On the Determinants of Academic Research Efficiency

Literature Analysis and Future Research Perspectives

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Abstract

What is academic research efficiency and what determines the differences between scholars' academic research efficiency? The literature on this topic has evolved exponentially during the last decades. However, the divergence of the approaches used, the differences in the bundles of outputs and inputs considered to estimate the efficiency frontiers, and the differences in the predictors of efficiency variability among scholars that are considered in prior studies, make it interesting to have an overview of the literature dedicated to this topic. Relying on a systematic review of empirical studies published between 1990 and 2012, this article proposes and discusses a framework which brings together a set of outputs and inputs related to academic research efficiency, and the individual, organizational, and contextual factors driving or hampering it. The ensuing results highlight several avenues, which would help university administrators and policy- makers to better foster academic research efficiency, and researchers to better channel their efforts in studying the phenomenon.

Keywords: Management of science; Efficiency; DEA; Stochastic programming.

Introduction

Debate is still ongoing regarding the assessment of the academic production of researchers. However, given the non-priced nature of many researchers' outputs and inputs, this performance measurement is still largely dominated by the Bibliometric evaluation which refers to the set of procedures for evaluating the scientific production of a researcher (or a set of researchers) from the count of his publications, the prestige of the journals in which they were published, and citations they generate. Among other things, these indicators have been and are still widely used by administrators of universities, developed and applied by peers in the individual assessment of researchers for promotions, distinctions, prizes, contracts, and research grants, and to track networks of collaboration among researchers through the counting of multi-authored articles [1,2,3].

However, and despite their relevancy, many authors claim that these indicators have to be contextualized in relation to the discipline of the researchers, their career stage, their ability to acquire new funds, the intensity of their interactions with partners outside the scientific community, etc. [4]. These data are not available in bibliometric databases and could be obtained only by questioning directly the researcher. In addition, bibliometric indicators do not measure productivity or the quality of a researcher, but only his contributions and his citations, without trying to identify the reasons that led him to publish or to be cited, nor the resources engaged to produce research. Moreover, they little inform us about the determinants that explain gaps of research production among academics [5,6,7,8,9].

These limits have spurred a parallel research stream in the literature concerned by the assessment of the technical efficiency of academic researchers. Intuitively, within education settings, technical efficiency is a measure of the extent to which institutions, (universities, researchers, research centers, etc.) efficiently allocate the physical inputs at their disposal for a given level of output. In other words, technical efficiency refers to the use of productive resources in the most technologically efficient manner.

This stream is characterized by the use of approaches that define efficiency in terms of the units of analysis (universities, departments, faculties, countries, researchers, etc.) which use the least inputs to produce a given level of output or alternatively produce the most output for a given bundle of inputs. The efficiency of other units of analysis in the sample is defined relative to these best performers [10, 11,12]. For a researcher, for example, his efficiency is measured according to his ability to perform more or less compared to his colleagues who are in comparable conditions. The contextualization and taking into account of other factors to assess the performance of researchers are also at the heart of these approaches [13,14].

Thus, several reasons are fulfilled to motivate the study of the efficiency of academic research. More specifically, we will use a systematic review of the literature method to study the foundation of these approaches, their main concepts and methods that they put forward to measure and to assess academic research. Indeed, we propose to realize a systematic review of empirical articles published between 1990 and 2012 on the efficiency of academic research in the higher education sector. We aim to identify and to synthesize all the existing high-quality evidence using transparent and reproducible methods to give the best statements about what is known. The systematic review will allow answering the following questions: 1) What are the bundles of inputs and outputs used in the academic research production frontier literature?; 2) What approaches and empirical techniques are used in the literature to measure the efficiency of academic research?; 3) What are the determinants that explain the differences in efficiency among academic research units of production?

This research is original in many respects. Firstly, to our knowledge, this is the first systematic review on academic research efficiency. Secondly, it will identify and integrate the findings of all available studies on this topic in order to enhance our understanding of the empirical steps in measuring academic research efficiency. Thirdly, this study will allow building an integrative and evidence-based framework that brings together sets of outputs and inputs related to academic research efficiency, as well as the individual, organizational, and contextual factors that may explain the differences in Decision-Making Units' (DMUs) efficiency levels. This is in line with the growing field of applications that involves the measurement of efficiency of DMUs, units of production of academic research in our case. Indeed, it is more and more accepted that DMUs should not only refer to firms or units of production, but should also refer to persons, countries, public institutions, projects. Finally, for researchers, university administrators, and national policy-makers, this research will identify several levers on which it is possible to act to improve the level of efficiency of academic research.

The rest of this article is organized as follows. Firstly, we will explain in more details the objective and scope of our study (Section 1). Secondly, we will describe the method of systematic review of literature used to locate, select, analyze, and synthetize the relevant literature (Section 2). Thirdly, we will present some general features of the reviewed studies (Section 3). Fourthly, we will then present the results of our review (Section 4). Finally, we will conclude with the highlights of the main results of this study.

1. Objective and scope of the study

This study consists of a systematic review of empirical articles published in scholarly journals between 1990 and 2012 on the topic of the technical efficiency of academic research. More specifically, the main goal of this article is twofold: (1) to study how the variable 'efficiency' was approached and measured by the authors; and (2) to identify the determinants that may explain the differences in efficiency between the different research production units (university, research center, researcher, organization, etc.).

For several decades, the study of efficiency was limited to economic organizations, especially firms. It is only from the mid-80s that this type of study has been expanded to other fields of activity (entrepreneurship, health sector, sports management, higher education, etc.). This was possible, mainly, due to the emergence of certain techniques estimating the efficiency frontier that are more flexible than the techniques involving the specification *a priori* of functional forms that are marked by many economic assumptions. Thus, we chose 1990 as the lower limit of the temporal horizon of our study. We think that covering a period of more than 20 years, starting in 1990, will allow us to better focus on the more relevant, insightful, and up-to-date contributions the on measurement of academic efficiency.

Applying a systematic review methodology to technical efficiency in academic research production offers new opportunities and challenges. In order to analyze the extent of knowledge on academic research efficiency and to generate a comprehensive classification of inputs, outputs, and the determinants of efficiency, we followed an established research procedure for a systematic literature review [see, e.g. 15]. The research design, research process, and relationship between the analysis and outcomes are presented in the following sections.

2. Methods

In this paper, we used a systematic literature review method. This method has a clear protocol for systematically searching defined databases over a defined time period, with transparent criteria for the inclusion or exclusion of studies as well as the analysis and reporting of study findings [16,17,18]. This method uses a rigorous, replicable, scientific, and transparent process, carries out exhaustive searches, adopts a consistent approach to combining information across different studies, and produces a clear statement of the findings of the review [19,20]. It attempts to identify the best available evidence to answer specific questions, establish explicit criteria for including or excluding studies, based on the scope of the review. Applying the principles of the systematic review will then help to limit bias (systematic errors), reduce chance effects, enhance the legitimacy and authority of the ensuing evidence, and provide more reliable results upon which to draw conclusions and make decisions [21,22,23].

