JOURNAL OF ECONOMIC SURVEYS

doi: 10.1111/joes.12270

PRODUCTIVITY AND EFFICIENCY ANALYSIS SOFTWARE: AN EXPLORATORY BIBLIOGRAPHICAL SURVEY OF THE OPTIONS

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Abstract. The software available to implement and carry out efficiency analysis is crucial for the diffusion of efficiency frontier techniques among applied researchers and policy makers. The implementation of up-to-date productivity and efficiency analysis is indeed important to advance our knowledge in many fields, ranging from the public and regulated sectors to the private ones. This contribution fills a gap in the existing literature and surveys the currently available options to estimate a variety of frontier methodologies using either general or dedicated programs. We outline directions for future research.

Keywords. Efficiency; Frontier models; Productivity; Review; Software

1. Introduction

The availability of software and codes to perform rigorous empirical analysis is important for applied researchers and the wider scientific community. It is also increasingly important given the need to exploit data resources and the availability of big data. This need is particularly felt in the so-called frontier literature on Productivity and Efficiency Analysis (PEA) that has boomed over the last decades, since these extremum estimators tend to be rather computationally intensive. There is a wide variety of methodological surveys available on this PEA frontier literature (examples include Murillo-Zamorano, 2004; Bogetoft and Otto, 2010; Del Gatto *et al.*, 2011; Parmeter and Kumbhakar, 2014, among others). Equally so, the enormous amounts of empirical applications of these PEA frontier methods have been

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capably summarised in a series of surveys per sector. Examples include agriculture (Bravo Ureta *et al.*, 2007), banking (Aiello and Bonanno, 2016), health care (Rosko and Mutter, 2011), ports (Odeck and Bråthen, 2012) and water and sanitation (Worthington, 2014), among others.

Perhaps Chang and Sueyoshi (1991) are the first to document a software for Data Envelopment Analysis (DEA) models, while Coelli (1996a) is the first to describe a program for Stochastic Frontier Analysis (SFA). Thereafter, a multitude of frontier software has been proposed. While on occasion a review of some PEA frontier software has appeared in the literature (for example, Hollingsworth, 1999; Barr, 2004), and some comparative review of available statistical tools and packages covers the gap of econometric software surveys (Korösi *et al.*, 1993), to the best of our knowledge no systematic and recent review of PEA software options is currently available. Therefore, the main research question that we address in this paper is: What software options exist to carry out frontier-based PEA? How many studies have analysed the existing software options? That is, what is the state of the art about the 'implementation' of techniques to produce (generate) empirical evidence on productivity and efficiency? And related to this question, how many options are already available to researchers interested in the implementation of frontier models? In the existing literature, there is a lack of a unifying view on the different options available in terms of software implementation. We fill this gap by making a state of the art survey of the available software options. We also report the outcome of a clustering and a cognitive map based on the keywords of the identified relevant documents. We open a perspective to further research (outside the scope of this paper) on the field including:

- a large-scale evaluation and comparative assessment of the performance/validity of the existing software;
- need of standard to check the quality of the available software and to create an open repository for their storage and maintenance.

The method applied to carry out the survey is based on a *systematic review*, taking into account the specificities of the objective of the study and the limitations of the technique.

The paper is organized as follows. The next section introduces the approach followed to carry out the systematic review. The subsequent section reports the main outcome of the paper that is the state of the art of the existing options of software for PEA and outlines a comparative analysis carried out on them. The final section concludes the paper and outlines directions for further research. In Appendix A, additional information on the queries carried out on Scopus and Google Scholar are reported, together with the flow diagrams of the systematic search and additional detailed information on the study carried out.

2. Methodology of the Survey

According to Petticrew and Roberts (2006, p. 19) a '*systematic* (literature) *review* is a review that strives to comprehensively identify, appraise and synthesize all the relevant studies on a given topic. Systematic reviews are often used to test just a single hypothesis, or a series of related hypotheses'. In sum, it tries:

1. To collect *all existing evidence* that fits some pre-specified *eligibility criteria* in order to answer a *specific research question.*
2. It uses explicit, *systematic methods* (adopting a replicable, scientific and transparent process) that are selected with the purpose of minimizing the inherent bias, and hence, enhancing the reliability of the findings.

