10896.00
Revenues from orders (€)	451240.13	764559.23	0.00	3333362.00	86950.00
Number of publications (n)	32.45	31.91	0.00	188.00	2.87
Doctorates in cooperation with external bodies (n)	2.49	4.04	0.00	22.00	0.63

Table 2. Efficiency scores (DEA on 2007 data) – descriptive statistics

	<i>CRS Efficiency</i>	<i>VRS Efficiency</i>	<i>Scale Efficiency</i>
Mean	0.745	0.786	0.937
St. Deviation	0.241	0.219	0.101
Min	0.173	0.216	0.432
Max	1.000	1.000	1.000
# efficient units	25	29	25

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 3. Malmquist index 2004-2007 – descriptive statistics

<i>Department</i>	<i>Malmquist index</i>	<i>Efficiency change</i>	<i>Frontier shift</i>
Mean	1.060	1.666	0.652
St. dev.	0.492	0.882	0.141
Min	0.072	0.529	0.104
Max	2.534	4.600	1.031
# improving units	35	56	2

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 4. Factors affecting efficiency (Kruskal-Wallis analysis)

<i>Effects of Metropolitan area (Milan)</i>	
H (observed value)	0.007
H (critic value)	3.481
p-value	0.934
<i>Effects of subject mix</i>	
H (observed value)	8.451
H (critic value)	9.488
p-value	0.076
<i>University effects</i>	
H (observed value)	9.426
H (critic value)	14.067
p-value	0.224
<i>Effects of tenured staff proportion</i>	
H (observed value)	0.163
H (critic value)	3.841
p-value	0.687
<i>Effects of departments' age</i>	
H (observed value)	1.172
H (critic value)	3.841
p-value	0.279

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3 **Evaluating the efficiency of research in academic departments: an empirical**
4 **analysis in an Italian Region**
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12 **Abstract.**

13 This paper investigates the efficiency of university departments on science,
14 technology and medicine in an Italian Region (Lombardy). The aim of the paper is
15 twofold: (i) to analyse the changes in productivity in recent years (from 2004 to
16 2007); and (ii) to detect factors that are potentially affecting efficiency. The research
17 benefited from a new and unique dataset (called QuESTIO) developed by the
18 Lombardy Regional Government. Using facilities and academic staff as inputs and
19 research grants and publications as outputs, the research activity of academic
20 departments was modelled. The methodological approach for computing efficiency
21 scores is Data Envelopment Analysis. Malmquist indexes have been used to measure
22 changes in productivity, while Kruskal-Wallis tests were employed to study the
23 potential determinants of efficiency. The main results were that in the period
24 considered, the academic departments improved their efficiency but, at the same time,
25 the efficiency frontier worsened. Moreover, external and measurable factors (such as,
26 scientific sector, proportion of tenured staff, location) have a limited impact in
27 explaining efficiency differentials. Policy implications of the results are discussed.
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32 **Keywords.**

33 University research, efficiency, research policies, Data Envelopment Analysis,
34 Malmquist index, higher education policy.
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1. Introduction and motivation

In recent years, higher education institutions have been studied increasingly. In the “knowledge economy” their importance for economic development, social equity, mobility, social cohesion and integration is widely acknowledged (Brennan & Teichler, 2008). Furthermore, given the difficult situation of public finances, considerations about resources allocation have been raised in many countries, calling for more evaluations and accountability. For these reasons the so-called ‘New Public Management’ movement, started at the beginning of the 1980s in the public sector in general, has also increasingly been affecting the universities. New Public Management (Hood, 1991, 1995) represents the request to public organisations to become more managerial, in particular by drawing on practices and models from the private sector. This process has been driven both by universities themselves and by governments through reforming efforts. The results, especially in many countries within Europe, share some common characteristics: first, the introduction of incentives schemes based on financial models for allocating public funds; second, new or strengthened assessment procedures and evaluation agencies; third, more emphasis on universities’ autonomy (OECD, 2003).

This work explores how the recent changes in the university system affected the efficiency of university research. In particular, the research sought to understand whether an overall increase in efficiency can be recognised or whether differences are present between universities given the previously-noted increased autonomy. Normally, the majority of the reforming efforts have been directed towards education activities, whilst an increase in efficiency of university research has been assigned to incentive systems and evaluation processes. These are expected to have had an overall positive effect on the system but, at the same time, they have left the universities in charge of finding and managing the ways to obtain better results. Given the autonomy of the universities and the decentralisation of responsibilities, significant efficiency changes are thus expected between and within universities. Furthermore, the idea that differentials in research performance are key for competition among departments is well established in the literature (Curran, 2000).

The research focused on universities research activities and not on education or knowledge/technology transfer activities. Universities’ education activities constitute the first and original mission of the universities but, at the same time, they are normally carefully regulated by laws and their efficiency and quality are already

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3 widely studied (Madden *et al.*, 1997). Indicators such as number of degrees awarded,
4 rate of success, years of study, have been widely used both to evaluate the universities
5 and to introduce new policies. The opposite holds for universities'
6 knowledge/technology transfer activities. Even if some argue for this to be a third
7 mission for academia and call for "entrepreneurial universities" (Clark, 1998;
8 Etzkowitz, 2003), others refuse this perspective and signal the risks of focusing on
9 and expanding the role of these activities. Moreover, the efficiency analysis of these
10 activities is hampered by the difficulties in finding the right indicators. There are
11 many different knowledge/technology transfer activities (for example, spin-off,
12 consultancies, research projects with firms, patents) and their evaluation can be based
13 only partially on economic values given the not-for-profit nature of (most)
14 universities (Landoni & Verganti, 2006). Finally, the focus of the study is on the
15 research activities as they are the core activities of universities; driving and informing
16 both education activities and knowledge/technology transfer activities. This
17 relationship especially holds for transfer activities because the value of the results
18 transferred relies heavily on the underlying research on which they are based.
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33 This paper adopts the standard definition of 'research' provided by the Organisation
34 for Economic Co-operation and Development (OECD): "Research and development
35 is a term covering three activities: basic research, applied research, and experimental
36 development" (OECD, 2002). However, only research activities that are normally
37 carried out within universities are considered.
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42 Furthermore, the focus of the efficiency analysis is on university departments and not
43 on the university as a whole. Universities are composed of different research
44 departments and their publication outputs, co-authorship behaviours and thus
45 efficiency usually differ significantly. An analysis at the level of the university can
46 put forward mixed results, while an analysis at the level of single departments is more
47 precise and coherent with the objectives of an efficiency analysis. For this reason, to
48 obtain a sample of comparable departments the research focused on natural science
49 departments. The choice of the department level for the analysis is coherent with the
50 focus on research activities: normally education activities are managed by
51 organisational entities inside the university that are transversal to more departments
52 and many transfer activities are centralised in a single organisational unit (such as a
53 liaison office or a knowledge/technology transfer office).
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3 The research considers departments located in the Lombardy region (Italy). A
4 regional focus has been adopted to ensure similar contextual variables, such as
5 policies and economic environment, for the universities included in the analysis.
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7 Furthermore, Lombardy is one of the more advanced European regions both for (i)
8 economic development and (ii) research activities and universities: more than 9.4
9 million inhabitants, GDP per capita >€34,000; 12 universities are located in the Region
10 (out of about 70 in all the country) with more than 230,000 students. Finally, the
11 regional level is increasingly recognised as a relevant level when analysing research
12 and innovation activities. Many authors (Cooke *et al.*, 1997; Porter, 1998; Lechner &
13 Dowling, 1999) underline that it is at a local level that the majority of the connections
14 between the different innovation actors take place. The localisation of knowledge and
15 the role of proximity as a driver of economic development (for example, clusters)
16 have also highlighted the importance of regional and local government in fostering
17 and strengthening the actors and their relationships.
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30 To summarise, the focus of the paper is on efficiency of research activities in
31 scientific departments in the Lombardy Region (Italy). The research questions are:

- 32 • did changes in the overall efficiency of departments' research occur between
33 2004 and 2007?
- 34 • Which are the main factors affecting efficiency?
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40 The next section presents recent literature on the topic, then the methodology and the
41 data used are introduced, finally results are presented and discussed.
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49 **Background**

50 The international literature about universities' efficiency (through non-parametric
51 techniques) has been developed both at institution-level (Athanasopoulos & Shale,
52 1997; McMillan & Datta, 1998; Ng & Li, 2000; Avkiran, 2001; Abbott &
53 Doucouliagos, 2003; Flagg, *et al.*, 2004; Warning, 2004) and department-level. The
54 latter is more relevant for the context of the present study.
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58 The contributions by Johnes & Johnes (1993, 1995) had a major influence on the
59 methodological approach. Johnes & Johnes (1993) measured the research
60 performance of UK economics departments by using staff numbers as inputs and

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3 publication counts and grants as outputs; the same strategy was adopted again for
4 deriving efficiency scores of economics department in a subsequent paper (Johnes &
5 Johnes, 1995). The authors ran several Data Envelopment Analysis (DEA) models to
6 test the robustness of results and claim for a possible use of results for policy
7 purposes, especially for establishing an optimal allocation of resources across
8 departments. These two contributions are the most important as they focus
9 exclusively on the research dimension of the universities' work.

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16 Madden *et al.* (1997) studied the efficiency of economics departments in 29
17 Australian universities. Inputs were teaching and research staff, outputs were
18 graduates and publications (for teaching and research respectively). As in other
19 studies listed below, here the focus was both on teaching and research performance,
20 even if the analysis were conducted at sub-unit level (that is at departmental level
21 instead of institutional level). The specific objective of the Madden *et al.* (1997) study
22 was to verify whether policies promoted by governments impacted on productivity;
23 they confirmed that there was actually an increase in productive efficiency.
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30 Thursby (2000, p. 400) analysed the efficiency of the Economics Research
31 Departments in the United States. He defined efficiency as follows:

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33 a department is deemed technically efficient if, when compared to departments
34 with similar level of inputs, it could produce greater research outputs without
35 increasing its inputs usage, or equivalently, it is one which, compared to
36 departments with similar levels of outputs, could produce the current levels of
37 outputs with fewer inputs.
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44 Thursby used publication, citation data and number of Ph.D.s as outputs and the
45 number of researchers and professors, graduate students, federal grants, library
46 acquisitions and a dummy for private ownership as inputs. He found that the average
47 level of efficiency in the United States is high (67% of economics departments appear
48 as efficient).
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53 Moreno and Tadeballi (2002) focused on 42 academic units distributed across seven
54 colleges in the United States. They used staff, financial resources and proxies for
55 structures (for example, building space) as inputs and number of students, full-time
56 equivalent enrolments and grant awards as outputs. In discussing their results, they
57 showed that efficiency scores do not illustrate information about effectiveness: that is,
58 they argued that a qualitative dimension is necessary for this purpose. Lastly, as their
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3 background is strongly managerial, they also suggested a use of efficiency analysis as
4 a planning tool, not only for evaluating universities' activities.
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7 Koksals and Nalcaci (2006) derived efficiency scores for 14 university departments at
8 the Middle East Technical University in Turkey, by using staff salaries, a composite
9 indicator of previous research quality and number of students as inputs and number of
10 publications, graduates and teaching indicators as outputs. Thus, in their contribution,
11 the authors focused also on the teaching activity of the departments. They decided to
12 use weights for teaching and research loads as suggested by university's
13 administrators through a preliminary survey. The paper suggests that the models
14 adopted for computing efficiency can serve to set new targets for inefficient
15 departments.
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17
18 Gimenez and Martinez (2006) focused on cost efficiency of the departments at the
19 Autonomous University of Barcelona. They computed cost-efficiency scores and
20 separated cost excess into three categories: technical efficiency, fixed factors, and
21 "scale effects" (due to the number of academics in the department). The units of
22 analysis were 42 departments and again the focus is on both teaching and research
23 activities. The inputs chosen were: expenditure on temporary hired teaching and
24 research staff, operational expenditures, expenditures on tenure staff. To measure the
25 outputs, they employed the following variables: results of a government evaluation
26 process of research, teaching load (measured through credits granted) and students'
27 opinions. The authors suggested that their analyses can be used to assess the
28 differences between (i) the observed cost of the units and (ii) the cost they would
29 achieve assuming long-term cost minimisation. Their result tells that size does not
30 matter in determining efficiency, while higher proportion of non-tenured staff is
31 associated with higher efficiency levels.
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34 In another exercise presented by Kocher *et al.* (2006) the analysis focused on the
35 productivity of research in economics across 21 OECD countries. The focus of the
36 paper was on research and the outputs selected are top publications (and impact
37 factors), while inputs are expenditure on research and development, number of
38 universities and total population. This study was quite different, however, with
39 respect to the relevant contributions for the present paper, as the unit of analysis is the
40 country (neither the university nor the department). The results suggest that research
41 productivity can be raised through an increase in the scale of operations.
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4 An interesting issue is to analyse the related literature about the Italian universities'
5 research. To the best of the authors' knowledge, there are only two specific
6 contributions that specifically analyse the efficiency of universities in producing
7 research outputs (Pesenti & Ukovich, 1996; Rizzi, 1999) and just one attempting to
8 focus on teaching production (Agasisti & Dal Bianco, 2009).