The stages in carrying out a systematic review: 1) formulating an explicit research question; 2) establishment of the criteria of inclusion and exclusion; 3) identifying relevant studies; 4) evaluation and selection of the studies; 5) summarizing and synthesizing study results. In addition, this method is characterized by many feedbacks and feed forward loops where researchers can adjust or change elements or results.

2.1. The inclusion/exclusion criteria

Six criteria were used to select and assess the potential studies. To be included in our systematic review, a study had:

1. to deal with the technical efficiency of academic research;
2. to estimate a parametric or a non-parametric frontier of efficiency of academic research;
3. to be an article published between January 1990 and December 2012 inclusively in a peer-review journal classified A*, A, B, or C by The Australian Business Deans Council (ABDC). Thus, other publication forms (conference proceedings, books, newspaper articles,

unpublished works, etc.) were not considered. Moreover, to ensure an acceptable level of quality, the articles published in journals ranked D by the ABDC ranking were excluded;

4. to include an empirical study of a sample of institutional (universities; faculties; departments; research centers; etc.) or individual academic researchers. Theoretical and conceptual studies, as well as case studies, were not retained. However, we did not restrict the data analysis method used by the authors—both descriptive statistics and econometric methods were included;
5. to consider academic research technical efficiency as the dependent variable (i.e., the variable to be explained). Consequently, articles which considered technical efficiency as an independent variable (i.e., an explanatory variable of another phenomenon like institution of higher education performance, productivity, etc.) were not included;
6. and finally, to explicitly propose a conceptual and/or operational definition of efficiency.

2.2. Data sources and search strategy

Our search strategy involved six separate search activities, namely, (1) a search for the most relevant keywords; (2) a snowballing search; (3) an electronic database search; (4) a screening and hand-search in selected electronic journals; (5) a hand-search in the lists of references of selected electronic articles; and (6) the contact of experts.

Before developing our search strategy, a specialist librarian in documentary research in administrative sciences was contacted to advise us about the most relevant databases on the topics of our study. Petticrew and Roberts [17] argued that given the problems in searching social science literature, reference snowballing is very relevant. Indeed, to identify studies quickly, we conducted snowballing initially, prior to electronic database searching. Snowballing includes both bibliographic, back-referencing (reviewing references of included studies) and citation tracking (reviewing references in which the included study has been cited). Having a few key relevant papers at hand before searching was very helpful to construct our initial keyword chain. Relevant databases (see Table 1) were searched for published articles using chains of keywords in various combinations using the Boolean operators 'AND' and 'OR' (see Appendix 1). After that, we performed a systematic hand-search of all issues of selected key journals to identify additional relevant articles that had not been identified via the electronic search strategy. The most important journals were selected according to the results of the first phase across a manual search made within volumes published between January 1990 and December 2012, namely: *Higher Education* (1621 articles); *Research Policy* (2241 articles); *Omega: the International Journal of Management Science* (1590 articles); *Education Economics* (390 articles). The fourth component of our localization strategy of documents was that of expert contacts. The most prominent authors of the literature selected in the first phase were contacted by email (of 8 authors selected, three responded). Hence, 10 documents were subsequently added. By so doing, we identified 16 676 potential articles for our systematic review.

Table 1
Results of electronic databases search

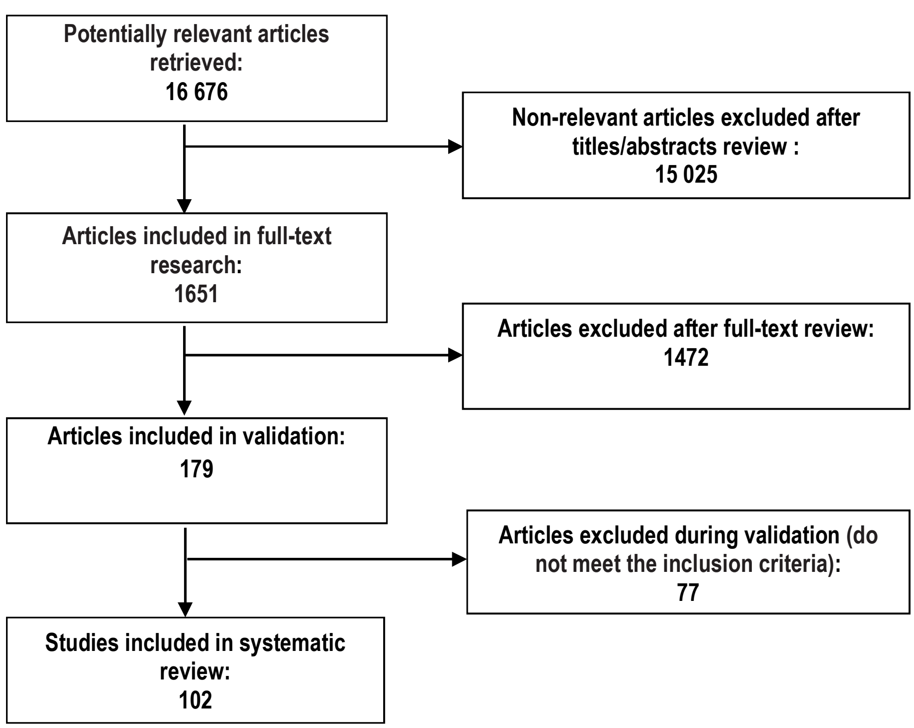
DATABASES	DOCUMENTS IDENTIFIED	DUPLICATES	UNIQUE DOCUMENTS
ISI Web of Science	9314	-	9314
ProQuest/ABI/INFORM Complete	1576	414	1162
EBESCO/Academic Search Premier	3038	199	2839
EBESCO/Business Source Complete	1975	468	1507

Science Direct	924	151	773
Econolit	334	136	198
Eric	930	244	686
Total	**18 091**	**1612**	**16 479**

2.3. Selection and data extraction

The selected articles were subjected to a triple screening process (Fig 1). A first sorting of the articles' title and summary allowed us to exclude 15 052 papers which did not meet the inclusion criteria. The main reasons for rejection where: 1) the article did not assess academic efficiency; 2) the article did not consider research among the portfolio of activities under investigation; 3) the article used bibliometric metrics without estimating a parametric or non-parametric efficiency frontier; and 4) the unit of analysis was outside the academic world (private laboratories, R&D activities, national systems of innovation, etc.). Therefore, 1651 articles were maintained.