The principal characteristics of this approach are:

- a clearly stated *objective* with pre-defined *eligibility criteria* for inclusion of the relevant materials;
- an explicit, reproducible *methodology*;

- a *systematic search* that attempts to identify all studies and relevant materials that would meet the eligibility criteria; and
- a *systematic presentation* and *synthesis* of the features of the included relevant studies and documents.

This approach has been developed initially in medical science to summarize and make sense of an often contradictory mass of empirical evidence available that is difficult to synthesise (see, for example, the reference in this field by Higgins and Green, 2011). The limitations of the approach have been described in many works, including Petticrew and Roberts (2006) who discuss the specific features of the approach for application in the social sciences. Tranfield *et al.* (2003) highlight the limits of the approach in the managerial field and propose a 'lighter' use of the approach to provide an 'evidence informed' or 'evidence aware' answer to the research question (objective) of the systematic review, instead of a stronger 'evidence-based' information. We follow this latter approach given the specific questions we wish to address.

In Box 1, we summarize the main choices we have made in our analysis pertaining to the main objective, the eligibility criteria, explicit methodology, systematic search and systematic presentation and synthesis.

Box 1. Choices Made in the Systematic Review.

Main objective (our research question)	How many and what software exist to carry out PEA? How many studies have analysed the existing software options?
Eligibility criteria	We include only those programs or software that are diffused as a package or a toolbox and for which there is sufficient English language documentation for the user.
Explicit methodology	Systematic review on two databases with a different coverage: Scopus and Google Scholar, integrated by expert knowledge and a 'light' application of the systematic review approach for social sciences.
Systematic search	All details about the queries run on the two databases are described in the paper and reported in Appendix A (Table A1).
Systematic presentation and synthesis	The outcome of the survey is reported in a summary way in Table 1 and in a more detailed way in Appendix A (Table A2). A mapping and clustering illustration of the main keywords is reported in Figures 1 and 2.

In the selection carried out on the identified papers in the English language solely (see more details below), we avoid that articles mentioning the simple application of an existing software were considered as relevant (for example, 'our results were computed in GAMS', 'we used FEAR', etc.). Equally so, articles that simply mention the availability of computer code or contain snippets of such code without a written documentation are ignored. Moreover, we distinguish between frontier software and articles describing conceptual or real decision support systems involving some use of frontier estimation. The latter type of articles are excluded in this survey: examples include Wang (2005), Pasupathy and Medina-Borja (2008), Johnson *et al.* (2010), Yousefi and Hadi-Vencheh (2010), Johnson and McGinnis (2011), Lai *et al.* (2011), Fernández-Montes *et al.* (2012) and Samoilenko and Osei-Bryson (2013).

Our survey is entirely bibliographical and is limited to sources in English. In particular, we have made no attempt to make an inventory of software that is undocumented.[1] For instance, these can be programs that do not contain any documents or user guides, ignoring any eventual minimal installation instructions. Or, it concerns code in software that is related to a specific article or working paper, often made available on repositories or researcher's web pages.[2] The key summary tables of the study (that is, Table 1 and Table A2) contain first and foremost references to the documents. The main reason to limit our survey to a bibliographical approach is that the methodology of doing a bibliographical search is rather well established. By contrast, the methodology to assemble all sources of software code is far less standardized.

Synthesizing the evidence, from the inspection of these summary tables it emerges that there has been an increase in the number of free open toolboxes proposed in the last years, denoting an increasing interest for the field and ability/willingness to share codes and programs. This leaves open the issue on how to control the quality of these existing packages (which one can be used for which purpose). We return to this issue in the concluding section when outlining directions for further research.

Let us now describe the main steps in our systematic search. The systematic survey on PEA software literature initiates with a list of 34 documents identified as relevant by expert knowledge (that is, the authors). In this list (see Appendix C, Table C1), there are 9 books, 17 articles, 2 reports and 6 user guides. We collect the keywords of these documents (when present) to run the first broad query in the two scientific literature databases considered in our analysis, namely, Scopus and Google Scholar. Books, manuals, reports, user guides and many types of documentation do not provide keywords associated. For those cases, the most repeated words in the title, abstract or introduction are taken as keywords to compose a complete repository of terms associated with (and to track the) software options. An overview on the process followed in the search on these two databases (Scopus and Google Scholar) is shown in Figure A1.