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11 The two contributions at departmental level (Pesenti & Ukovich, 1996; Rizzi, 1999)
12 used a similar set of variables and focused both on teaching and research outputs. The
13 main scope for these contributions was to provide information and suggestions for
14 allocating resources within a university.

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16
17 Contributions about the efficiency of Italian higher education have been conducted at
18 institution-level (thus, not considering separately the structures devoted to teaching
19 and research). This is because the strategy and the mission of universities and the
20 balance between teaching and research are defined at institutional level (Bonaccorsi &
21 Daraio, 2007, p. 22).

22
23
24 Among these contributions at an institutional level Agasisti & Dal Bianco (2006)
25 studied the efficiency of 58 Italian public universities by using, as inputs, number of
26 staff, financial resources and students and, as outputs, graduates and research grants.
27 They suggested the use of efficiency analysis for policy purposes, especially to
28 evaluate the differences in performance between efficient and inefficient units. Later,
29 Agasisti & Salerno (2007) analysed the cost efficiency of another sample of Italian
30 universities by adding some qualitative measures for inputs and outputs. They
31 concluded that a redistribution of inputs across universities could lead to an overall
32 improvement of efficiency in the Italian higher education sector.

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34
35 Bonaccorsi *et al.* (2006) used a robust non-parametric technique (developed by
36 Daraio & Simar, 2005) to take in account external conditions affecting the
37 productivity of universities. The inputs and outputs adopted are quite similar to
38 previous studies (that is, staff numbers, expenses and spaces as inputs and
39 publications and graduates as outputs) but they also included some "external" factors:
40 university size, number of departments within the university, percentage of private
41 funding, number of curricula activated. They concluded that economies of scale and
42 scope are not relevant factors in explaining (in)efficiency.

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45 To sum up, the literature seems to suggest that, to analyse research efficiency of
46 universities, that is, the efficiency in the production of research outputs:

- inputs can be classified under three main groups: human resources, financial resources and structures (for example, facilities, buildings);
- outputs can be grouped into publications and grants.

Methodology and data

Methodology

The methodology is articulated accordingly to the two steps adopted to answer the research questions of the paper: on one hand the efficiency analysis (including efficiency scores of the departments, changes across time and time trends), on the other hand the effort to identify the determinants of efficiency.

Data Envelopment Analysis (DEA) (Charnes *et al.*, 1978) was the methodology used to analyse efficiency. It deals with the efficiency problem of complex organisations that produce many outputs using several inputs at a time. This paper only briefly discusses some characteristics of DEA, referring the interested reader to Johnes (2004), Cooper *et al.*, (2006) and Zhu (2003).

In a DEA model, the notion of efficiency is that of “technical efficiency”, defined as the relative ability of each decision making unit (DMU) in producing outputs, where the term “relative” means that each organisation is compared with any other homogeneous unit. DEA could be represented by a linear programming technique where each DMU tries to maximise the efficiency ratio (output over inputs) choosing the best set of weights. There are two ways to deal with a DEA formulation: (i) input oriented (that is, the ability to minimise inputs when outputs are given) and (ii) output oriented (maximisation of outputs given a certain bundle of inputs). The latter approach is used in this paper, as the typical problem for a research unit is to maximise outputs (publications, grants) given its inputs (research staff, laboratories). DEA mathematical formulation can deal with both constant returns to scale (CRS) and variable returns to scale (VRS). The seminal work of Charnes *et al.* (1978) introduced a constant-return-to-scale (CRS) model where DMU dimension has no importance in defining efficiency performance (see equation 2). DMUs face the same efficiency frontier, independently of their relative size. One can cast doubts on the comparability of small and large units. Larger units exploit common inputs to produce different outputs, whereas smaller ones benefit from substantial advantages in organising activities. A further model, developed by Banker *et al.* (1984) introduces

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3 in DEA modelling the dimension factor, by comparing units according to their
4 dimension; that is, by considering that the unit's dimension can affect efficiency
5 (VRS efficiency).
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10 Smaller units are associated with increasing economies of scale and bigger units with
11 decreasing economies of scale. In the middle, there is a "grey area" of constant
12 returns to scale. So, it is also possible to compute the scale efficiency. This is defined
13 as the ratio CRS/VRS efficiencies and interpreted as the ability of each institution to
14 operate at its optimal scale dimension; in other words, in a VRS formulation, each
15 DMU is compared only with those units having a comparable size.
16
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18 It is also possible to measure changes in efficiency across time (the-relevant period
19 here is between 2004 and 2007). For measuring the determinants of the changes in
20 efficiency scores, Malmquist index has been used (for more information about this
21 index see Johnes (2004) and Coelli *et al.*, (2006)). Considering a DMU, named P that
22 has a change in production position from P_t (in period t) to P_{t+1} (in period $t+1$), the
23 change in the production frontier could have occurred in a non-neutral way; that is, it
24 could be determined both by efficiency changes and shifts in the efficiency frontier.
25 Thus, for measuring the change in the efficiency score, it is possible to break down
26 the score in these two different components. Both of the components have a specific
27 mean: the resulting score for the DMU could have positive or negative effects due to
28 the own efficiency change or due to the shift (movement) of the frontier. Thus the
29 resulting efficiency index is composed of two parts. The first component of the
30 equation is the ratio of technical efficiency in time period $t+1$ on the technical
31 efficiency in the period t . Since it measures the change in technical efficiency, it is
32 equal to 1 if no changes occurred, greater than 1 if the change was positive and less
33 than 1 if it was negative. The second component measures the shift in the production
34 frontier: if it is equal to 1 it has no effect on the efficiency score, if it is greater than 1
35 it has a positive effect and if it is less than 1 it has a negative effect. In other words, a
36 shift in a production frontier that makes worse the relative position of the DMU (the
37 other DMUs are performing relatively better than before) provides a second
38 component less than 1. The index (Malmquist index) resulting from the combination
39 of these two components will be equal to 1 if there is no net effect of changes in
40 technical efficiency and frontier changes; it will be greater than 1 if the net effect is
41 positive and less than 1 if it is negative.
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5 The second task in the methodology is to study some potential determinants of
6 efficiency. To pursue this objective, some external factors (for example, location
7 effects, discipline effects) were identified and then efficiency scores were compared
8 across different groups of units. The comparison was made by means of the Kruskal-
9 Wallis test (Kruskal & Wallis, 1952). This test allows the researcher to detect if there
10 are statistical differences across the groups analysed (for example, when comparing
11 the efficiency scores of units located in a metropolitan area with those located
12 elsewhere, the test indicates if this location effect generates a statistical difference
13 between the average scores of the two groups).
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22 *Data*

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24 The research used a unique dataset that consists of input and output variables about
25 research and technology transfer activities in university departments located within
26 the Lombardy Region. This dataset is based on information coming from QuESTIO
27 system, a mapping of research and technological transfer organisations developed in
28 the Lombardy region. The QuESTIO system, launched in 2004 by the regional
29 government, was intended to be a transparency and incentive tool for the research and
30 technological transfer market by reducing any information unevenness often binding
31 cooperation among producers and users of knowledge. The system collects, updated
32 and publishes financial, organisational and structural characteristics of research
33 organisations and knowledge business intelligence services in Lombardy.
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42 Since it aims at presenting the most detailed picture of regional community active in
43 research and technological transfer, the dataset has some specific criteria that are
44 pivotal for the analyses. First, the system is focused on every structure where such
45 activities are carried out, even where that structure is a part of a wider organisation.
46 Second, these structures should have significant management autonomy so that their
47 accountancy shall be determinable. The first criterion enables the regional
48 administration to collect information on every single department, being acknowledged
49 that the performance of departments belonging to the same university can differ
50 significantly. As a consequence the university departments, as well as sections and
51 institutes of the National Research Council or a research and development unit
52 belonging to a company, provide data that refers solely to their specific resources and
53 outputs. The second criterion assures that each structure included in the dataset is
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3 responsible (to some extent) for its strategy and performances thus justifying
4 application of the DEA technique.
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7 The Lombardy innovation system maps 364 structures of which 147 are university
8 departments, 151 are knowledge business intelligence services, 13 are hospital and
9 medical research centres, 34 are public research organisations and 19 are company
10 research and development units.
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16 The geographical analysis shows a concentration in the Province of Milan and a little
17 less in Bergamo, Brescia, Pavia and Varese, which is explained by the presence of
18 universities in those cities. The dataset was built by considering those university
19 departments that provided information for the whole period 2004–2007 (units for
20 which there are not missing data), by selecting the following variables:
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24 25 26 Inputs

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28 I1 Laboratories: the areas (measured in square meters) devoted to laboratories
29 belonging to or accessible by the department.
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32 I2 Highly-qualified human resources: persons who perform research and technology
33 transfer activities, regardless of their qualifications. They are mainly full professors,
34 associated professors, permanent researchers, post-doctoral scholarships and PhD
35 students. It includes employees dedicated to activities in support of research, such as,
36 certification, tests and measurements, patenting and commercialisation, financial
37 assistance, partners search, technologies monitoring, events organisation, editing of
38 technical-scientific “spreading publications”.
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41 I3 Other personnel: administrative personnel that should ensure the efficient working
42 of human resources devoted to research and technology transfer activities.
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45 46 47 48 49 Outputs

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51 O1 Revenues from financed activities: activities financed with regional or national
52 calls for bids. This variable denotes the ability of the department to compete with
53 other research organisations in getting public-funded research, thus measuring the
54 amount of research that meet requirements of national and regional research and
55 innovation strategies.
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59 O2 Revenues from financed activities from abroad: internationally-funded activities
60 that show the capacity to draw on international funding, such as European projects,

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3 O3 Revenue from orders: measures how far research activities carried out in a
4 department are funded by companies or other institutions.
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7 O4 Yearly number of publications: yearly publications in academic international
8 journals. This is the traditional and widespread variable used to measure the output of
9 research activities.
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12 O5 Doctorates in cooperation with external bodies: sheds light on the capability of
13 departments in attracting funds for doctoral students and to establish cooperation with
14 institutions and companies. Since this variable could be interpreted such as an
15 indicator of technology transfer activities, it was investigated if it could alter the
16 efficiency scores and a DEA model has been estimated without considering it.
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23 As discussed in the previous section, the choice of input and output variables is
24 compatible with the most recent literature. The final sample contains 75 departments,
25 for 4 years; overall, there are 300 observations, revealing considerable variation
26 (Table 1).
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32 <Table 1> about here
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34 35 **Results and discussion**

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38 This section illustrates and discusses the results obtained through the DEA analysis of
39 the university departments in the Lombardy Region.
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42 The results are presented in two main sections. The first is devoted to a description of
43 the efficiency scores with reference to the year 2007 (the last year available, where
44 the results are more stable, as previously discussed). It analyses the change in
45 efficiency between the first year of the dataset (2004) and the last year (2007) as well
46 as the presence of time trends in the efficiency scores. The second section examines
47 statistical differences in efficiency scores due to external factors, such as localisation
48 and discipline subject.
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58 *DEA efficiency scores, year 2007*

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60 Table 2 reports the descriptive statistics about the efficiency scores derived with
reference to the year 2007 (the annex reports the specific scores for each department).