The second screening went beyond the title and summary into the main body of the articles and led us to exclude another 1472 articles that did not sufficiently focus on the technical efficiency of academic production. Finally, among the 179 articles remaining after the second screening, 77 were discarded because they did not consider academic efficiency as a dependent variable or did not explicitly estimate a frontier of efficiency (parametric or non-parametric). As a result of this 3-step strategy, 102 articles which matched all the inclusion criteria were ultimately selected for thorough content analysis[1].



[1] The list of analyzed articles selected in the systematic review is available from the authors on request.

Fig. 1. Systematic review flow diagram

Detailed results of the selection process of the articles by type of strategy of localization (i.e., electronic, manual, and expert contact) are presented in Table 2. It appears that the electronic database search helped identify about 91.17% of the articles included in the analysis, while the manual search and contacts of experts provided, respectively, 6.86% and 1.96% of the documents included in the systematic review. This corroborates the recommendations of several experts in the method of systematic reviews, including McManus et al. [24], advocating that electronic research must be supplemented by other techniques of documentary research in order to ensure a greater comprehensiveness of the selection strategy of documents.

Table 2
Data sources and studies' selection

DATABASES	ELECTRONIC SEARCH	MANUAL SEARCH	CONTACT EXPERT	TOTAL
Articles identified	16479	187	10	**16676**
First sorting	1623	51	4	**1678**
Second sorting	93(91.17 %)	7(6.86 %)	2(1.96 %)	**102**

3. General characteristics of the included studies

The examination of the 102 articles included in our systematic review brought out a wide range of issues related to efficiency and its explanatory factors. In this section, we will present some general features of the reviewed studies.

The distribution of the reviewed articles per publication year shows that 2006 was an outstanding date for research on academic efficiency (Fig. 2). Beginning with a very limited number of articles per year for the period 1990-2005, the rate of published articles on the topic of technical efficiency of the academic research production sector has increased remarkably since 2006 to reach an average of over 8 articles per year for the period 2006-2012, with three peaks in 2006 (11 articles), 2011 (11 articles), and 2012 (10 articles). Moreover, European Higher Education Institutions (HEIs) are the most often studied, followed by China and, to a lesser degree, North American research institutions. This publication trend may be explained by the series of research assessment exercises undertaken in many European countries, especially in the UK, during the last two decades [25]. Such research assessments inform the selective allocation of funds for research by the higher education funding bodies in these countries. They provide accountability for public investment in research and produce evidence of the benefits of this investment [26,27,28].

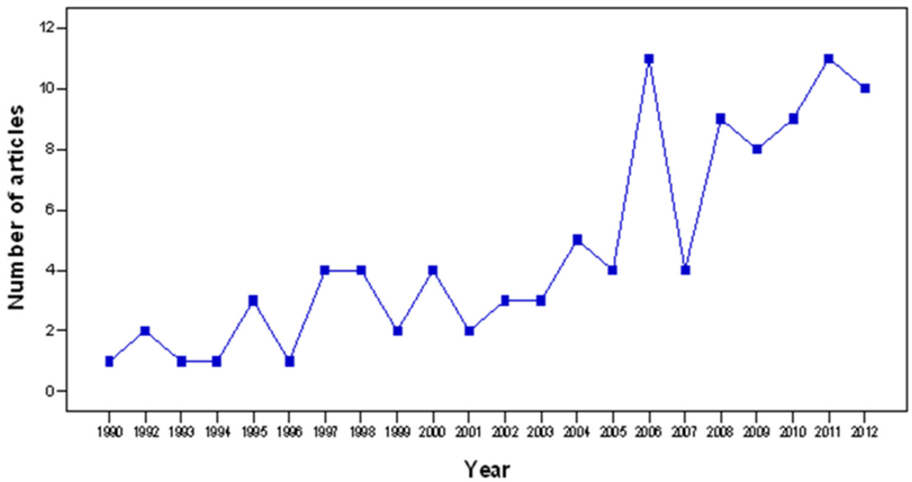


Fig.2. Publication trend

Trends of units of analysis

Figure 3 shows the distribution of articles according to the unit of analysis. We can see that university is the most studied unit of analysis (52.94% or 54 articles out of 102 articles) [e.g. 29,30,10, 31], followed by department (31,37% or 32 articles out of 102 articles) [e.g. 32,33,11], and research centers (4.9% or 5 articles out of 102 articles) [e.g. 34,35,36]. At the other extreme, we found faculties (0.98% or 1 article out of 102 articles) [e.g. 37], research programs (2.94% or 3 articles out of 102 for each case) [e.g. 38,39], and studies dedicated to the comparison of countries represent 3.92% or 4 articles out of 102 articles [e.g. 39,40].

These results show that no empirical evidence has yet been available for the efficiency of individual researchers as measured by the frontier analysis approaches. Many scholars recognized that the study of academic efficiency at the individual level is very challenging [41,13,42], because it needs a two-stage data collection procedure. Indeed, for outputs (number of contributions, number of citations, Hirsch's h index, etc.), we need to collect metrics compiled by databases such as Web of Science of the Social Sciences Citations Index (SSCI) of the Thomson ISI, Scopus, Google Scholar, whereas for inputs (e.g., academic staff, research funds, facilities and laboratories) and determinants of efficiency (e.g., social capital, seniority, composition of staff and agglomeration effects), we need to conduct surveys with samples of researchers [43].

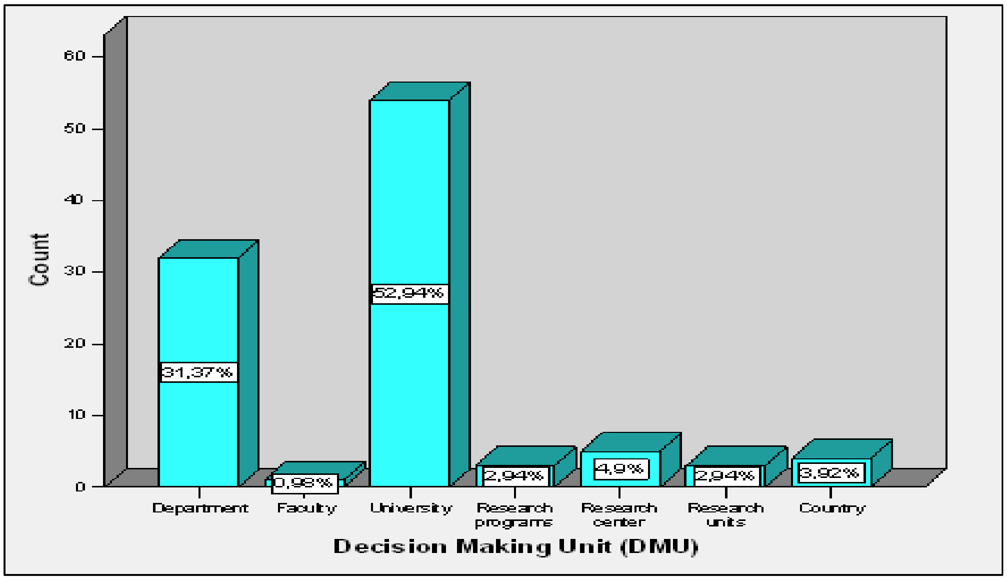


Fig. 3. Distribution of the articles by units of analysis

Explanation of efficiency differences

As can be seen in Figure 4, almost two-thirds of the articles selected in our systematic review used DEA to determine the efficiency frontier (69 articles out of 102 articles). As this approach is deterministic, it is limited to determine efficiency scores without allowing for the identification of the determinants of efficiency gaps between the DMUs. Indeed, DEA produces a single comprehensive measure of performance (efficiency score) for each DMU. This is done by constructing an empirical best practice or efficient frontier as a result of identifying a set of efficient DMUs (on the efficient frontier) and inefficient DMUs (not on the efficient frontier).