The systematic search on Scopus was conducted with eight specifications described by the scripts reported in the top panel of Table A1. The search was carried out on 1 December 2016, from 14h08m (UTC+01:00) to 17h20m. The query Q1 (see Table A1), was run over all the disciplinary fields in the Scopus search engine. We obtained a dataset of 7814 documents that includes research papers, articles in press, books, reports, technical notes, letters, reviews and conference proceedings distributed among the main areas of life science, health science, physical science, social science and humanities, from the year 1988 to 2016. After this first step, the query Q1 was rewritten in terms of Q2 to remove case studies that are not relevant for the purpose of this survey. A total of 3266 documents in 160 subject categories resulted from this specification, ranging from 21 to 1492 occurrences per subject category.

Thereafter, we introduced further refinements on subject classes to exclude general and irrelevant documents. This process leads us to the queries Q3 and Q4 (see Table A1). These refinements resulted in a total of 627 potentially relevant documents. Subsequently, the queries Q5 and Q6 (see Table A1) were run to limit the obtained documents to the specific knowledge area related to PEA software reviews. As an outcome, we obtained 395 potential relevant documents. Lastly, from this set of 395 potential relevant documents, a title-based selection lead us to consider 29 documents for a deeper exploration based on the documents' abstract and body. The reading of the 29 documents obtained led us to consider one relevant document. The left side of the flow diagram of Figure A1 reports a graphical representation of this process run on Scopus.

The systematic literature search on Google Scholar followed a similar reasoning, but with a difference in the specifications concerning refinements and re-refinements (since the Google Scholar engine limits queries to 256 characters). The Google Scholar systematic search was carried out on 2 December 2016, at 13h21m and ended at 16h38m (UTC+01:00). It consists in six specifications: from the broadest to the more specific ones (see Figure A1 right side flow diagram). The general terms in Q7 and Q8 are the same as Q1 and Q2 carried out in Scopus, but with a different syntax. These queries lead to a wider set of results due to Google Scholar's extensive capacity to find out documents throughout Internet servers and a wider variety of document sources and types. The attempt to increase the precision of results for geographic

Table 1. Overview of the Software Tools Available for PEA (Last Updated: 16 February 2018).

Software	Type	Reference and/or web pages
AMPL	DEA	Green (1996)
GAMS	DEA	http://www.gams.com/latest/gamslib_ml/libhtml/gamslib_dea.html Olesen and Petersen (1996); Ferris and Voelker (2002)
Mathematica	DEA	Ley (1996)
Matlab	DEA	DEA Toobox (Álvarez *et al.*, 2016); http://www.deatoolbox.com/
R	DEA & SFA	R Packages (available on https://cran.r-project.org/web/packages, except when otherwise indicated): - additiveDEA (Soteriades, 2017); - Benchmarking (Bogetoft and Otto, 2010, 2015); - FEAR (Wilson, 2014); www.clemson.edu/economics/faculty/wilson/Software/FEAR/fear.html) - Frontier - Frontiles (Daouia and Laurent, 2015); - Nonparaeff (Oh and Suh, 2013); - npsf (Badunenko *et al.*, 2017); - Productivity (Dakpo *et al.*, 2016); - semsfa (Ferrara and Vidoli, 2015); - SFA (Straub, 2015); - spfrontier (Pavlyuk, 2016); - SSFA (Fusco and Vidoli, 2015); - TFDEA (Shott and Lim, 2015); - rDEA (Simm and Besstremyannaya, 2016); - DJL (Lim, 2016).
SAS	DEA & SFA	proc qlim Emrouznejad (2005)
STATA	DEA & SFA	frontier, xtfrontier Kumbhakar and Wang (2015) Tauchmann (2012) Stata Packages: - DEAS (Ji and Lee, 2010); - https://sourceforge.net/projects/deas/ - SFA (Kumbhakar *et al.*, 2015) - https://sites.google.com/site/sfbook2014/home/data-and-programs - sfcross (Belotti *et al.*, 2013) - http://www.econometrics.it/?p=286 - sfpanel (Belotti *et al.*, 2013) - http://www.econometrics.it/?p=286 - tenonradial, teradial, teradialbc, nptestind, and nptestrts (Badunenko and Mozharovskyi, 2016) - www.stata.com/meeting/germany16/slides/de16_badunenko.pdf