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5 <Table 2> about here
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9 The research efficiency of university departments in the Lombardy region is high
10 (CRS efficiency = 0.75, VRS efficiency = 0.78). What is worth pointing out is a
11 strong heterogeneity across departments: indeed, the standard deviation is >0.2 .
12

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14 Data about scale efficiency suggests that all the departments have almost reached
15 their optimal scale of operations (given their present scale), as the scale efficiency
16 score is very high (>0.93) and standard deviation is very low (about 0.1)
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19 The picture that emerges from this first analysis of efficiency scores is a sector where
20 there is a number of very efficient units (both assuming constant or variable returns to
21 scale) and a number of departments that experienced low levels of technical
22 efficiency; thus, as the anecdotal evidence suggests, there is quite a strong
23 differentiation among departments.
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28 As the focus of the paper is the efficiency of academic departments in the Lombardy
29 region, the results' robustness was checked by considering revenues from entities
30 located in the Lombardy region as a separate output (REV_LOMB). The correlation
31 among results obtained by the baseline model and this modified model is very high
32 (>0.97), suggesting that both models report a similar picture.
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38 39 *Efficiency changes between 2004 and 2007: a Malmquist analysis*

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41 Following the methodology described above, the Malmquist index has been
42 calculated to disentangle the efficiency changes due to "pure" efficiency improvement
43 (or worsening) and technological improvement (or worsening). The descriptive
44 statistics about the results are reported in Table 3.
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49 <Table 3> about here
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53 The picture that emerges highlights an interesting phenomenon. It looks like an
54 improvement in productivity did not occur (because the Malmquist index is around 1)
55 but, looking at the decomposition of the index, the reality appears more complex: an
56 efficiency change happened, it was very positive (the index is >1.6) and involved the
57 majority of the departments (56 out of 70); conversely, there was a worsening of the
58 technology frontier (the "frontier shift" indicator is <0.7).
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What is “technology” in a regional research system, when research performance is defined as the ability to attract financial resources and to publish in academic journals? Technology could be defined as the bundle of policies that should help in improving research efficiency, for example, information technologies, research grants, support for publishing research results or to attract financial resources from international grants or companies. This fact raises two reflections. The first is that maybe the universities (and, consequently, the research units) look not at the regional incentives but at the national ones (as the Ministry is still the main financer of the universities’ activities) and at international ones (the research reputation strongly depends upon the ability to publish in international journals and to attract international grants). If this is the case, a question arises about the opportunity for a regional government to be involved in this sector. A second (possibly alternative) reflection is that the policies adopted for boosting research productivity were not adequately designed. To properly design a policy in this field the necessary first step is to understand what affect the academic productivity. In this context, Faria (2002) suggests that policies for fostering the overall productivity of the research sector are: (i) competition in the labour market among researchers (for example, through career or salary incentives) and (ii) increasing research funds. Did the policies of Lombardy Region respect these elements? Are there other elements that affect research productivity? These are interesting starting point for further research in this field.

As a result, however, each academic unit in 2007, on average, is in the same position *relative to the frontier* as in 2004. The vast majority of the units actually improved their productivity in the period (“efficiency change” >1) but the “frontier shift” was <1 : it means that the performance differential is much less dispersed in 2007 but at the same time it happens because the frontier is not improved: the best performers did not improve, or even worsened their efficiency. The result is a “research system” in the region that performs better on average but without having excellence.

DEA efficiency scores, year 2007: the external factors affecting efficiency

This section explores what affects a department’s performance. Several factors were tested using the Kruskal-Wallis test (Table 4).

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3 <Table 4> about here
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7 *4.2.1 First external factor: are departments located in Milan metropolitan area*
8 *(regional capital) more efficient than other departments?*
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10 The assumption was that in a metropolitan area the competition among research
11 centres enforces departments' managerial efficiency. In Milan, there is an important
12 concentration of public and private research institutions and the competition for
13 resources is not limited to departments. The high concentration of research facilities
14 may justify a greater effort by departments in fostering a more balanced use in input
15 resources or may impulse an effort in control for managerial quality. Elsewhere,
16 Agasisti (2009) demonstrated that the effect of competition on Italian universities'
17 performance is positive; but, there, output was defined through teaching dimension's
18 measures.
19

20 There is no evidence of difference in efficiency performance between the two groups
21 (indeed, the observed value of the H statistic is nearly 0 and the p-value >0.9). This
22 evidence suggests that there is no "concentration" effect or "location" effect on
23 efficiency performance of university departments or, at least, in the relative rankings.
24 At the same time, this result may suggest i) the existence of no competitive pressure
25 in a high concentration area as Milan.
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39 *4.2.2. Second external factor: can different scientific sectors affect university*
40 *department efficiency?*
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42 As "output" is measured by using (i) publication counts and (ii) research grants (of
43 different kinds), it is important to recall that there are some differences in the average
44 number and quality of publication across different disciplines (for example, medicine
45 versus engineering or biology), as well as in the attractiveness of research funds (for
46 example, in engineering fields it is simpler to attract grants for applied research than
47 in physics).
48

49 The idea that disciplines greatly vary in costs and productivity is not new and the
50 suggestion to take this factor into account is important to obtain not-biased results
51 (Sarrico & Dyson, 2004). Recently, Sarrico *et al.* (2009) demonstrated a strong role of
52 "subject mix" (defined as the disciplinary composition of institutions) in explaining
53 the efficiency differentials among Portuguese higher education institutions. The
54 authors acknowledged that "(...) research production also varies significantly from
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3 subject to subject, with medical, some natural and technical sciences being more
4 prolific in the number of articles than most of the social sciences and humanities”
5 (Sarrico *et al.*, 2009, p. 290).
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9 No significant difference among university departments classified by scientific sectors
10 was found: the observed value of the H statistic is >8.4.
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13 14 *4.2.3. Third external factor: is there a “university effect”?*

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16 An alternative explanation of efficiency can refer to the existence of a “university
17 effect”, that is if a university is more efficient than others, then its departments could
18 be more productive than those belonging to other universities. This assumption finds
19 its justification in the setting of strategies at university levels, not at subunits levels. In
20 this respect, Bonaccorsi & Daraio (2007, pp. 22–23) pointed out that:
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24 the notion of strategy is much more relevant and interesting if assumed at the
25 overall university level. On the one hand, most strategic decisions are made at
26 university level.... The fundamental reason for assuming the university level
27 as the unit of analysis is that at the university level the problem of attribution
28 of inputs (in particular, human resources, funding and physical capital) to
29 specific units of outputs, can be kept under control.
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38 Even if these authors recognised that a lower unit of analysis could provide useful
39 information on the actual research process, they suggest that a “university effect” (due
40 to different strategies and characteristics at macro-level) can be detected.
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43 The tests suggest that such effect is not explaining efficiency differentials for the
44 sample (observed value of the H statistic is 9.4, well below the critical value of 14.06
45 and the p-value is 0.22).
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49 50 *4.2.4. Fourth external factor: does the number of tenured academic staff influence* 51 *efficiency?* 52

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54 The proportion of tenured research staff theoretically can affect the efficiency of a
55 department: there is anecdotal evidence that tenured and non-tenured staff face quite
56 different stimulus and incentives. Nevertheless, the direction of this influence is not
57 clear *a priori*: tenured staff are certainly more expert in attracting research grants and
58 in publishing academic papers, also thanks to reputational advantages; conversely,
59 non-tenured staff can have an incentive to be more productive, for instance as a mean
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3 to obtain a tenured position. The promotion system can affect productivity if
4 researchers are satisfied with rules promoting this dimension.
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7 A complementary idea behind this question is that the different human capital of
8 researchers (in the paper, indirectly measured via the tenured status) can affect the
9 research productivity of the research groups and, so, of the department. In this respect,
10 an interesting example is the paper by Rodgers & Neri (2007), who specifically
11 attempted to correlate the human capital of researchers with the research productivity
12 of Australian departments of economics. They found that human capital differential
13 accounts for about 50% of the observed differences in research productivity. If human
14 capital is (even indirectly) captured by the tenured status (for example, researchers with
15 more experience should have reached their tenured position), then a correlation
16 between the proportion of tenured researchers and the department's results should be
17 expected.
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20 The analysis did not find evidence of a statistical influence of this factor on research
21 efficiency (the value of the H statistic is 0.16 and the related p-value is >0.6).
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26 27 28 29 30 31 32 *4.2.5. Fifth external factor: can departments' "longevity" affect research efficiency?*

33 Finally, the possible effects due to the longevity of departments was examined. As
34 inputs were measured as numbers of academic staff and laboratories/facilities, it is
35 reasonable that older departments accumulated higher stocks of inputs that could
36 influence their outputs.
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39 A key assumption here is that older departments can favour more cohesion among its
40 members, facilitating the climate of collaboration and common motivation, which
41 enhances research productivity.
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44 Another interesting point of view about this potential phenomenon is that it is related
45 to the "critical mass" dimension. Among the economic aspects of research, Hare &
46 Wyatt (1992) underlined that the ability in producing research relies upon the human
47 capital accumulated by the individual researchers; thus:
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53 combining this process with the notion that there are economies of scale in
54 research may dispose university departments to feel they need to have at least
55 some critical mass of researchers working in the same area in order to function
56 properly as research units. (Hare & Wyatt, 1992, pp. 55–56)
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Consequently, it could be reasonable to assume that older departments are more likely to have reached such “optimal” scale dimension than the more recently established ones.

The statistical analysis did not provide statistically robust results on this effect, indeed the value of the H statistic is 1.172, while the critical value is around 3.8, so that the p-value is 0.27).

To sum up, the empirical analysis suggests that none of these factors (location in metropolitan area, scientific sector, university effect, proportion of tenured academic staff, departments “longevity”) is able to adequately explain efficiency differentials. This result should be considered as positive, especially when thinking to the use of efficiency scores for policy purposes (for example, resources allocation). Indeed, a usual criticism of the efficiency analyses is that they provide results which are affected by factors that are not under the control of the units themselves: when this is the case, a procedure of resource allocation following efficiency results would be inequitable. At the same time, it could be possible that there are some elements that could influence efficiency and that are related to some “soft” characteristics of the academic units, typically (i) the incentive systems and (ii) the governance/management. For instance, the perception of the academic staff about the importance of publications for their career. Rodgers & Neri (2007) suggested that the “departmental environment” is important and they define it through several measures centred on the “human capital” of researchers who work in the department. Unfortunately, the QuESTIO dataset does not collect such data: an extension of this dataset along this dimension could help to improve significantly the understanding of this pattern.

The governance/management of the academic departments has not been analysed in the study, as the only information available in this respect (the presence of a quality system or a management control system) is a very indirect measure of the governance process and the data recovery on this topic was quite imprecise. Another way to improve the QuESTIO dataset should be to better investigate this dimension, by including some qualitative descriptions about the way department managers organise and coordinate the activities and resources, formulate strategies and foresight studies and manage networking activities (Sala *et al.*, forthcoming; Salerno *et al.*, 2008). Without knowing the characteristics of the “management style” of each department, it

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3 is impossible to derive policy implications from such dimension. At the same time, a
4 possible way to better understand the potential incidence of such phenomenon is to
5 conduct case studies about the successful academic departments (for example, those
6 with higher efficiency scores or those that substantially improved scores in recent
7 years).

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12 Finally, a potential candidate to analyse the efficiency differentials is the interaction
13 between research and teaching activities conducted by the departments. Typically, the
14 literature did not pay enough attention to the interaction between teaching and
15 research at department level, mainly because both activities were considered as inputs
16 and outputs (see section 2). In this paper, the focus was exclusively on the research
17 activities but it raises also questions about the effects that the (unmeasured) teaching
18 activities play on the research result. This issue is very relevant both in theoretical
19 terms (are there economies of scope, or tradeoffs, between the two activities?) and in
20 empirical ones (which is the optimal allocation of energies between teaching and
21 research?). This interesting issue was at the centre of several contributions since the
22 seminal paper by Cohn *et al.* (1989) that, for the first time, addressed and modelled
23 the multi-outputs nature of academic activities. Recently, the theme has been explored
24 by Bonaccorsi & Daraio (2007) for a sample of European universities. In the present
25 paper, this topic has not been explored because QuESTIO dataset does not record data
26 about the teaching dimension of the departments' activities (as before, it could
27 represent a substantial improvement of the dataset).

