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A network DEA quantity and quality-orientated production model: An application to Australian university research services

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ABSTRACT

The motivation for this analysis is the recently developed Excellence in Research for Australia (ERA) program developed to assess the quality of research in Australia. The objective is to develop an appropriate empirical model that better represents the underlying production of higher education research. In general, past studies on university research performance have used standard DEA models with some quantifiable research outputs. However, these suffer from the twin maladies of an inappropriate production specification and a lack of consideration of the quality of output. By including the qualitative attributes of peer-reviewed journals, we develop a procedure that captures both quality and quantity, and apply it using a network DEA model. Our main finding is that standard DEA models tend to overstate the research efficiency of most Australian universities.

1. Introduction

The motivation for this study is the Australian Commonwealth government's Excellence in Research for Australia (ERA) program, recently developed to assess the quality of research in Australian universities. Implemented in 2008, the ERA initiative was a key element in the previous Labor government's agenda for the reform of Australia's higher education system as a means of providing assurances to government, industry, business, and others stakeholders of the quality of research conducted in Australian universities. Moreover, the ERA was aimed not only at improving the overall level of research quality in Australia, but also '…sits within a broader movement internationally, with the emphasis on excellence and quality being found in the performance-based funding schemes of a number of other countries' [1].

There is then clearly a need for an appropriate measure of the productive efficiency of research. This is not least because of the need to account for the billions of dollars of research income (both public and private) the sector attracts, the significant contribution this research makes to the Australian economy, and for the purpose of enhancing the domestic and international reputations of both individual institutions and the sector as a whole. In doing so, it should create greater transparency and accountability of publicly funded institutions and appropriately recognize the efforts of those universities producing research and therefore deserving of funding. As Herbst [2] points out, 'The rationale of performance funding is that funds should flow to institutions where performance is manifest: 'performing' institutions should receive more income than lesser performing institutions, which would provide performers with a competitive edge and would stimulate less performing institutions to perform. Output should be rewarded, not input'.

To meet this need, we set two objectives for this analysis. First, the development of a suitable production model that best represents university research activity while considering the appropriate inputs that generate outputs. One of the most contentious issues in existing higher education efficiency studies is that the number of research publications produced and the amount of grants received are both considered outputs, yet may also comprise inputs [3–9]. Without exception, these studies employ standard data envelopment analysis (DEA) to measure technical efficiency based on the production assumption of some set of inputs used to generate some set of outputs. However, the rigidity of standard DEA treats the production process as a 'black box' in that it simply transforms inputs into outputs and neglects any possible intervening processes, including dissimilar series or parallel functions.

In the case of the abovementioned studies, this has meant that while the number of publications and/or the value of grants are rightly outputs in their own right, it fails to illustrate the relationship between the variables and the mapping of the underlying production process. In reality, decision-making units (DMUs), here universities, often perform several different functions and readily

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separate these functions into different components, in a series or in parallel and/or in a more complex form of network type. This suggests that the outputs produced in a certain series may become intermediate inputs in a subsequent production stage. To determine the appropriate production process that best represents university research production, we employ the network DEA (NDEA) approach.

The second objective of our analysis relates to a rather more practical concern regarding the measurement of research output in the Australian context. The ERA 2010 surveyed all Australian universities on their journal publications over the period 2003–08, categorizing each journal into one of four broad groupings. These were A* (virtually all papers are of very high quality), A (the majority of papers are of very high quality), B (a few papers are of very high quality) and C journals (the papers are peer reviewed and of some quality, but do not meet the criteria of the higher tiers). Subsequently, ERA 2012 evaluated research undertaken between 1 January 2005 and 31 December 2010. However, unlike ERA 2010, ERA 2012 did not provide any journal categorization other than meeting the minimum requirement of a peer-reviewed publication. The lack of a quality indicator thus questions whether we accurately measure the research performance of Australian universities. It also raises questions on how funding is allocated where there is no attempt to identify quality research publications.