(*Continued*)

Table 1. *Continued.*

Software	Type	Reference and/or web pages
Program		**Author(s) and/or Web Pages**
BSFM	SFA	Arickx *et al.* (1997)
DEA-Excel	DEA	Jablonský (2014); http://nb.vse.cz/˜jablon/dea.htm
DEAFrontier	DEA	Zhu (2014); www.deafrontier.com/deasolver.html
DEAQual	DEA	http://wak2.web.rice.edu/
DEAP	DEA	Coelli (1996b); www.uq.edu.au/economics/cepa/deap.php
DEA-Solver-Pro	DEA	Cooper *et al.*, (2006); www.saitech-inc.com/Products/Prod-DSP.asp
DPIN	DEA	O'Donnell (2010); www.uq.edu.au/economics/cepa/dpin.php
EMS	DEA	Scheel (2000); http://www.holger-scheel.de/ems/
Frontier	SFA	Coelli (1996a); www.uq.edu.au/economics/cepa/frontier.php
Frontier Analyst	DEA	Hussain and Jones (2001); http://banxia.com/frontier/
Inverse DEA	DEA	http://maxdea.com/InverseDEA.htm
LIMDEP and NLOGIT	DEA & SFA	Greene (1995); Greene (2002); www.limdep.com/ http://www.limdep.com/products/nlogit/
MaxDEA	DEA	Cheng (2014); www.maxdea.cn/
OnFront	DEA	http://onfront.software.informer.com/
Open Source DEA	DEA	www.opensourcedea.org/
PIM-DEAsoft	DEA	Thanassoulis (2001); www.deasoftware.co.uk/
ISYDS (SIAD)	DEA	Meza *et al.* (2005); www.uff.br/decisao/
SmartDEA	DEA	Akçay *et al.* (2012)
TFPIP	DEA	Coelli (1997); www.uq.edu.au/economics/cepa/tfpip.php
WinBUGS	SFA	Griffin and Steel (2007); www2.warwick.ac.uk/fac/sci/statistics/staff/academic/steel/steel_homepage/software
Online Program		**Web Pages**
DEAOS	DEA	www.deaos.com/
DEA Solver Online	DEA	www.dea.fernuni-hagen.de
WebdeA	DEA	https://sites.google.com/site/dsslabunipi/tools

Since the submission, we have found the following additional R packages:
- Compind (Vidoli and Fusco, 2018);
- MultiplierDEA (Puthanpura, 2018);
- npbr (Daouia *et al.*, 2017);
- sfadv (Desjeux, 2017).

regions, general terms and unrelated areas considerations lead us to 719 thousand occurrences. Further refinements and specifications (see queries Q9, Q10 and Q11 in Table A1) lead us to a title inspection on a total of 296 potentially relevant documents.

As an outcome of this title inspection, 82 documents were selected as potentially relevant documents and thereafter 33 final documents were retained for abstract reading (one of which was already included in the outcome from the Scopus database). Since in total 16 out of these 33 potentially relevant documents also belong to the initial expert documents list, a number of 17 documents was added to the original list from the systematic search (Appendix C, Table C2) and 16 documents are added from additional sources (Appendix C, Table C3). The right side of the flow diagram of Figure A1 summarizes this selection process.

Table 2. Summary Table on the Comparative Analysis Carried Out on the Software Options.

Options	Dimensions	Definition
Libraries, Solvers and Language-Based Algorithms	Frontier Models	DEA and/or SFA models included in the package/software
General Purpose DEA/SFA Software	System requirements	Hardware and Operating Systems requirements to run the program
Web-server Programs	Variable and constraints limitations	Problem size of the linear programming model which the package can execute
	User Interface	Command Line, Graphical User Interface or Interface from other Applications
	Report Structure	Main features and capabilities of the software results
	Cost	Academic and Commercial license prices retrieved between Nov. 2016 and Jan. 2017
	User Support	Provision of technical support, documents and orientation to users.