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40 Finally, the issue of research quality still remains open. Indeed, the analysis is focused
41 only on a quantitative dimension of research, while quality is important to adequately
42 assess the performance. Typically the lack of data on this respect justifies the scarce
43 attention to this problem. However, the QuESTIO dataset will, in future, include some
44 qualitative indicators, like H and citation indexes. Attention will be devoted to this
45 topic in future research, also exploring trade-offs between research quantity and
46 quality.
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References

Abbott, M., Doucouliagos, C., (2003), The Efficiency of Australian Universities: a Data Envelopment Analysis, *Economics of Education Review*, 22(1), pp. 89–97.

Agasisti, T., (2009), Market Forces and Competition in University Systems: Theoretical Reflections and Empirical Evidence from Italy, *International Review of Applied Economics*, 23(4), pp. 463–483.

Agasisti, T., Dal Bianco, A., (2006), Data Envelopment Analysis of the Italian University System: Theoretical Issues and Policy Implications, *International Journal of Business Performance Management*, 8(4), pp. 344–367.

Agasisti, T., Dal Bianco, A., (2009), Reforming the University Sector: Effects on Teaching Efficiency. Evidence from Italy, *Higher Education*, 57(4), pp. 477–498.

Agasisti, T., Salerno, C., (2007), Assessing the cost efficiency of Italian universities, *Education Economics*, 15(4), pp. 455–471.

Athanassopoulos, A.D., Shale, E., (1997), Assessing the Comparative Efficiency of Higher Education Institutions in the UK by Means of Data Envelopment Analysis, *Education Economics*, 5(2), pp. 117–134.

Avkiran, N.K., (2001), Investigating Technical and Scale Efficiencies of Australian Universities Through Data Envelopment Analysis, *Socio-Economic Planning Sciences*, 35(1), pp. 57–80.

Banker, R. D., Charnes, A., Cooper, W., (1984), Models for Estimation of Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science*, 30, pp. 1078–1092.

Bonaccorsi, A., Daraio, C., (2007), *Universities and strategic knowledge creation*, (Cheltenham, Edward Elgar Publisher).

Bonaccorsi, A., Daraio, C., Simar, L., (2006), Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data, *Scientometrics*, 66(2), pp. 389–410.

Brennan, J., Teichler U., (2008), The future of higher education and of higher education Research, *Higher Education*, 56, pp. 259–264.

1
2
3 Charnes, A., Cooper, W.W., Rhodes, E. (1978) Measuring the efficiency of decision
4 making units, *European Journal of Operational Research*, 2, pp. 429–444.

5
6
7 Clark, B., (1998), *Creating Entrepreneurial Universities: Organizational Pathways of*
8 *Transformation, Issues in Higher Education* (Elsevier Science, New York).

9
10
11 Cohn, E., Rhine, S.L.W., Santos, M.C. (1989), Institutions of higher education as
12 multi-product firms: economies of scale and scope, *Review of Economics and*
13 *Statistics*, 71, pp. 284–290.

14
15
16
17 Cooke P., Uranga M. G., Etzebarria G. (1997) Regional Innovation Systems:
18 Institutional and organisational dimensions, *Research Policy*, 26, pp. 475–491.

19
20
21 Cooper, W.W., Seiford L.M., Tone K., (2006), *Introduction to Data Envelopment*
22 *Analysis and Its Uses* (Springer, New York).

23
24
25
26 Curran, P.J., (2000), Competition in UK Higher Education: competitive advantage in
27 the Research Assessment Exercise and Porter's diamond, *Higher Education*
28 *Quarterly*, 54(4), pp. 386–410.

29
30
31 Daraio, C., Simar L., (2005), Introducing environmental variables in nonparametric
32 frontier models: a probabilistic approach, *Journal of Productivity Analysis*, 24(1), pp.
33 93–121.

34
35
36
37 Etzkowitz, H., (2003), Research groups as 'quasi-firms': the invention of the
38 entrepreneurial university, *Research Policy*, 32(1), pp. 109–121.

39
40
41 Faria, J.R., Scientific, business and political networks in academia, *Research in*
42 *Economics*, 56(1), 187-198. —IS THIS FARI (2002) AS REFERENCED IN THE
43
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46
47
48
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57
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TEXT.

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58
59
60
Flagg, A.T., Allen, D.O., Field, K., Thurlow, T.W., (2004), Measuring the Efficiency
of British Universities: a Multi-Period Data Envelopment Analysis, *Education*
Economics, 12(3), pp. 231–249.

Gimenez, V.M., Martinez, J.L., (2006), Cost efficiency in the university: a
departmental evaluation model, *Economics of Education Review*, 25, pp. 543–553.

Hare, P., Wyatt, G., (1992), Economics of academic research and its implications for
higher education, *Oxford Review of Economic Policy*, 8(2), pp. 48–66.

1
2
3 Hood, C. (1991), A public management for all seasons? *Public Administration*, 69,
4 pp. 3–19.

5
6
7 Hood, C. (1995), The new public management in the 1980s: Variations on a theme.
8 *Accounting Organizations and Society*, 20(2/3), pp. 93–110.

9
10
11 Johnes, G., Johnes, J., (1993), Measuring the Research Performance of UK
12 Economics Departments: an Application of Data Envelopment Analysis, *Oxford*
13 *Economic Papers*, 45, pp. 332–347.

14
15
16
17 Johnes, G., Johnes, J., (1995), Research Funding and Performance in UK University
18 Departments of Economics: A Frontier Analysis, *Economics of Education Review*,
19 14(3), pp. 301–314.

20
21
22
23 Johnes, J., (2004), *Efficiency Measurement*, in Johnes, G., Johnes, J., (eds),
24 International Handbook on the Economics of Education (Edward Elgar Publishing
25 Ltd, Cheltenham).

26
27
28
29 Kocher, M.G., Luptàcik, M., Sutter, M., (2006), Measuring Productivity of Research
30 in Economics. A Cross-Country Study Using DEA, *Socio-Economic Planning*
31 *Sciences*, 40, pp. 314–332.

32
33
34
35 Koksall, G., Nalcaci, B., (2006), The relative efficiency of departments at a Turkish
36 engineering college: a data envelopment analysis, *Higher Education*, 51(1), pp. 173–
37 289.

38
39
40
41 Kruskal, W.H, Wallis, W.A., (1952), Use of ranks in one-criterion variance analysis,
42 *Journal of the American Statistical Association*, 47(260), pp. 583–621.

43
44
45 Landoni, P., Verganti, R., (2006), Fostering Knowledge and Technology Transfer
46 through evaluation systems at a regional level, *International Journal of Technology*
47 *Transfer and Commercialisation*, 5(4), pp. 355–372.

48
49
50
51 Lechner C., Dowling M. (1999) The Evolution of Industrial Districts and Regional
52 Networks: The Case of the Biotechnology Region Munich/Martinsried, *Journal of*
53 *Management and Governance*, 3, pp. 309–338.

54
55
56
57 Levin, H.M., (1991), Raising productivity in higher education, *Journal of Higher*
58 *Education*, 62(3), pp. 242–262.

1
2
3 Madden, G., Savage, S., Kemp, S., (1997), Measuring public sector efficiency: a
4 study of economics departments at Australian universities, *Education Economics*,
5 5(2), pp. 153–167.
6
7

8
9 Marinova, D., Newman, P., (2008), The changing research funding regime in
10 Australia and academic productivity, *Mathematics and Computers in Simulation*
11 78(2-3), pp. 283–291.
12
13

14
15 McMillan, M.L., Datta, D., (1998), The Relative Efficiencies of Canadian
16 Universities: A DEA Perspective, *Canadian Public Policy*, 24(4), pp. 485–511.
17

18
19 Moreno, A.A., Tadepali, R., (2002), Assessing Academic Department Efficiency at a
20 Public University, *Managerial and Decision Economics*, 23, pp. 385–397.
21
22

23 Ng, Y.C., Li, S.K., (2000), Measuring the Research Performance of Chinese Higher
24 Education Institutions: An Application of Data Envelopment Analysis, *Education*
25 *Economics*, 8(2), pp. 139–156.
26
27

28
29 Organisation for Economic Co-operation and Development (OECD), (2002),
30 *Proposed Standard Practise for Surveys of Research and Experimental Development*
31 *- Frascati Manual, sixth edition* (Paris, OECD).
32
33

34
35 Organisation for Economic Co-operation and Development (OECD), (2003),
36 *Education policy analysis* (Paris, OECD).
37

38
39 Pesenti, R., Ukovich, W., (1996), *Evaluating Academic Activities Using DEA*,
40 Internal Report (Trieste, DEEI, Università di Trieste).
41
42

43
44 Porter M.E. (1998) *Clusters and the New Economics of Competition*, (Boston,
45 Harvard Business School Press).
46

47
48 Rizzi, D., (1999), L'efficienza dei dipartimenti dell'Università Cà Foscari di Venezia
49 via DEA e DFA (The efficiency of departments at University Cà Foscari through
50 DEA and DFA), *Working Paper, Università Cà Foscari di Venezia, Dipartimento di*
51 *Scienze Economiche*.
52
53

54
55 Rodgers, J. R., Neri, F., (2007), Research Productivity of Australian Academic
56 Economists: Human-Capital and Fixed Effects, *Australian Economic Papers*, 41(6),
57 pp. 67–87.
58
59
60

1
2
3 Sala A., Landoni P., Verganti R., (forthcoming) “R&D networks: an evaluation
4 framework” *International Journal of Technology Management*.

5
6
7 Salerno M., Landoni P., Verganti R. (2008), Designing foresight studies for
8 Nanoscience and Nanotechnology (NST) future developments, *Technological
9 Forecasting & Social Change*, 75(8), pp. 1202–1223.

10
11
12 Sarrico, C.S., Dyson, R.G., (2004), Restricting virtual weights in data envelopment
13 analysis, *European Journal of Operational Research*, 159(1), pp. 17–34.

14
15
16 Sarrico, C.S., Teixeira, P.N., Rosa, M.J., Cardoso, M.F., (2009), Subject mix and
17 productivity in Portuguese universities, *European Journal of Operational Research*,
18 197(2), pp. 287–295.

19
20
21 Thursby, J.G., (2000), What Do We Say about Ourselves and What Does It Mean?
22 Yet Another Look at Economics Department Research, *Journal of Economic
23 Literature*, 38, pp. 383–404.

24
25
26 Warning, S., (2004), Performance Differences in German Higher Education:
27 Empirical Analysis of Strategic Groups, *Review of Industrial Organization*, 24, pp.
28 393–408.

29
30
31 Zhu, J., (2003), *Quantitative Models for Performance Evaluation and Benchmarking*,
32 (Kluwer Academic Publisher, Boston, MA).