In addition, the lack of any indicator of quality leaves us uncertain as to whether the standard of university research publication has improved throughout the (albeit limited) ERA exercise to date. To better measure the quality of research publication, we propose an approach that aggregates the number of publications for each university using weights. We detail the procedure in the data section. An essential aspect in deriving a qualitative dataset of research publications is that based on our production model, it is an intermediate measure, which could influence efficiency scores in its various stages. This suggests that the lack of a reliable research publication dataset could distort efficiency scores, especially in the second stage of our production model where both the quantity and quality of research outputs determine the allocation of research grants to universities.

The remainder of the paper is structured as follows. Section 2 describes the basic NDEA framework used for our research production model. Section 3 details the data sources, including the methodology for measuring research publication quality and quantity. Section 4 presents the empirical results. Section 5 provides some brief remarks.

2. Conceptual framework for the research production model

As elsewhere around the world, the research production model in Australian universities is complex. Perusing the many higher education studies employing standard DEA, we can see that it is common to specify the inputs as full-time equivalent (FTE) academic staff and capital stock (or some proxy) and the outputs as the number of publications and the value of grants. The problem with this model is that the inputs used to produce outputs may not be rational because of incorrect sequencing. There is then a need to adopt an approach that takes into account a network of

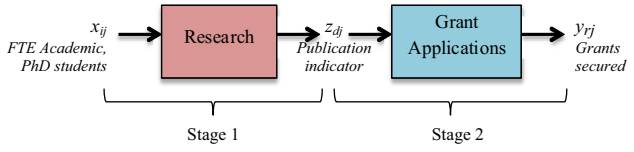

Fig. 1. A university research production model.

'divisions' or 'sub-processes' to appropriately assess the divisional efficiencies and the overall efficiency of universities.

One such approach is the NDEA model [10–12], which has been employed in numerous studies across a wide range of industries, including airports [13–14], banks [15–20], hotels [21], electric utilities [22–24], university libraries [25] and research and development [26–27]. In brief, NDEA is made up of a network of 'divisions' or 'nodes', which when viewed together, comprise the individual DMU. Each node transforms inputs into outputs, and in some nodes, the outputs become inputs themselves to produce yet other outputs in yet other nodes. Each node generates an efficiency (i.e. divisional efficiency) score that we can compare with the corresponding node of other DMUs. We evaluate overall efficiency score using the final node. Importantly, depending on the precise nature of the nodes, we may attach different weights to each node to recognize the particular emphasis of the production model.

Fig. 1 depicts our NDEA model for universities. The model comprises two stages. In the first stage, inputs x_{ij} produce intermediate outputs z_{dj}. In our university research production model, we use two primary inputs in Stage 1 (Node 1), namely, FTE academics and doctorates by research as student load for the j-th university. We consider only PhD students because of their longer period of candidature, suggesting that they more readily engage in research collaboration and co-authorship with academics than say, coursework only or shorter-period masters research students. This is especially the case where PhD students quite often serve as research assistants in the production of publications, while it is increasingly common for PhD students in Australia to submit their theses by publication or as a series of published papers, thus evidencing that PhD students are an input in publication [28].

We specify a single output for Stage 1, which is the publication indicator described later. While we acknowledge that PhD completions are also an output in the first stage, our production model only focuses on the outcomes of research activity. In the second stage, z_{dj} becomes an intermediate input in the process of grant application in order to win grants (i.e. grants secured) denoted by y_{rj}. Hence, in Stage 2 (Node 2), the publication indicator becomes an intermediate input and grants awarded our final output.

3. Data sources and method

3.1. Data

The data consists of 37 annual observations of Australian universities over the period 2004–11. All data are from the Higher Education Statistics and Financial Reports compiled by the Commonwealth Department of Education (www.education.gov.au) [previously Department of Education, Science, and Training (DEST) and Department of Education, Employment and Workplace Relations (DEEWR)]. We specify a production model where the research production process includes only research-relevant inputs. The primary inputs are FTE academics (comprising 'research-only' academic staff and 'teaching and research' academic staff), and doctorates by research (student load). As the intermediate output, we consider the publication indicator. The final output for the NDEA is research income (i.e. grants won), comprising research income from across the designated categories of Australian Competitive Grants, Other Public Sector Grants, Industry and Other Grants, and Cooperative Research Centers (CRC).

The measurement of university performance is critically dependent on the reliability of the research publication output, which should incorporate both quality and quantity. There are many