The documents are classified into books (including book chapters), articles in scientific journals, proceedings (conference papers and reviews), reports (working papers, white papers, press releases, erratum, essays and sales or marketing documents with a report structure) and manuals (user guides, letters, notes on software or any relevant documents with a manual structure).

The number of versions available of each document merits some discussion. In Google Scholar, each document may have different versions when the document is found with different years in different repositories or different editions of the same book. Also, different digital extension formats (such as .doc, .docx, .pdf), proceedings papers that are later published as journal articles and different language sources, or author name abbreviations may lead to different versions of the same document.

It has to be noted that the additional documents reported in Appendix C, Table C3 were added on the basis of expert knowledge because their keywords did not match with our initial keyword specification. This is really an area of further research since combining expert knowledge and other kinds of systematic source searches (for example, web sites of PEA scholars) may bring valuable information on existing software options.

3. Comparative Analysis of the Available Options

In this section, we summarize the main characteristics of each PEA software and packages inventoried by our systematic review. The main result of this paper is the content of Table 1. Table 1 summarizes, to the best of our knowledge, the available software for PEA based on the systematic review described above, with the exception on the rDEA and DJL R packages which have been added later through a last consultation made by 16 February 2018. Table 2 describes seven main dimensions (based on Barr, 2004) for which the comparative assessment on the existing software for PEA is carried out, namely, Frontier

Models, System Requirement, Variable and Constraints Limitation, User interface, Reports' Structure, Cost and User Support. More details can be found in the Appendix A, Table A2.

The programs present in the Table A2 are divided in two categories: General purpose software (econometric programing languages) and Dedicated software, which also includes web-based programs. The programing languages are able to feature any DEA or SFA approach with proper knowledge of the algorithm design and specific characteristics of the tool. Our comparative analysis also lists a set of specific libraries each program grants the usage. By way of example, Benchmarking and FEAR are libraries that can be attached to the general-purpose statistical package R to enable access to up-to-date advances in DEA and SFA analysis. The web-based programs bring benefits of interoperability among different operating systems and save hardware capacity and resources. They require web browsers to perform the analysis. For instance, Opensource DEA aims to provide a free open platform and code that can be used and modified by anyone.

The information considered for the first dimension is summarized as FDH, DEA and SFA models, parametric or non-parametric approaches, in the Appendix A, Table A2. The choice of the most appropriate frontier model is a source of discussions in surveys of core methods for productivity measurement (Murillo-Zamorano, 2004; Del Gatto *et al.*, 2011), which mostly depends on the decision maker goals, data set and characteristics of the empirical area of assessment. A wide range of DEA models are considered by each package, from the traditional constant and variable returns to scale DEA models (Charnes *et al.*, 1978; Banker *et al.*, 1984), additive slack-based (Charnes *et al.*, 1985; Tone, 2001), extensions of Andersen and Petersen (1993) Super-efficiency and Malmquist (1953) productivity indexes to more recent and specific models such as the O'Donnell (2008) decomposition of the Hicks-Moorsteen Total Factor Productivity index, Podinovski (2004) model of trade-offs or Tone and Tsutsui (2010) dynamic slack-based model.

Most of these models are available for both input-oriented and output-oriented cases. A total of 41 instances of DEA models were inventoried: readers are advised to check the relevant documentation to see which package can perform which specific model. Some packages such as DEA-Solver-Pro, DEAFrontier and MaxDEA permit the implementation of recent advances on network DEA models: for example, network variable returns to scale (Chen and Zhu, 2004), network slack-based (Tone and Tsutsui, 2009) and dynamic slack-based (Tone and Tsutsui, 2014) models. The inverse DEA model of Wei *et al.* (2000) has a unique package designed exclusively to perform this particular model. Finally, FDH refers to the Free Disposal Hull non-parametric estimators (Deprins *et al.*, 1984).

With regard to SFA, the most relevant models inventoried are the time invariant model (Battese *et al.*, 1989), the generalized production frontier (Battese and Coelli, 1988), the Pitt and Lee (1981) model of technical inefficiency, the conventional Aigner *et al.* (1977) cross-sectional estimation of SFA, Stevenson (1980) likelihood function model for cross-sectional data and the Reifschneider and Stevenson (1991) reformulation of traditional two-stage approaches. Readers are advised to consult the references to verify which models and stochastic error distribution are assumed in each instance of SFA software.