Table 1. Inputs/outputs descriptive statistics

	<i>Mean</i>	<i>Standard deviation</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Average difference 2004–2007</i>
Laboratories (m ²)	2,243.83	6,917.93	0.00	60180.00	80.24
Human resources (n)	105.50	83.30	9.00	445.00	16.19
High Qualified Human resources (n)	98.33	79.66	8.00	434.00	16.00
Other personnel (n)	7.12	6.83	0.00	32.00	-0.30
Revenues from financed activities (€)	486936.06	557412.78	0.00	3039361.00	142196.00
Financed activities from abroad (€)	118587.58	256766.37	0.00	1805922.00	10896.00
Revenues from orders (€)	451240.13	764559.23	0.00	3333362.00	86950.00
Number of publications (n)	32.45	31.91	0.00	188.00	2.87
Doctorates in cooperation with external bodies (n)	2.49	4.04	0.00	22.00	0.63

Table 2. Efficiency scores (DEA on 2007 data) – descriptive statistics

	<i>CRS Efficiency</i>	<i>VRS Efficiency</i>	<i>Scale Efficiency</i>
Mean	0.745	0.786	0.937
St. Deviation	0.241	0.219	0.101
Min	0.173	0.216	0.432
Max	1.000	1.000	1.000
# efficient units	25	29	25

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 3. Malmquist index 2004-2007 – descriptive statistics

<i>Department</i>	<i>Malmquist index</i>	<i>Efficiency change</i>	<i>Frontier shift</i>
Mean	1.060	1.666	0.652
St. dev.	0.492	0.882	0.141
Min	0.072	0.529	0.104
Max	2.534	4.600	1.031
# improving units	35	56	2

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 4. Factors affecting efficiency (Kruskal-Wallis analysis)

<i>Effects of Metropolitan area (Milan)</i>	
H (observed value)	0.007
H (critic value)	3.481
p-value	0.934
<i>Effects of subject mix</i>	
H (observed value)	8.451
H (critic value)	9.488
p-value	0.076
<i>University effects</i>	
H (observed value)	9.426
H (critic value)	14.067
p-value	0.224
<i>Effects of tenured staff proportion</i>	
H (observed value)	0.163
H (critic value)	3.841
p-value	0.687
<i>Effects of departments' age</i>	
H (observed value)	1.172
H (critic value)	3.841
p-value	0.279

Evaluating the efficiency of research in academic departments: an empirical analysis in an Italian Region

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Abstract.

This paper investigates the efficiency of university departments on science, technology and medicine in an Italian Region (Lombardy). The aim of the paper is twofold: (i) to analyse the changes in productivity in recent years (from 2004 to 2007); and (ii) to detect factors that are potentially affecting efficiency. The research benefited from a new and unique dataset (called QuESTIO) developed by the Lombardy Regional Government. Using facilities and academic staff as inputs and research grants and publications as outputs, the research activity of academic departments was modelled. The methodological approach for computing efficiency scores is Data Envelopment Analysis. Malmquist indexes have been used to measure changes in productivity, while Kruskal-Wallis tests were employed to study the potential determinants of efficiency. The main results were that in the period considered, the academic departments improved their efficiency but, at the same time, the efficiency frontier worsened. Moreover, external and measurable factors (such as, scientific sector, proportion of tenured staff, location) have a limited impact in explaining efficiency differentials. Policy implications of the results are discussed.

Keywords.

University research, efficiency, research policies, Data Envelopment Analysis, Malmquist index, higher education policy.

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1. Introduction and motivation

In recent years, higher education institutions have been studied increasingly. In the “knowledge economy” their importance for economic development, social equity, mobility, social cohesion and integration is widely acknowledged (Brennan & Teichler, 2008). Furthermore, given the difficult situation of public finances, considerations about resources allocation have been raised in many countries, calling for more evaluations and accountability. For these reasons the so-called ‘New Public Management’ movement, started at the beginning of the 1980s in the public sector in general, has also increasingly been affecting the universities. New Public Management (Hood, 1991, 1995) represents the request to public organisations to become more managerial, in particular by drawing on practices and models from the private sector. This process has been driven both by universities themselves and by governments through reforming efforts. The results, especially in many countries within Europe, share some common characteristics: first, the introduction of incentives schemes based on financial models for allocating public funds; second, new or strengthened assessment procedures and evaluation agencies; third, more emphasis on universities’ autonomy (OECD, 2003).

This work explores how the recent changes in the university system affected the efficiency of university research. In particular, the research sought to understand whether an overall increase in efficiency can be recognised or whether differences are present between universities given the previously-noted increased autonomy. Normally, the majority of the reforming efforts have been directed towards education activities, whilst an increase in efficiency of university research has been assigned to incentive systems and evaluation processes. These are expected to have had an overall positive effect on the system but, at the same time, they have left the universities in charge of finding and managing the ways to obtain better results. Given the autonomy of the universities and the decentralisation of responsibilities, significant efficiency changes are thus expected between and within universities. Furthermore, the idea that differentials in research performance are key for competition among departments is well established in the literature (Curran, 2000).

The research focused on universities research activities and not on education or knowledge/technology transfer activities. Universities’ education activities constitute the first and original mission of the universities but, at the same time, they are normally carefully regulated by laws and their efficiency and quality are already

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3 widely studied (Madden *et al.*, 1997). Indicators such as number of degrees awarded,
4 rate of success, years of study, have been widely used both to evaluate the universities
5 and to introduce new policies. The opposite holds for universities'
6 knowledge/technology transfer activities. Even if some argue for this to be a third
7 mission for academia and call for “entrepreneurial universities” (Clark, 1998;
8 Etzkowitz, 2003), others refuse this perspective and signal the risks of focusing on
9 and expanding the role of these activities. Moreover, the efficiency analysis of these
10 activities is hampered by the difficulties in finding the right indicators. There are
11 many different knowledge/technology transfer activities (for example, spin-off,
12 consultancies, research projects with firms, patents) and their evaluation can be based
13 only partially on economic values given the not-for-profit nature of (most)
14 universities (Landoni & Verganti, 2006). Finally, the focus of the study is on the
15 research activities as they are the core activities of universities; driving and informing
16 both education activities and knowledge/technology transfer activities. This
17 relationship especially holds for transfer activities because the value of the results
18 transferred relies heavily on the underlying research on which they are based.
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33 This paper adopts the standard definition of ‘research’ provided by the Organisation
34 for Economic Co-operation and Development (OECD): “Research and development
35 is a term covering three activities: basic research, applied research, and experimental
36 development” (OECD, 2002). However, only research activities that are normally
37 carried out within universities are considered.
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42 Furthermore, the focus of the efficiency analysis is on university departments and not
43 on the university as a whole. Universities are composed of different research
44 departments and their publication outputs, co-authorship behaviours and thus
45 efficiency usually differ significantly. An analysis at the level of the university can
46 put forward mixed results, while an analysis at the level of single departments is more
47 precise and coherent with the objectives of an efficiency analysis. For this reason, to
48 obtain a sample of comparable departments the research focused on natural science
49 departments. The choice of the department level for the analysis is coherent with the
50 focus on research activities: normally education activities are managed by
51 organisational entities inside the university that are transversal to more departments
52 and many transfer activities are centralised in a single organisational unit (such as a
53 liaison office or a knowledge/technology transfer office).
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3 The research considers departments located in the Lombardy region (Italy). A
4 regional focus has been adopted to ensure similar contextual variables, such as
5 policies and economic environment, for the universities included in the analysis.
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7 Furthermore, Lombardy is one of the more advanced European regions both for (i)
8 economic development and (ii) research activities and universities: more than 9.4
9 million inhabitants, GDP per capita >€34,000; 12 universities are located in the Region
10 (out of about 70 in all the country) with more than 230,000 students. Finally, the
11 regional level is increasingly recognised as a relevant level when analysing research
12 and innovation activities. Many authors (Cooke *et al.*, 1997; Porter, 1998; Lechner &
13 Dowling, 1999) underline that it is at a local level that the majority of the connections
14 between the different innovation actors take place. The localisation of knowledge and
15 the role of proximity as a driver of economic development (for example, clusters)
16 have also highlighted the importance of regional and local government in fostering
17 and strengthening the actors and their relationships.
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30 To summarise, the focus of the paper is on efficiency of research activities in
31 scientific departments in the Lombardy Region (Italy). The research questions are:

- 32 • did changes in the overall efficiency of departments' research occur between
33 2004 and 2007?
- 34 • Which are the main factors affecting efficiency?
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40 The next section presents recent literature on the topic, then the methodology and the
41 data used are introduced, finally results are presented and discussed.
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49 **Background**

50 The international literature about universities' efficiency (through non-parametric
51 techniques) has been developed both at institution-level (Athanasopoulos & Shale,
52 1997; McMillan & Datta, 1998; Ng & Li, 2000; Avkiran, 2001; Abbott &
53 Doucouliagos, 2003; Flagg, *et al.*, 2004; Warning, 2004) and department-level. The
54 latter is more relevant for the context of the present study.
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58 The contributions by Johnes & Johnes (1993, 1995) had a major influence on the
59 methodological approach. Johnes & Johnes (1993) measured the research
60 performance of UK economics departments by using staff numbers as inputs and

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3 publication counts and grants as outputs; the same strategy was adopted again for
4 deriving efficiency scores of economics department in a subsequent paper (Johnes &
5 Johnes, 1995). The authors ran several Data Envelopment Analysis (DEA) models to
6 test the robustness of results and claim for a possible use of results for policy
7 purposes, especially for establishing an optimal allocation of resources across
8 departments. These two contributions are the most important as they focus
9 exclusively on the research dimension of the universities' work.

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16 Madden *et al.* (1997) studied the efficiency of economics departments in 29
17 Australian universities. Inputs were teaching and research staff, outputs were
18 graduates and publications (for teaching and research respectively). As in other
19 studies listed below, here the focus was both on teaching and research performance,
20 even if the analysis were conducted at sub-unit level (that is at departmental level
21 instead of institutional level). The specific objective of the Madden *et al.* (1997) study
22 was to verify whether policies promoted by governments impacted on productivity;
23 they confirmed that there was actually an increase in productive efficiency.
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30 Thursby (2000, p. 400) analysed the efficiency of the Economics Research
31 Departments in the United States. He defined efficiency as follows:

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33 a department is deemed technically efficient if, when compared to departments
34 with similar level of inputs, it could produce greater research outputs without
35 increasing its inputs usage, or equivalently, it is one which, compared to
36 departments with similar levels of outputs, could produce the current levels of
37 outputs with fewer inputs.
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44 Thursby used publication, citation data and number of Ph.D.s as outputs and the
45 number of researchers and professors, graduate students, federal grants, library
46 acquisitions and a dummy for private ownership as inputs. He found that the average
47 level of efficiency in the United States is high (67% of economics departments appear
48 as efficient).
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53 Moreno and Tadeballi (2002) focused on 42 academic units distributed across seven
54 colleges in the United States. They used staff, financial resources and proxies for
55 structures (for example, building space) as inputs and number of students, full-time
56 equivalent enrolments and grant awards as outputs. In discussing their results, they
57 showed that efficiency scores do not illustrate information about effectiveness: that is,
58 they argued that a qualitative dimension is necessary for this purpose. Lastly, as their
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3 background is strongly managerial, they also suggested a use of efficiency analysis as
4 a planning tool, not only for evaluating universities' activities.
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7 Koksal and Nalcaci (2006) derived efficiency scores for 14 university departments at
8 the Middle East Technical University in Turkey, by using staff salaries, a composite
9 indicator of previous research quality and number of students as inputs and number of
10 publications, graduates and teaching indicators as outputs. Thus, in their contribution,
11 the authors focused also on the teaching activity of the departments. They decided to
12 use weights for teaching and research loads as suggested by university's
13 administrators through a preliminary survey. The paper suggests that the models
14 adopted for computing efficiency can serve to set new targets for inefficient
15 departments.
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18 Gimenez and Martinez (2006) focused on cost efficiency of the departments at the
19 Autonomous University of Barcelona. They computed cost-efficiency scores and
20 separated cost excess into three categories: technical efficiency, fixed factors, and
21 "scale effects" (due to the number of academics in the department). The units of
22 analysis were 42 departments and again the focus is on both teaching and research
23 activities. The inputs chosen were: expenditure on temporary hired teaching and
24 research staff, operational expenditures, expenditures on tenure staff. To measure the
25 outputs, they employed the following variables: results of a government evaluation
26 process of research, teaching load (measured through credits granted) and students'
27 opinions. The authors suggested that their analyses can be used to assess the
28 differences between (i) the observed cost of the units and (ii) the cost they would
29 achieve assuming long-term cost minimisation. Their result tells that size does not
30 matter in determining efficiency, while higher proportion of non-tenured staff is
31 associated with higher efficiency levels.
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34 In another exercise presented by Kocher *et al.* (2006) the analysis focused on the
35 productivity of research in economics across 21 OECD countries. The focus of the
36 paper was on research and the outputs selected are top publications (and impact
37 factors), while inputs are expenditure on research and development, number of
38 universities and total population. This study was quite different, however, with
39 respect to the relevant contributions for the present paper, as the unit of analysis is the
40 country (neither the university nor the department). The results suggest that research
41 productivity can be raised through an increase in the scale of operations.
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4 An interesting issue is to analyse the related literature about the Italian universities'
5 research. To the best of the authors' knowledge, there are only two specific
6 contributions that specifically analyse the efficiency of universities in producing
7 research outputs (Pesenti & Ukovich, 1996; Rizzi, 1999) and just one attempting to
8 focus on teaching production (Agasisti & Dal Bianco, 2009).