Figure 4 also shows that the two-step procedure was used in 27.45% of cases (28 articles out of 102 articles). This procedure evaluates, for each DMU, the relative efficiency in the first stage, and then regresses, in the second stage, the efficiency scores against a set of explanatory variables of variations of these efficiency scores. In this category, 4 articles out of 28 [44,11,39] opted for a two-step approach that uses a bootstrap procedure derived from the work of Simar and Wilson [45].

These authors contended that the DEA efficiency estimates are biased and serially correlated, which invalidates conventional inference in two-stage approaches. To overcome this shortcoming, they proposed a procedure, based on a double bootstrap, that enables consistent inference within models explaining efficiency scores while simultaneously producing standard errors and confidence intervals for these efficiency scores.

Finally, few studies (4.9% or 5 articles out of 102) used the one-step approach to estimate a stochastic parametric frontier [46,47]. This approach estimates, simultaneously, the frontier of efficiency and the explanatory factors that potentially affect efficiency scores. Among the five articles using this approach, four used a stochastic frontier [25,48,10]. The fifth used a new technique proposed by Bonaccorsi et al. [13]. This technique introduces conditional measures of efficiency to take into account external factors and decomposes the indicators of productivity accordingly.

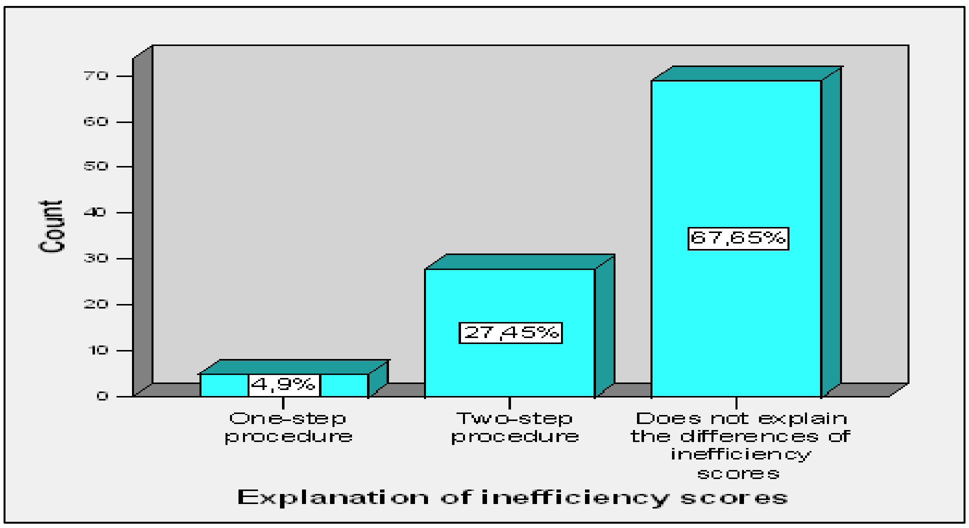


Fig. 4. Distribution of the article by procedure of explanation of efficiencies differences

4. Findings

In this section, we will discuss the empirical steps in measuring and analyzing academic research efficiency and classification of inputs, outputs, and determinants of academic research efficiency used in the 102 selected articles of our systematic review, and finish with the study of dominant effects to explain differences in efficiency of academic research.

4.1. Empirical steps in measuring and analyzing academic research efficiency

Despite their dissimilar contexts and techniques, the empirical studies selected in our systematic review generally share a common three successive-step procedure that determines: 1) the choice of frontier efficiency measurement approach; 2) the specification of outputs and inputs; and 3) the method used to explain the efficiency differences and the factors thought to be responsible for these differences. This process will be used as a framework to present the analytical results that emerge from the in-depth analysis of the articles selected in our systematic review.

Step 1: Choice of efficiency measurement approach

In the empirical literature on efficiency measurement, there are two major approaches which are distinguished with regard to two features: whether the approach is parametric or not, and whether it is deterministic or stochastic. Parametric methods assume a specific functional form for the frontier whereas non-parametric methods do not; and deterministic methods attribute the distance of a given DMU from its frontier to inefficiency whereas stochastic methods assume that some of it is due to random error. Two techniques are commonly used to estimate a production frontier: 1) *the mathematical programming approach* that allows the construction of a non-parametric piece-wise-linear convex best practice frontier constructed as such that no observed point should lie outside it. The most commonly employed version of this approach is a linear programming non-parametric tool referred to as data envelopment analysis (DEA) [42,45]. DEA is a deterministic method in that the entire deviation from the frontier is assessed as being the result of inefficiency; or 2) *the econometric approach* that consists of a parametric function fitted to the data as such that no observed point should lie outside. Thus the econometric approach allows to estimate a stochastic frontier function that introduces a disturbance term encompassing all events outside the control of the DMU, including both uncontrollable factors directly concerned with the actual production function (such as differences in operating environments) and econometric errors (such as misspecification of the production function and measurement error). This, in turn, permits the decomposition of deviations from the efficient frontier into two components, inefficiency and noise [49].

Selected articles in this literature review show that the use of the non-parametric approach to estimate the efficiency frontier is dominant. Indeed, 78.43% or 80 articles of 102 used data envelopment analysis (DEA) to estimate deterministic frontiers. As can be seen in Figure 4, only 16.67% or 17 articles of 102 used a parametric approach based on explicit and predetermined stochastic production, profit, or cost function. Finally, few studies (4.9% or 5 articles of 102) have used simultaneously both approaches to estimate the efficiency frontier in order to compare the efficiency scores obtained by the two approaches, which allow performing a sensitivity analysis of the efficiency scores.

Step 2: Specification of inputs and outputs

This step necessitates to define and to measure the outputs and the inputs of DMUs. As revealed by the systematic review of the literature, there is not yet a consensus regarding the outputs and inputs to be considered to determine the efficiency of the production of research units.