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11 The two contributions at departmental level (Pesenti & Ukovich, 1996; Rizzi, 1999)
12 used a similar set of variables and focused both on teaching and research outputs. The
13 main scope for these contributions was to provide information and suggestions for
14 allocating resources within a university.

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17 Contributions about the efficiency of Italian higher education have been conducted at
18 institution-level (thus, not considering separately the structures devoted to teaching
19 and research). This is because the strategy and the mission of universities and the
20 balance between teaching and research are defined at institutional level (Bonaccorsi &
21 Daraio, 2007, p. 22).

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24 Among these contributions at an institutional level Agasisti & Dal Bianco (2006)
25 studied the efficiency of 58 Italian public universities by using, as inputs, number of
26 staff, financial resources and students and, as outputs, graduates and research grants.
27 They suggested the use of efficiency analysis for policy purposes, especially to
28 evaluate the differences in performance between efficient and inefficient units. Later,
29 Agasisti & Salerno (2007) analysed the cost efficiency of another sample of Italian
30 universities by adding some qualitative measures for inputs and outputs. They
31 concluded that a redistribution of inputs across universities could lead to an overall
32 improvement of efficiency in the Italian higher education sector.

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35 Bonaccorsi *et al.* (2006) used a robust non-parametric technique (developed by
36 Daraio & Simar, 2005) to take in account external conditions affecting the
37 productivity of universities. The inputs and outputs adopted are quite similar to
38 previous studies (that is, staff numbers, expenses and spaces as inputs and
39 publications and graduates as outputs) but they also included some "external" factors:
40 university size, number of departments within the university, percentage of private
41 funding, number of curricula activated. They concluded that economies of scale and
42 scope are not relevant factors in explaining (in)efficiency.

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45 To sum up, the literature seems to suggest that, to analyse research efficiency of
46 universities, that is, the efficiency in the production of research outputs:

- inputs can be classified under three main groups: human resources, financial resources and structures (for example, facilities, buildings);
- outputs can be grouped into publications and grants.

Methodology and data

Methodology

The methodology is articulated accordingly to the two steps adopted to answer the research questions of the paper: on one hand the efficiency analysis (including efficiency scores of the departments, changes across time and time trends), on the other hand the effort to identify the determinants of efficiency.

Data Envelopment Analysis (DEA) (Charnes *et al.*, 1978) was the methodology used to analyse efficiency. It deals with the efficiency problem of complex organisations that produce many outputs using several inputs at a time. This paper only briefly discusses some characteristics of DEA, referring the interested reader to Johnes (2004), Cooper *et al.*, (2006) and Zhu (2003).

In a DEA model, the notion of efficiency is that of “technical efficiency”, defined as the relative ability of each decision making unit (DMU) in producing outputs, where the term “relative” means that each organisation is compared with any other homogeneous unit. DEA could be represented by a linear programming technique where each DMU tries to maximise the efficiency ratio (output over inputs) choosing the best set of weights. There are two ways to deal with a DEA formulation: (i) input oriented (that is, the ability to minimise inputs when outputs are given) and (ii) output oriented (maximisation of outputs given a certain bundle of inputs). The latter approach is used in this paper, as the typical problem for a research unit is to maximise outputs (publications, grants) given its inputs (research staff, laboratories). DEA mathematical formulation can deal with both constant returns to scale (CRS) and variable returns to scale (VRS). The seminal work of Charnes *et al.* (1978) introduced a constant-return-to-scale (CRS) model where DMU dimension has no importance in defining efficiency performance (see equation 2). DMUs face the same efficiency frontier, independently of their relative size. One can cast doubts on the comparability of small and large units. Larger units exploit common inputs to produce different outputs, whereas smaller ones benefit from substantial advantages in organising activities. A further model, developed by Banker *et al.* (1984) introduces

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3 in DEA modelling the dimension factor, by comparing units according to their
4 dimension; that is, by considering that the unit's dimension can affect efficiency
5 (VRS efficiency).
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10 Smaller units are associated with increasing economies of scale and bigger units with
11 decreasing economies of scale. In the middle, there is a "grey area" of constant
12 returns to scale. So, it is also possible to compute the scale efficiency. This is defined
13 as the ratio CRS/VRS efficiencies and interpreted as the ability of each institution to
14 operate at its optimal scale dimension; in other words, in a VRS formulation, each
15 DMU is compared only with those units having a comparable size.
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18 It is also possible to measure changes in efficiency across time (the-relevant period
19 here is between 2004 and 2007). For measuring the determinants of the changes in
20 efficiency scores, Malmquist index has been used (for more information about this
21 index see Johnes (2004) and Coelli *et al.*, (2006)). Considering a DMU, named P that
22 has a change in production position from P_t (in period t) to P_{t+1} (in period $t+1$), the
23 change in the production frontier could have occurred in a non-neutral way; that is, it
24 could be determined both by efficiency changes and shifts in the efficiency frontier.
25 Thus, for measuring the change in the efficiency score, it is possible to break down
26 the score in these two different components. Both of the components have a specific
27 mean: the resulting score for the DMU could have positive or negative effects due to
28 the own efficiency change or due to the shift (movement) of the frontier. Thus the
29 resulting efficiency index is composed of two parts. The first component of the
30 equation is the ratio of technical efficiency in time period $t+1$ on the technical
31 efficiency in the period t . Since it measures the change in technical efficiency, it is
32 equal to 1 if no changes occurred, greater than 1 if the change was positive and less
33 than 1 if it was negative. The second component measures the shift in the production
34 frontier: if it is equal to 1 it has no effect on the efficiency score, if it is greater than 1
35 it has a positive effect and if it is less than 1 it has a negative effect. In other words, a
36 shift in a production frontier that makes worse the relative position of the DMU (the
37 other DMUs are performing relatively better than before) provides a second
38 component less than 1. The index (Malmquist index) resulting from the combination
39 of these two components will be equal to 1 if there is no net effect of changes in
40 technical efficiency and frontier changes; it will be greater than 1 if the net effect is
41 positive and less than 1 if it is negative.
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5 The second task in the methodology is to study some potential determinants of
6 efficiency. To pursue this objective, some external factors (for example, location
7 effects, discipline effects) were identified and then efficiency scores were compared
8 across different groups of units. The comparison was made by means of the Kruskal-
9 Wallis test (Kruskal & Wallis, 1952). This test allows the researcher to detect if there
10 are statistical differences across the groups analysed (for example, when comparing
11 the efficiency scores of units located in a metropolitan area with those located
12 elsewhere, the test indicates if this location effect generates a statistical difference
13 between the average scores of the two groups).
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23 *Data*

24 The research used a unique dataset that consists of input and output variables about
25 research and technology transfer activities in university departments located within
26 the Lombardy Region. This dataset is based on information coming from QuESTIO
27 system, a mapping of research and technological transfer organisations developed in
28 the Lombardy region. The QuESTIO system, launched in 2004 by the regional
29 government, was intended to be a transparency and incentive tool for the research and
30 technological transfer market by reducing any information unevenness often binding
31 cooperation among producers and users of knowledge. The system collects, updated
32 and publishes financial, organisational and structural characteristics of research
33 organisations and knowledge business intelligence services in Lombardy.
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42 Since it aims at presenting the most detailed picture of regional community active in
43 research and technological transfer, the dataset has some specific criteria that are
44 pivotal for the analyses. First, the system is focused on every structure where such
45 activities are carried out, even where that structure is a part of a wider organisation.
46 Second, these structures should have significant management autonomy so that their
47 accountancy shall be determinable. The first criterion enables the regional
48 administration to collect information on every single department, being acknowledged
49 that the performance of departments belonging to the same university can differ
50 significantly. As a consequence the university departments, as well as sections and
51 institutes of the National Research Council or a research and development unit
52 belonging to a company, provide data that refers solely to their specific resources and
53 outputs. The second criterion assures that each structure included in the dataset is
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3 responsible (to some extent) for its strategy and performances thus justifying
4 application of the DEA technique.
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7 The Lombardy innovation system maps 364 structures of which 147 are university
8 departments, 151 are knowledge business intelligence services, 13 are hospital and
9 medical research centres, 34 are public research organisations and 19 are company
10 research and development units.
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16 The geographical analysis shows a concentration in the Province of Milan and a little
17 less in Bergamo, Brescia, Pavia and Varese, which is explained by the presence of
18 universities in those cities. The dataset was built by considering those university
19 departments that provided information for the whole period 2004–2007 (units for
20 which there are not missing data), by selecting the following variables:
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24 25 26 Inputs

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28 I1 Laboratories: the areas (measured in square meters) devoted to laboratories
29 belonging to or accessible by the department.
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32 I2 Highly-qualified human resources: persons who perform research and technology
33 transfer activities, regardless of their qualifications. They are mainly full professors,
34 associated professors, permanent researchers, post-doctoral scholarships and PhD
35 students. It includes employees dedicated to activities in support of research, such as,
36 certification, tests and measurements, patenting and commercialisation, financial
37 assistance, partners search, technologies monitoring, events organisation, editing of
38 technical-scientific “spreading publications”.
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41 I3 Other personnel: administrative personnel that should ensure the efficient working
42 of human resources devoted to research and technology transfer activities.
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45 46 47 48 49 Outputs

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51 O1 Revenues from financed activities: activities financed with regional or national
52 calls for bids. This variable denotes the ability of the department to compete with
53 other research organisations in getting public-funded research, thus measuring the
54 amount of research that meet requirements of national and regional research and
55 innovation strategies.
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59 O2 Revenues from financed activities from abroad: internationally-funded activities
60 that show the capacity to draw on international funding, such as European projects,

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O3 Revenue from orders: measures how far research activities carried out in a department are funded by companies or other institutions.

O4 Yearly number of publications: yearly publications in academic international journals. This is the traditional and widespread variable used to measure the output of research activities.

O5 Doctorates in cooperation with external bodies: sheds light on the capability of departments in attracting funds for doctoral students and to establish cooperation with institutions and companies. Since this variable could be interpreted such as an indicator of technology transfer activities, it was investigated if it could alter the efficiency scores and a DEA model has been estimated without considering it.

As discussed in the previous section, the choice of input and output variables is compatible with the most recent literature. The final sample contains 75 departments, for 4 years; overall, there are 300 observations, revealing considerable variation (Table 1).

<Table 1> about here

Results and discussion

This section illustrates and discusses the results obtained through the DEA analysis of the university departments in the Lombardy Region.

The results are presented in two main sections. The first is devoted to a description of the efficiency scores with reference to the year 2007 (the last year available, where the results are more stable, as previously discussed). It analyses the change in efficiency between the first year of the dataset (2004) and the last year (2007) as well as the presence of time trends in the efficiency scores. The second section examines statistical differences in efficiency scores due to external factors, such as localisation and discipline subject.

DEA efficiency scores, year 2007

Table 2 reports the descriptive statistics about the efficiency scores derived with reference to the year 2007 (the annex reports the specific scores for each department).

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3 <Table 2> about here
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7 The research efficiency of university departments in the Lombardy region is high
8 (CRS efficiency = 0.75, VRS efficiency = 0.78). What is worth pointing out is a
9 strong heterogeneity across departments: indeed, the standard deviation is >0.2.

10 Data about scale efficiency suggests that all the departments have almost reached
11 their optimal scale of operations (given their present scale), as the scale efficiency
12 score is very high (>0.93) and standard deviation is very low (about 0.1)

13 The picture that emerges from this first analysis of efficiency scores is a sector where
14 there is a number of very efficient units (both assuming constant or variable returns to
15 scale) and a number of departments that experienced low levels of technical
16 efficiency; thus, as the anecdotal evidence suggests, there is quite a strong
17 differentiation among departments.

18 As the focus of the paper is the efficiency of academic departments in the Lombardy
19 region, the results' robustness was checked by considering revenues from entities
20 located in the Lombardy region as a separate output. The correlation among results
21 obtained by the baseline model and this modified model is very high (>0.97),
22 suggesting that both models report a similar picture.
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26 *Efficiency changes between 2004 and 2007: a Malmquist analysis*

27 Following the methodology described above, the Malmquist index has been
28 calculated to disentangle the efficiency changes due to "pure" efficiency improvement
29 (or worsening) and technological improvement (or worsening). The descriptive
30 statistics about the results are reported in Table 3.
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37 <Table 3> about here
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47 The picture that emerges highlights an interesting phenomenon. It looks like an
48 improvement in productivity did not occur (because the Malmquist index is around 1)
49 but, looking at the decomposition of the index, the reality appears more complex: an
50 efficiency change happened, it was very positive (the index is >1.6) and involved the
51 majority of the departments (56 out of 70); conversely, there was a worsening of the
52 technology frontier (the "frontier shift" indicator is <0.7).
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What is “technology” in a regional research system, when research performance is defined as the ability to attract financial resources and to publish in academic journals? Technology could be defined as the bundle of policies that should help in improving research efficiency, for example, information technologies, research grants, support for publishing research results or to attract financial resources from international grants or companies. This fact raises two reflections. The first is that maybe the universities (and, consequently, the research units) look not at the regional incentives but at the national ones (as the Ministry is still the main financer of the universities’ activities) and at international ones (the research reputation strongly depends upon the ability to publish in international journals and to attract international grants). If this is the case, a question arises about the opportunity for a regional government to be involved in this sector. A second (possibly alternative) reflection is that the policies adopted for boosting research productivity were not adequately designed. To properly design a policy in this field the necessary first step is to understand what affect the academic productivity. In this context, Faria (2002) suggests that policies for fostering the overall productivity of the research sector are: (i) competition in the labour market among researchers (for example, through career or salary incentives) and (ii) increasing research funds. Did the policies of Lombardy Region respect these elements? Are there other elements that affect research productivity? These are interesting starting point for further research in this field.

As a result, however, each academic unit in 2007, on average, is in the same position *relative to the frontier* as in 2004. The vast majority of the units actually improved their productivity in the period (“efficiency change” >1) but the “frontier shift” was <1: it means that the performance differential is much less dispersed in 2007 but at the same time it happens because the frontier is not improved: the best performers did not improve, or even worsened their efficiency. The result is a “research system” in the region that performs better on average but without having excellence.

DEA efficiency scores, year 2007: the external factors affecting efficiency

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This section explores what affects a department’s performance. Several factors were tested using the Kruskal-Wallis test (Table 4).

<Table 4> about here

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4.2.1 *First external factor: are departments located in Milan metropolitan area (regional capital) more efficient than other departments?*

The assumption was that in a metropolitan area the competition among research centres enforces departments' managerial efficiency. In Milan, there is an important concentration of public and private research institutions and the competition for resources is not limited to departments. The high concentration of research facilities may justify a greater effort by departments in fostering a more balanced use in input resources or may impulse an effort in control for managerial quality. Elsewhere, Agasisti (2009) demonstrated that the effect of competition on Italian universities' performance is positive; but, there, output was defined through teaching dimension's measures.

There is no evidence of difference in efficiency performance between the two groups (indeed, the observed value of the H statistic is nearly 0 and the p-value >0.9). This evidence suggests that there is no "concentration" effect or "location" effect on efficiency performance of university departments or, at least, in the relative rankings. At the same time, this result may suggest i) the existence of no competitive pressure in a high concentration area as Milan.

4.2.2. *Second external factor: can different scientific sectors affect university department efficiency?*

As "output" is measured by using (i) publication counts and (ii) research grants (of different kinds), it is important to recall that there are some differences in the average number and quality of publication across different disciplines (for example, medicine versus engineering or biology), as well as in the attractiveness of research funds (for example, in engineering fields it is simpler to attract grants for applied research than in physics).

The idea that disciplines greatly vary in costs and productivity is not new and the suggestion to take this factor into account is important to obtain not-biased results (Sarrico & Dyson, 2004). Recently, Sarrico *et al.* (2009) demonstrated a strong role of "subject mix" (defined as the disciplinary composition of institutions) in explaining the efficiency differentials among Portuguese higher education institutions. The authors acknowledged that "(...) research production also varies significantly from subject to subject, with medical, some natural and technical sciences being more

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prolific in the number of articles than most of the social sciences and humanities” (Sarrico *et al.*, 2009, p. 290).

No significant difference among university departments classified by scientific sectors was found: the observed value of the H statistic is >8.4 .

4.2.3. *Third external factor: is there a “university effect”?*

An alternative explanation of efficiency can refer to the existence of a “university effect”, that is if a university is more efficient than others, then its departments could be more productive than those belonging to other universities. This assumption finds its justification in the setting of strategies at university levels, not at subunits levels. In this respect, Bonaccorsi & Daraio (2007, pp. 22–23) pointed out that:

the notion of strategy is much more relevant and interesting if assumed at the overall university level. On the one hand, most strategic decisions are made at university level.... The fundamental reason for assuming the university level as the unit of analysis is that at the university level the problem of attribution of inputs (in particular, human resources, funding and physical capital) to specific units of outputs, can be kept under control.

Even if these authors recognised that a lower unit of analysis could provide useful information on the actual research process, they suggest that a “university effect” (due to different strategies and characteristics at macro-level) can be detected.

The tests suggest that such effect is not explaining efficiency differentials for the sample (observed value of the H statistic is 9.4, well below the critical value of 14.06 and the p-value is 0.22).

4.2.4. *Fourth external factor: does the number of tenured academic staff influence efficiency?*

The proportion of tenured research staff theoretically can affect the efficiency of a department: there is anecdotal evidence that tenured and non-tenured staff face quite different stimulus and incentives. Nevertheless, the direction of this influence is not clear *a priori*: tenured staff are certainly more expert in attracting research grants and in publishing academic papers, also thanks to reputational advantages; conversely, non-tenured staff can have an incentive to be more productive, for instance as a mean

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3 to obtain a tenured position. The promotion system can affect productivity if
4 researchers are satisfied with rules promoting this dimension.
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7 A complementary idea behind this question is that the different human capital of
8 researchers (in the paper, indirectly measured via the tenured status) can affect the
9 research productivity of the research groups and, so, of the department. In this respect,
10 an interesting example is the paper by Rodgers & Neri (2007), who specifically
11 attempted to correlate the human capital of researchers with the research productivity
12 of Australian departments of economics. They found that human capital differential
13 accounts for about 50% of the observed differences in research productivity. If human
14 capital is (even indirectly) captured by the tenured status (for example, researchers with
15 more experience should have reached their tenured position), then a correlation
16 between the proportion of tenured researchers and the department's results should be
17 expected.
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19 The analysis did not find evidence of a statistical influence of this factor on research
20 efficiency (the value of the H statistic is 0.16 and the related p-value is >0.6).
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23 4.2.5. *Fifth external factor: can departments' "longevity" affect research efficiency?*

24 Finally, the possible effects due to the longevity of departments was examined. As
25 inputs were measured as numbers of academic staff and laboratories/facilities, it is
26 reasonable that older departments accumulated higher stocks of inputs that could
27 influence their outputs.
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29 A key assumption here is that older departments can favour more cohesion among its
30 members, facilitating the climate of collaboration and common motivation, which
31 enhances research productivity.
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33 Another interesting point of view about this potential phenomenon is that it is related
34 to the "critical mass" dimension. Among the economic aspects of research, Hare &
35 Wyatt (1992) underlined that the ability in producing research relies upon the human
36 capital accumulated by the individual researchers; thus:
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38 combining this process with the notion that there are economies of scale in
39 research may dispose university departments to feel they need to have at least
40 some critical mass of researchers working in the same area in order to function
41 properly as research units. (Hare & Wyatt, 1992, pp. 55–56)
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Consequently, it could be reasonable to assume that older departments are more likely to have reached such “optimal” scale dimension than the more recently established ones.

The statistical analysis did not provide statistically robust results on this effect, indeed the value of the H statistic is 1.172, while the critical value is around 3.8, so that the p-value is 0.27).

To sum up, the empirical analysis suggests that none of these factors (location in metropolitan area, scientific sector, university effect, proportion of tenured academic staff, departments “longevity”) is able to adequately explain efficiency differentials. This result should be considered as positive, especially when thinking to the use of efficiency scores for policy purposes (for example, resources allocation). Indeed, a usual criticism of the efficiency analyses is that they provide results which are affected by factors that are not under the control of the units themselves: when this is the case, a procedure of resource allocation following efficiency results would be inequitable. At the same time, it could be possible that there are some elements that could influence efficiency and that are related to some “soft” characteristics of the academic units, typically (i) the incentive systems and (ii) the governance/management. For instance, the perception of the academic staff about the importance of publications for their career. Rodgers & Neri (2007) suggested that the “departmental environment” is important and they define it through several measures centred on the “human capital” of researchers who work in the department. Unfortunately, the QuESTIO dataset does not collect such data: an extension of this dataset along this dimension could help to improve significantly the understanding of this pattern.

The governance/management of the academic departments has not been analysed in the study, as the only information available in this respect (the presence of a quality system or a management control system) is a very indirect measure of the governance process and the data recovery on this topic was quite imprecise. Another way to improve the QuESTIO dataset should be to better investigate this dimension, by including some qualitative descriptions about the way department managers organise and coordinate the activities and resources, formulate strategies and foresight studies and manage networking activities (Sala *et al.*, forthcoming; Salerno *et al.*, 2008). Without knowing the characteristics of the “management style” of each department, it

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3 is impossible to derive policy implications from such dimension. At the same time, a
4 possible way to better understand the potential incidence of such phenomenon is to
5 conduct case studies about the successful academic departments (for example, those
6 with higher efficiency scores or those that substantially improved scores in recent
7 years).

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12 A potential candidate to analyse the efficiency differentials is the interaction between
13 research and teaching activities conducted by the departments. Typically, the
14 literature did not pay enough attention to the interaction between teaching and
15 research at department level, mainly because both activities were considered as inputs
16 and outputs (see section 2). In this paper, the focus was exclusively on the research
17 activities but it raises also questions about the effects that the (unmeasured) teaching
18 activities play on the research result. This issue is very relevant both in theoretical
19 terms (are there economies of scope, or tradeoffs, between the two activities?) and in
20 empirical ones (which is the optimal allocation of energies between teaching and
21 research?). This interesting issue was at the centre of several contributions since the
22 seminal paper by Cohn *et al.* (1989) that, for the first time, addressed and modelled
23 the multi-outputs nature of academic activities. Recently, the theme has been explored
24 by Bonaccorsi & Daraio (2007) for a sample of European universities. In the present
25 paper, this topic has not been explored because QuESTIO dataset does not record data
26 about the teaching dimension of the departments' activities (as before, it could
27 represent a substantial improvement of the dataset).

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40 Finally, the issue of research quality still remains open. Indeed, the analysis is focused
41 only on a quantitative dimension of research, while quality is important to adequately
42 assess the performance. Typically the lack of data on this respect justifies the scarce
43 attention to this problem. However, the QuESTIO dataset will, in future, include some
44 qualitative indicators, like H and citation indexes. Attention will be devoted to this
45 topic in future research, also exploring trade-offs between research quantity and
46 quality.
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References

Abbott, M., Doucouliagos, C., (2003), The Efficiency of Australian Universities: a Data Envelopment Analysis, *Economics of Education Review*, 22(1), pp. 89–97.

Agasisti, T., (2009), Market Forces and Competition in University Systems: Theoretical Reflections and Empirical Evidence from Italy, *International Review of Applied Economics*, 23(4), pp. 463–483.

Agasisti, T., Dal Bianco, A., (2006), Data Envelopment Analysis of the Italian University System: Theoretical Issues and Policy Implications, *International Journal of Business Performance Management*, 8(4), pp. 344–367.