Accurately measuring research activity outputs and inputs is extremely difficult because they are diverse and multi-faceted. In addition, two other problems must be faced. The first one relates to the circular meaning of some core variables. This is the case, for instance, of research grants, which can be considered as a measure of research output (because they are assigned to virtuous researchers) and also as a representative of an input because they support research projects. The second issue refers to the measure of intangible aspects, which are particularly relevant in output specification. Let’s consider, for instance, the problems in evaluating the quality of research or the academic reputation [50,51,38,44]. Moreover, several other authors highlight the fact that many of the prior studies, especially those using DEA, mainly focus on the methodology of estimation of the frontier at the expense of the choice of inputs and outputs. Finally, and as advocated by many authors, the choice of outputs and inputs is often determined by the actual availability of variables at the fixed DMU level [38,13,49].

The examination of the 102 articles included in our systematic review reveals that relatively little attention has been paid to how inputs and outputs should be chosen, and to how they can be regrouped in generic categories. Therefore, to take up this challenge, we relied on the work of [52, 29,13] that we consider among the richest and most original studies identified in our systematic review that tried to justify the choice of outputs and inputs to be considered in the production process of academic research. The structure of the inputs and outputs presented in these studies has been enriched by the contributions of several other studies selected in our systematic review, including [38,35,53,12,31].

Thus, we regroup the outputs and the inputs used in the 102 articles selected in our systematic review in three groups of outputs and six groups of inputs. Indeed, the categories of outputs are *research* that encompasses the subcategories of research outputs, research productivity indices, and quality of research indicators; *teaching* that regroups two subcategories, namely teaching outputs, and quality of teaching indicators; and *entrepreneurial* that refers to entrepreneurial outputs.

Moreover, the examination of the articles selected in the systematic review showed that the multi-outputs model is largely dominant in previous work on the efficiency of academic research. This preponderance is justified, first, by the fact that all of the studies included in the systematic review focused on meso-level units (university, department, research unit, research center, etc.) or macro-level unit (country). These units generally record diverse types of research productions (articles in refereed journals, books, book chapters, quality indicators, etc.).

As for the inputs used in the studies selected in our systematic review, six categories were distinguished: firstly, *human capital* category that refers to academic staff and non-academic staff; secondly, *physical capital* category that refers to productive capital (building spaces, laboratories, etc.); thirdly, *research funds* category that encompasses budget funds and research income; fourthly, operating budget that refers to income and current expenditures; fifthly, *stock of cumulative knowledge* that regroups three sub-categories: knowledge embedded in human resources, knowledge embedded in machinery and equipment, and public involvement in R&D; sixthly, *agglomeration effects* category that refers to regional effect and entrepreneurial environment. Table of detailed definitions of inputs and outputs is available on request.

Step 3: Explaining differences in efficiency

Once the inputs and the outputs were specified, in addition, it is useful to identify the environmental variables that may explain the differences among the efficiency scores of DMUs. In this regard, the synthesis of the articles selected in the systematic review, and many other contributions from the wide literature dedicated to researchers' productivity and performance, enabled us to classify our 102 articles in three groups. However, it is important to specify that the explanatory variables identified in the latter literature were used to explain the variations of academic productivity or other research outputs, but never to explain academic inefficiency at the individual level. Our paper is the first investigation of this matter, and hence it is in some ways exploratory.

A first majority group (69 articles out of 102 articles) is composed of studies that are limited to determine the levels of efficiency of DMUs, without trying to explain the differences in efficiency between them. Such studies do not account for the impacts of either the operating environment or the statistical noise on producer performance.

A second group of studies (28 articles out of 102 articles) using DEA or econometric frontier treated the efficiency scores as the dependent variable in an auxiliary regression [19]. More specifically, these studies first estimated the frontier and predicted the efficiency of each DMU. The efficiency scores were subsequently regressed against a set of DMU-specific variables in an attempt to identify potential reasons explaining the differences in the predicted inefficiencies among DMUs. Even though this two-step procedure is likely to be informative into the causes of inefficiency, it leads to three main problems. First, DEA and SFA generate variables of efficiency scores that have limited distributions. To fill these gaps, 4 articles selected in the systematic review used bootstrap techniques in order to estimate the level of bias and the confidence interval of efficiency scores [55,12].

Finally, a third group including only 5 studies used the procedure of Battese et al. [56] that specifies a single-stage procedure allowing the estimation of DMU-level inefficiencies and the identification of efficiency determinants in one step.

Appendix 2 summarizes the findings regarding the determinants of efficiency of academic research.

4.2. Study of dominant effects to explain differences in efficiency of academic research

The method of vote counting was used to analyze the effects of the determinants of efficiency of academic research identified in our systematic review. Following Littell et al. [57], we categorized the direction of the impact of each determinant in three categories: positive effect, negative effect, and neutral effect (no difference between groups, unclear, or missing). To achieve this, the following two criteria were applied: (1) the determinant must have been included in an explanatory model of efficiency of academic research; and (2) we assumed the presence of a dominant effect of a given determinant oriented in one direction when this determinant was found significant and oriented in this direction in a proportion of 60%.

The results of the vote counting analysis reported in Table 3 and Figure 5 focused on the twelve categories of determinants displayed in Appendix 2. These twelve categories totalize 132 determinants. It can be seen that determinants from 5 of the twelve categories have a positive overall dominant effect on the efficiency of academic research. These categories are: (1) seniority and composition of staff; (2) institutional factors; (3) size effects; (4) financial structure; and (5) scientific meritocracy.

To delve further in to the analysis of vote counting, several interesting conclusions can be highlighted. Overall, it seems that the size of the institution is an important predictor of its efficiency: the higher the number of full-time equivalent student enrolment or the number of faculties, the higher the institutions' efficiency. The latter variable can also be a crude proxy for university interdisciplinarity. The importance of faculty composition also has to be taken into consideration when assessing efficiency. We found that universities with a medical/pharmacy faculty are characterized by higher efficiency. Additionally, we found that the scientific meritocracy of the academic staff, as measured by the ratio of citation over publication or by H-index, is positively associated with efficiency. Prestige and reputation of institution (as measured by the year of founding) was among the other statistically significant determinants of efficiency: younger universities seemed to be less efficient. Furthermore, the results of the vote counting show that institutional factors such as university type (autonomous/ government universities), administrative structures, existence of research councils, and regular evaluations are positively associated with efficiency. As far as location is considered, HEIs that are located in more prosperous regions (with higher GDP levels per capita) were not found to display higher efficiency levels. Finally, for the seven other determinants, namely, research fields, prestige and the reputation of the institution, gender effects, agglomeration effects, students' characteristics, protection of intellectual property, and quality indicators, we were not able to assert the presence of a dominant effect on the efficiency of academic research.

Table 3
Results of vote counting

Groups of determinants	Number of indicators	Recurrence of the significant impact			Presence of a dominant overall effect
		-	+	N.S	
Seniority and composition staff	17	2	14	1	DOE +
Institutional factors	18	2	9	7	DOE +
Size effects	29	5	11	13	DOE +
Funding structure	24	3	16	5	DOE +
Scientific meritocracy	3	-	3	-	DOE +
Search fields	4	-	2	2	DOE?
Prestige and reputation of the institution	8	1	3	4	DOE?
Gender effect	3	1	1	1	DOE?
Agglomeration effects	16	3	4	9	DOE?
Students' characteristics	9	-	5	4	DOE?
Protection of intellectual property	3	1	2	-	DOE?
Quality indicators	4	1	2	1	DOE?

NOTE: DOE : Dominant Overall Effect

5. Integrative conceptual framework of academic research efficiency

The examination of 102 articles included in our systematic review brought out a wide range of issues related to the measurement of technical efficiency and its explanatory factors. Although some inputs and outputs are more recurring in the analyzed studies, there is no clear consensus on the structure about inputs and outputs to consider in assessing the efficiency of academic research, as well as for the determinants of efficiency that may explain the differences among the efficiency scores of DMUs. To advance knowledge in this direction, and based upon the findings of our systematic review and on the vote counting analysis, we propose an integrative framework providing a comprehensive and coherent characterization of the state of knowledge in this field. This framework presented in Figure 5 brings together a set of inputs and outputs related to academic production and environmental variables driving or hampering it. We will use this framework to organize the presentation and discussion of our findings.

This framework regroups, in meaningful categories, inputs and outputs identified through the data extraction grid used as part of the systematic review, as well as the underlying determinants that have a dominant effect on the explanation of efficiency's levels of DMUs that were identified through the vote counting procedure. It is structured in two blocks. The upper block represents the production process of research linking inputs to outputs. As can be seen, the inputs are grouped into six rubrics (human capital, physical capital, research funds, operating budget, cumulative stock of knowledge, and agglomeration effects). Likewise, overall, we distinguished seven outputs (refereed articles, books, book chapters, refereed conferences, professional publications, other deliverables, and quality indicators).

The bottom block of the conceptual framework presents eleven major rubrics that regroup the explanatory variables of efficiency variations among DMUs identified in our systematic literature, and confirmed as having dominant effects, by the vote counting method: funding structure, seniority and composition of staff, gender effect, search fields, institutional factors, social capital, size, and effort to protect intellectual property. These eight sets of explanatory variables were in turn grouped in three families of variables that refer to: (1) individual attributes; (2) internal variables (i.e., specific to the DMUs); and (3) contextual variables (i.e., related to the environment where the DMU operates).

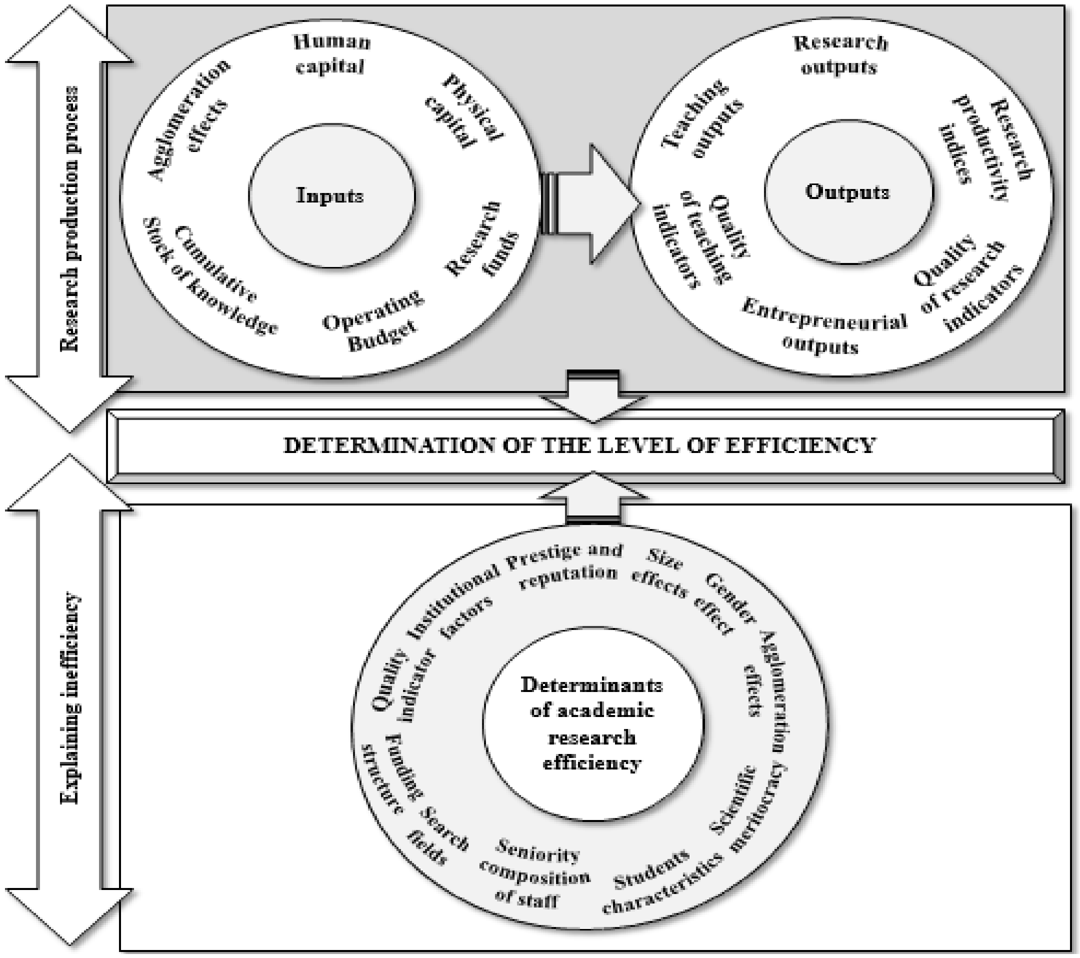


Fig. 5. Integrative conceptual framework of efficiency academic research

Conclusion

Assessing the relative performance of academic researchers is a very daunting task, which is propelled by numerous issues: great heterogeneity of contexts, divergence of the approaches used, difficulty to specify the bundles of outputs and inputs considered to estimate the efficiency frontiers, non-recurrence in prior studies of empirical evidence regarding the predictors of academic efficiency, lack of primary studies which are able to credibly address causality at the researcher's level. To document these challenges, we relied on a systematic review of empirical studies dealing with academic efficiency and published between 1990 and 2012. As advocated by many authors, a systematic review allows synthesizing information from multiple studies conducted in different contexts and across different groups of DMUs, which provides a stronger basis for generalizing findings than single studies [16,17].

As a main result of this systematic review, we edified and discussed a framework that brings together sets of inputs and outputs related to the measurement of the academic efficiency process, as well as the factors driving or hampering it.