Agasisti, T., Dal Bianco, A., (2009), Reforming the University Sector: Effects on Teaching Efficiency. Evidence from Italy, *Higher Education*, 57(4), pp. 477–498.

Agasisti, T., Salerno, C., (2007), Assessing the cost efficiency of Italian universities, *Education Economics*, 15(4), pp. 455–471.

Athanassopoulos, A.D., Shale, E., (1997), Assessing the Comparative Efficiency of Higher Education Institutions in the UK by Means of Data Envelopment Analysis, *Education Economics*, 5(2), pp. 117–134.

Avkiran, N.K., (2001), Investigating Technical and Scale Efficiencies of Australian Universities Through Data Envelopment Analysis, *Socio-Economic Planning Sciences*, 35(1), pp. 57–80.

Banker, R. D., Charnes, A., Cooper, W., (1984), Models for Estimation of Technical and Scale Inefficiencies in Data Envelopment Analysis, *Management Science*, 30, pp. 1078–1092.

Bonaccorsi, A., Daraio, C., (2007), *Universities and strategic knowledge creation*, (Cheltenham, Edward Elgar Publisher).

Bonaccorsi, A., Daraio, C., Simar, L., (2006), Advanced indicators of productivity of universities. An application of robust nonparametric methods to Italian data, *Scientometrics*, 66(2), pp. 389–410.

Brennan, J., Teichler U., (2008), The future of higher education and of higher education Research, *Higher Education*, 56, pp. 259–264.

1
2
3 Charnes, A., Cooper, W.W., Rhodes, E. (1978) Measuring the efficiency of decision
4 making units, *European Journal of Operational Research*, 2, pp. 429–444.

5
6
7 Clark, B., (1998), *Creating Entrepreneurial Universities: Organizational Pathways of*
8 *Transformation, Issues in Higher Education* (Elsevier Science, New York).

9
10
11 Cohn, E., Rhine, S.L.W., Santos, M.C. (1989), Institutions of higher education as
12 multi-product firms: economies of scale and scope, *Review of Economics and*
13 *Statistics*, 71, pp. 284–290.

14
15
16
17 Cooke P., Uranga M. G., Etxebarria G. (1997) Regional Innovation Systems:
18 Institutional and organisational dimensions, *Research Policy*, 26, pp. 475–491.

19
20
21 Cooper, W.W., Seiford L.M., Tone K., (2006), *Introduction to Data Envelopment*
22 *Analysis and Its Uses* (Springer, New York).

23
24
25
26 Curran, P.J., (2000), Competition in UK Higher Education: competitive advantage in
27 the Research Assessment Exercise and Porter's diamond, *Higher Education*
28 *Quarterly*, 54(4), pp. 386–410.

29
30
31 Daraio, C., Simar L., (2005), Introducing environmental variables in nonparametric
32 frontier models: a probabilistic approach, *Journal of Productivity Analysis*, 24(1), pp.
33 93–121.

34
35
36
37 Etzkowitz, H., (2003), Research groups as 'quasi-firms': the invention of the
38 entrepreneurial university, *Research Policy*, 32(1), pp. 109–121.

39
40
41 Faria, J.R., Scientific, business and political networks in academia, *Research in*
42 *Economics*, 56(1), 187-198.

43
44
45 Flagg, A.T., Allen, D.O., Field, K., Thurlow, T.W., (2004), Measuring the Efficiency
46 of British Universities: a Multi-Period Data Envelopment Analysis, *Education*
47 *Economics*, 12(3), pp. 231–249.

48
49
50
51 Gimenez, V.M., Martinez, J.L., (2006), Cost efficiency in the university: a
52 departmental evaluation model, *Economics of Education Review*, 25, pp. 543–553.

53
54
55 Hare, P., Wyatt, G., (1992), Economics of academic research and its implications for
56 higher education, *Oxford Review of Economic Policy*, 8(2), pp. 48–66.

57
58
59 Hood, C. (1991), A public management for all seasons? *Public Administration*, 69,
60 pp. 3–19.

1
2
3 Hood, C. (1995), The new public management in the 1980s: Variations on a theme.
4 *Accounting Organizations and Society*, 20(2/3), pp. 93–110.

7
8
9
10
11
12
13
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44
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49
50
51
52
53
54
55
56
57
58
59
60
Johnes, G., Johnes, J., (1993), Measuring the Research Performance of UK
Economics Departments: an Application of Data Envelopment Analysis, *Oxford
Economic Papers*, 45, pp. 332–347.

Johnes, G., Johnes, J., (1995), Research Funding and Performance in UK University
Departments of Economics: A Frontier Analysis, *Economics of Education Review*,
14(3), pp. 301–314.

Johnes, J., (2004), *Efficiency Measurement*, in Johnes, G., Johnes, J., (eds),
International Handbook on the Economics of Education (Edward Elgar Publishing
Ltd, Cheltenham).

Kocher, M.G., Luptàcik, M., Sutter, M., (2006), Measuring Productivity of Research
in Economics. A Cross-Country Study Using DEA, *Socio-Economic Planning
Sciences*, 40, pp. 314–332.

Koksal, G., Nalcaci, B., (2006), The relative efficiency of departments at a Turkish
engineering college: a data envelopment analysis, *Higher Education*, 51(1), pp. 173–
289.

Kruskal, W.H, Wallis, W.A., (1952), Use of ranks in one-criterion variance analysis,
Journal of the American Statistical Association, 47(260), pp. 583–621.

Landoni, P., Verganti, R., (2006), Fostering Knowledge and Technology Transfer
through evaluation systems at a regional level, *International Journal of Technology
Transfer and Commercialisation*, 5(4), pp. 355–372.

Lechner C., Dowling M. (1999) The Evolution of Industrial Districts and Regional
Networks: The Case of the Biotechnology Region Munich/Martinsried, *Journal of
Management and Governance*, 3, pp. 309–338.

Levin, H.M., (1991), Raising productivity in higher education, *Journal of Higher
Education*, 62(3), pp. 242–262.

Madden, G., Savage, S., Kemp, S., (1997), Measuring public sector efficiency: a
study of economics departments at Australian universities, *Education Economics*,
5(2), pp. 153–167.

1
2
3 Marinova, D., Newman, P., (2008), The changing research funding regime in
4 Australia and academic productivity, *Mathematics and Computers in Simulation*
5 78(2-3), pp. 283–291.
6
7

8
9 McMillan, M.L., Datta, D., (1998), The Relative Efficiencies of Canadian
10 Universities: A DEA Perspective, *Canadian Public Policy*, 24(4), pp. 485–511.
11

12
13 Moreno, A.A., Tadejali, R., (2002), Assessing Academic Department Efficiency at a
14 Public University, *Managerial and Decision Economics*, 23, pp. 385–397.
15

16
17 Ng, Y.C., Li, S.K., (2000), Measuring the Research Performance of Chinese Higher
18 Education Institutions: An Application of Data Envelopment Analysis, *Education*
19 *Economics*, 8(2), pp. 139–156.
20
21

22
23 Organisation for Economic Co-operation and Development (OECD), (2002),
24 *Proposed Standard Practise for Surveys of Research and Experimental Development*
25 *- Frascati Manual, sixth edition* (Paris, OECD).
26
27

28
29 Organisation for Economic Co-operation and Development (OECD), (2003),
30 *Education policy analysis* (Paris, OECD).
31

32
33 Pesenti, R., Ukovich, W., (1996), *Evaluating Academic Activities Using DEA*,
34 Internal Report (Trieste, DEEI, Università di Trieste).
35

36
37 Porter M.E. (1998) *Clusters and the New Economics of Competition*, (Boston,
38 Harvard Business School Press).
39

40
41 Rizzi, D., (1999), L'efficienza dei dipartimenti dell'Università Cà Foscari di Venezia
42 via DEA e DFA (The efficiency of departments at University Cà Foscari through
43 DEA and DFA), *Working Paper, Università Cà Foscari di Venezia, Dipartimento di*
44 *Scienze Economiche*.
45
46
47

48
49 Rodgers, J. R., Neri, F., (2007), Research Productivity of Australian Academic
50 Economists: Human-Capital and Fixed Effects, *Australian Economic Papers*, 41(6),
51 pp. 67–87.
52

53
54 Sala A., Landoni P., Verganti R., (forthcoming) "R&D networks: an evaluation
55 framework" *International Journal of Technology Management*.
56
57
58
59
60

1
2
3 Salerno M., Landoni P., Verganti R. (2008), Designing foresight studies for
4 Nanoscience and Nanotechnology (NST) future developments, *Technological*
5 *Forecasting & Social Change*, 75(8), pp. 1202–1223.
6
7

8
9 Sarrico, C.S., Dyson, R.G., (2004), Restricting virtual weights in data envelopment
10 analysis, *European Journal of Operational Research*, 159(1), pp. 17–34.
11

12
13 Sarrico, C.S., Teixeira, P.N., Rosa, M.J., Cardoso, M.F., (2009), Subject mix and
14 productivity in Portuguese universities, *European Journal of Operational Research*,
15 197(2), pp. 287–295.
16
17

18
19 Thursby, J.G., (2000), What Do We Say about Ourselves and What Does It Mean?
20 Yet Another Look at Economics Department Research, *Journal of Economic*
21 *Literature*, 38, pp. 383–404.
22
23

24
25 Warning, S., (2004), Performance Differences in German Higher Education:
26 Empirical Analysis of Strategic Groups, *Review of Industrial Organization*, 24, pp.
27 393–408.
28
29

30
31 Zhu, J., (2003), *Quantitative Models for Performance Evaluation and Benchmarking*,
32 (Kluwer Academic Publisher, Boston, MA).
33
34
35
36
37
38
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Table 1. Inputs/outputs descriptive statistics

	<i>Mean</i>	<i>Standard deviation</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Average difference 2004–2007</i>
Laboratories (m ²)	2,243.83	6,917.93	0.00	60180.00	80.24
Human resources (n)	105.50	83.30	9.00	445.00	16.19
High Qualified Human resources (n)	98.33	79.66	8.00	434.00	16.00
Other personnel (n)	7.12	6.83	0.00	32.00	-0.30
Revenues from financed activities (€)	486936.06	557412.78	0.00	3039361.00	142196.00
Financed activities from abroad (€)	118587.58	256766.37	0.00	1805922.00	10896.00
Revenues from orders (€)	451240.13	764559.23	0.00	3333362.00	86950.00
Number of publications (n)	32.45	31.91	0.00	188.00	2.87
Doctorates in cooperation with external bodies (n)	2.49	4.04	0.00	22.00	0.63

Table 2. Efficiency scores (DEA on 2007 data) – descriptive statistics

	<i>CRS Efficiency</i>	<i>VRS Efficiency</i>	<i>Scale Efficiency</i>
Mean	0.745	0.786	0.937
St. Deviation	0.241	0.219	0.101
Min	0.173	0.216	0.432
Max	1.000	1.000	1.000
# efficient units	25	29	25

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 3. Malmquist index 2004-2007 – descriptive statistics

<i>Department</i>	<i>Malmquist index</i>	<i>Efficiency change</i>	<i>Frontier shift</i>
Mean	1.060	1.666	0.652
St. dev.	0.492	0.882	0.141
Min	0.072	0.529	0.104
Max	2.534	4.600	1.031
# improving units	35	56	2

Source: authors' elaborations on QuESTIO data, Lombardy Region and IRER.

Table 4. Factors affecting efficiency (Kruskal-Wallis analysis)

<i>Effects of Metropolitan area (Milan)</i>	
H (observed value)	0.007
H (critic value)	3.481
p-value	0.934
<i>Effects of subject mix</i>	
H (observed value)	8.451
H (critic value)	9.488
p-value	0.076
<i>University effects</i>	
H (observed value)	9.426
H (critic value)	14.067
p-value	0.224
<i>Effects of tenured staff proportion</i>	
H (observed value)	0.163
H (critic value)	3.841
p-value	0.687
<i>Effects of departments' age</i>	
H (observed value)	1.172
H (critic value)	3.841
p-value	0.279