The analysis of the articles selected in this systematic review provides a number of other results that are emphasized in the following points:

First: *The preponderance of the use of DEA*: It is explained in the consulted literature as the difficulty to specify a researcher's production function that is subject to several conceptual and measurement limits. Mainly, accurately defining and measuring the various inputs and outputs of a researcher's production function are difficult tasks [52]. This problem is reinforced by the difficulty in targeting the potential explanatory factors that may influence a researcher's ability to achieve high efficiency [49,59].

Second: *The individual researcher as the unit of analysis*: Two units of analysis were the most often studied by authors. Indeed, 85% of the articles included in our systematic review focused exclusively on the department or university as a unit of analysis. However, no study adopted the individual researchers as its unit of analysis. As mentioned previously, this might be explained by the difficulty to collect individual data on all types of inputs and outputs, as mentioned previously. This is an important issue in this research field as demonstrated by Halilem et al. [59], the results of this study showed eloquently that ‘‘despite the emerging constraints and opportunities determined by their institutional context, researchers still exist in an Ivory Tower, where the explanation of their behavior is still a matter of individual differences’’ (Halilem et al. [59, p. 431].

Third: *The systematic review showed that the multi-output model is largely dominant in previous work on the efficiency of research*: This preponderance is justified, first, by the fact that all of the studies included in the systematic review focused on meso-level units (university, department, research unit, research center, etc.) or macro (country). These analytical units generally record diverse productions (articles in refereed journals, books, book chapters, quality indicators, etc.). The systematic review also showed that in many studies, the various types of publications were combined with other indicators referring to teaching and entrepreneurship activities. This is attributed to the current context of the university, characterized by external and internal pressures to promote its entrepreneurial role [60,61].

Fourth: *The results of the systematic review revealed that researchers involved in certain fields are more productive and more cited than others*: This finding is consolidated in the scientometric literature where many authors found that among the variables that have significant impacts on academic productivity, field differences account for the strongest one [62,10,39].

Fifth: *The specification of the researcher's production function*: On the basis of the results of the systematic review, research funds and the time dedicated by the researcher to research activities emerge as two essential inputs in any study that aims to assess the researcher's academic production frontier. For outputs, publications in academic journals stand out clearly as the most reliable output to measure the scientific production of a researcher. As advocated by many authors, this indicator ensures a sufficient level of homogeneity of the researchers' outputs, which is a necessary condition for the estimation of any production function [63]. This homogeneity, however, remains sensitive to the quality of the articles [64].

Sixth: *The determinants of academic efficiency seem to be chosen in an ad hoc manner and without necessarily being grounded in theory*: Many studies among those selected in our systematic review did not refer explicitly to models or theoretical approaches when they considered the explanatory variables of academic efficiency. Their purpose seems mainly driven by empirical or methodological considerations. Indeed, these studies could be qualified as comparative or evaluative, essentially sought to hierarchize the efficiency levels and to identify inefficient DMUs. Other articles were dedicated to the development and refinement of analytical techniques to estimate the efficiency frontier. This leads us to propose to better anchor the choice of inputs, outputs, and determinants of the efficiency of research into theories, and to test hypotheses based on the predictions of these theories.

Finally: *The consideration of the multi-output model at the individual level*: The systematic review showed that the multi-output model is largely dominant in previous work on the efficiency of academic production. Accordingly, peer-reviewed publication counts within a specified period of time are widely used as a proxy for research activities in combination with other indicators as indicators of research quality [13,65], of teaching involvement [10,42,31], and of entrepreneurial initiatives [29,50,66].

Managerial implications

The results of this study involve important practical implications for the management of universities. Firstly, the measurement of academic efficiency allows the benchmark of the observed value of the output, and the output value that should be observed if the DMU (university, department, research institution, research center, researcher, etc.) was efficient. This information could be useful for managerial purposes and in particular to assess a DMU's relative positioning. For instance, each DMU's managers can figure out how much inputs (grants from government, external funding, etc.) must increase to enhance their DMU efficiency.

Secondly, overall, although we found that many factors influence academic efficiency, the vote counting analysis showed that five determinants emerge as having a positive and recurrent effect on this efficiency: i) seniority and composition of staff; ii) institutional factors; iii) size effects; iv) financial structure; and v) scientific meritocracy. These determinants can be leveraged to improve the productivity and the impact of academic research. The identification of these determinants is not only very insightful, but may also be informative for university administrators and national policy-makers who, more often than not, tend to assume that no intervention is required to foster the quantity as well as quality of the research produced by scholars [67]. Indeed, currently, an implicit assumption seems to be that the development of the research skills of scholars is learned by osmosis [68], in a gradual and partly unconscious process of absorption resulting from working in a supportive environment that provides opportunities to interact with highly- productive scholars whose publications are frequently cited [69]. But, given the major productivity and impact performance differences among scholars, one has to assume that systematic policy interventions are required if this is to change in any meaningful way [70].

Thirdly, along these lines, the results of this study show that university size as measured by the number of faculties, the size of research programs, the total full-time equivalent of student enrolment, the presence of a medical-pharmacy faculty, etc., has a significant and positive impact on academic efficiency. Given that larger universities are generally more likely to be in top-tier universities, their scholars are more likely to have a higher level of academic efficiency than their colleagues in the second and third-tier universities. This suggests that the second and third-tier universities may improve their recruitment policies as well as their career development policies by adopting material, intellectual, and social incentives used by top-tier universities to improve the research skills of their faculty members.

Finally, with regard to meritocracy that refers to best scholars that have effectively the most successful careers as reflected by 'top' publications, grantees or citations [71,72], and in spite of the ongoing debate on advantages and disadvantages of incentives on researchers' performance [73], there is a broad consensus to encourage and reward excellence of research [74]. In fact, many studies on institutional productivity in publications, licencing, patenting, and technological entrepreneurship contend that academics are motivated by personal financial gain, as well as by additional funding for their research activities [75]. Accordingly, administrators of universities that did not rely on a reward and incentive system should develop such a system to encourage and reward excellence of research.

Such social incentives may induce faculty members to do what they would not do otherwise: to try harder to publish and to publish more while hoping to be cited and be cited more frequently.

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Appendix 1. Keywords chain used to identify relevant articles

Keywords chain:

((academic **OR** university* **OR** public **OR** center) **AND** (faculty **OR** faculties **OR** researcher **OR** scientist **OR** department **OR** unit) **AND** (research* **OR** scientific* **OR** publicat* **OR** citation* **OR** entrepreneur* **OR** commercial* **OR** Patent* **OR** Consult* **OR** spinoff* **OR** Spillover*) **AND** ((perform* **OR** productiv* **OR** efficiency* **OR** technical efficiency* **OR** inefficiency*) **OR** (DEA **OR** SER **OR** SFA **OR** Data Envelopment Analysis **OR** Stochastic efficiency **OR** Stochastic Frontier Analysis **OR** Bayesian Approach **OR** Malmquist Index parametric **OR** parametric **OR** nonparametric **OR** deterministic **OR** econometric frontier **OR** two-step procedure **OR** one-step procedure **OR** fully efficient frontier **OR** variable return to scale **OR** VRS **OR** Constant return to scale **OR** CRS)))

NOTE.
1. Asterisk (*) use to find a root word plus all the words made by adding letters to the end of it.

Appendix 2.

Classification of determinants of academic research efficiency and their definitions

Category	Determinants explaining differences in efficiency	Selected references
SIZE EFFECTS	• The existence of an engineering and/or medical-pharmacy faculty • Number of faculties (schools) within the university • Orientation or vocation of the institution • Size of research programs (indirectly measured via the total number of full-time equivalent staff) • Total full-time equivalent student enrolment	[Kempkes and Pohl 2010; Wolszczak-Derlacz and Parteka 2011; Agasisti and Pohl 2012] [Bonaccorsi et al. 2006; Wolszczak-Derlacz and Parteka 2011] [Warning 2004; Kounetas et al. 2011; Wolszczak-Derlacz and Parteka 2011] [Cherchye and Abeele 2005; Abboot and Doucouliagos 2009; Kounetas et al. 2011] [McMillan and Datta 1998; Robst 2000; Stevens 2005; Bonaccorsi et al. 2006; Agasisti and Salerno 2007; Abboot and Doucouliagos 2009; Abramo et al. 2011]
INSTITUTIONAL FACTORS	• University type (comprehensive/ specialist) • Teaching pressure of a department (ratio of total teaching load) • University type (autonomous/ government universities) • Publishing conventions between subject disciplines • Existence of research councils and regular evaluations • Perceived de facto influence of the deans • Ownership structure • Time dedicated by the department to research • State regulation: capture whether a university operates under comparatively liberal or restrictive state regulation	[Johnes and Yu 2008] [Sellers-Rubio et al. 2010] [Kantabutra and Tang 2010] [Kounetas et al. 2011] [Schubert 2009] [Schubert 2009] [Kounetas et al. 2011] [Sellers-Rubio et al. 2010] [Kempkes and Pohl 2008]
SENIORITY AND COMPOSITION OF STAFF	• Proportion of full-time versus non full-time researchers • Proportion of promoted versus non-promoted colleagues • The quality of institutions and colleagues: productivity externalities • Experimental character (the quality of the colleagues' publications) • Relational capital • The number of years since obtaining a PhD degree • The average age of the permanent colleagues • The proportion of senior academic staff • Proportion of staff over 50 years old • Proportion of doctoral students in the research staff • Proportion of lecturers, and proportion of adjunct professors compared to total staff • Human resources dedicated to science and technology (to measure the potential spillovers of such activities on universities)	[Abboot and Doucouliagos 2009; Sellers-Rubio et al. 2010; Abramo et al. 2011; Sav 2012] [Carayol and Matt 2006; Stevens 2005] [Allison and Long 1990; Carayol and Matt 2004; Carayol and Matt 2006] [Groot and Garcia-Valderrama 2006; Sellers-Rubio et al. 2010] [Schubert 2009; Lu 2012] [McMillan and Datta 1998; Landry et al. 2010] [Carayol and Matt 2006] [Abboot and Doucouliagos 2009] [Stevens 2005] [Groot and Garcia-Valderrama 2006] [Agasisti et al. 2011; Stevens 2005] [Agasisti and Pohl 2012]

FUNDING STRUCTURE	• The degree of external funding of scientific research • Research expenditures • University industry interaction • Revenues core (share of core funding revenues in total revenues) • Percentage of private contracts over total university budget • Venture capital • Proportion of full-time faculty eligible for MRC and/or NSERC grants	[Warning 2004; Cherchye and Abeele 2005; Agasisti and Salerno 2007] [Robst 2000; Guan and Chen 2012] [Dai and Popp 2005; Guan and Chen 2012] [Wolszczak-Derlacz and Parteka 2011] [Harman 2002; Bonaccorsi et al. 2006] [Guan and Chen 2012] [McMillan and Datta 1998]
PRESTIGE AND REPUTATION OF THE INSTITUTION	• Year of foundation • Old/new universities • Variable for the Dawkins universities • Attractiveness and scientific vitality • Academic reputation score from US News and World Report • Age: stock of reputation, the age of the university is incorporated to capture this path-dependent effect	[Kuo and Ho 2008; Wolszczak-Derlacz and Parteka 2011] [Mamun 2012] [Abbott and Doucouliagos 2009] [Bonaccorsi and Daraio 2003] [Mensah and Werner 2003] [Warning 2004; Kounetas et al. 2011]
SCIENTIFIC MERITOCRACY	• Ratio of citation over publication • Fraction of SSCI and SCI publication • H-index	[Abramo et al. 2011] [Warning 2004] [McMillan and Datta 1998]
GENDER EFFECT	• The share of women in the academic staff	[Stevens 2005; Wolszczak-Derlacz and Parteka 2011]
AGGLOMERATION EFFECTS	• Geographical location • Regional effect • Unemployment rate • GDP per capita to detect potential influence of the economic development of a region on the universities' performance	[Bonaccorsi and Daraio 2003; Agasisti and Salerno 2007] [Ng and Li 2000; Kempkes and Pohl 2008; Agasisti and Pohl 2012] [Agasisti and Pohl 2012] [Kempkes and Pohl 2010, Wolszczak-Derlacz and Parteka 2011; Agasisti and Pohl 2012]
SOCIAL CAPITAL	• Capital building experiences over time affect the formation and pattern of scientific careers • Indexes evaluating the extent and intensity of the network links engage with managers and / or professionals in private companies and public organisations	[Bozeman et al. 2001; Bozeman and Corley 2004; Lu 2012] [Cherchye and Abeele 2005; Bonaccorsi et al. 2006; Katharaki and Katharakis 2010; Landry et al. 2010; Lu 2012]
QUALITY INDICATOR	• (%) Student faculty ratio (as a measure of the potential teaching quality) • (%) Tenured faculty (faculty employed that have received tenure to produce scholarly research activity)	[Warning 2004; Kempkes and Pohl 2008; Sav 2012] [Sav 2012]
CHARACTERISTICS OF STUDENTS	• The proportion of overseas students • Proportion of (arts/sciences-status) students • Proportion of students aged ≥ 25 years	[Kempkes and Pohl 2008] [Stevens 2005] [Stevens 2005]

	• (%) Student retention (is used as a measure of student academic preparedness)	[Sav 2012]
PROTECTION OF INTELLECTUAL PROPERTY	• Protection mechanisms	[Link and Siegel 2005; Guan and Chen 2012; Landry and Amara 2012]