The system requirement dimension in the Table A2 looks at the different operating systems and processor requirements in which the programs can operate. The dimension 'Variable and Constraints Limitation' refers to the problem size, that is, the number of decision making units and input/output variables which the program can handle without additional data scaling or adjustments. This information is retrieved from manuals, online documentations, reports and case study applications to present a synthetic content of the packages.[3]

The user's interface considers three types of usage platforms: DOS command line (CLI) or specific integrated developer environments (IDE) (for example, the R command line prompt), particular graphical user interfaces (GUI) designed by the developers and outsourced graphical user interfaces (for example, MS Excel in which the software borrows the environment and graphical resources to perform and report the assessment). The report structure presents the main features of the software results, such as the efficiency projection, individual scores, graphs, scripts, weights, lambdas (intensity), peers, slacks and summary statistics (when statistical tools[4] are included). Some of the simplest software options generate only a single text file with main results.

The costs listed in the seventh column relate to standalone commercial licences for a single computer during the period of one year, and are separated into academic users (university students and faculty) and business users (public[5] and private companies). Many packages require additional solvers, packages or programs to analyse the frontier models described in the second column. This information is added after the main prices, relating the specific solver/program in parenthesis, to obtain an accurate picture of the total costs for interested readers. Some programs offer customized prices depending on the problem size (that is, number of DMUs, constraints and resource items), or grant discounts for a second year renewal. Readers are invited to consult the references and websites for more details. Finally, the user support dimension relates to the provision of technical support, user guides, documentation, manuals, FAQ, training courses and other forms of contact and support for clients (with pricing information when applicable).

On the one hand, the necessity of empirical application against the background of a rapid development of many DEA models and ways to estimate the SFA frontiers with different assumptions for different purposes gives a lead to the usage of standard programing languages (for example, R, Matlab,[6] Gams and AMPL[7]) instead of dedicated programs. Dedicated or specific software products are designed for a limited number of features, tools and specific properties, without the possibility to explore new approaches or assumptions that may contribute to advance theory. Programing languages make it easier to follow the frontier of scientific knowledge by allowing for improvements in conventional models and by providing the tools to bring forth recent considerations. On the other hand, the inconvenience for the user to learn the syntax of a mathematical programing language and the additional work to perform simple statistical analysis may lead some researchers to opt for easier specific DEA and SFA programs.

There are few considerations that must be stated. All DEA software products in this comparative assessment are able to perform both constant (CRS) and variable (VRS) returns to scale models, and most can also handle the non-decreasing and non-increasing returns to scale variations. For instance, PIM-DEAsoft is a much customized product with different price specifications depending on license quantity, number of DMUs, license expiration time (with an option for a permanent license) and additional models. The price information in the Table A2 regards a single license for 1 year to evaluate up to 50 units including all additional packages. DPIN 3.1 and TFPIP 1.0 use DEA variants of the CRS model for both output- and input-oriented cases to estimate the production frontier and compute productivity indexes and determinants of efficiency change. Thus, DPIN focuses on the estimation of production technology and levels of efficiency change into Hicks-Moorsteen indices of Total Factor Productivity (TFP), whereas TFPIP approaches the Törnqvist (1936) and Fisher (1922) index number methods of TFP.

LIMDEP and NLOGIT are the only specific software products available that perform both efficiency evaluation in terms of DEA modelling and for SFA, and that can also consider partial or environmental effects on data. Readers might find prior versions of DEAFrontier referred in some textbooks and papers as Excel DEA Solver, with the same basic DEA models and tools.

We report cluster and density maps produced by the main keywords of these relevant documents identified in Appendix B: in particular, Figures B1 and B2.

4. Conclusions and Future Research

In this paper, we have presented a state of the art review of the existing software options available to carry out frontier estimation and PEA analysis. The information provided is probably particularly suited for applied economists interested in the interdisciplinary field of PEA, as well as to researchers and policy makers interested in the state of the art on the tools available for frontier models implementation.

The survey has been limited to searching for the software and its related documentation. In a second step, we provide a summary comparative analysis on the relevant software/documents found on the basis of the self-declared information on the web site and/or reported in the documentation. This means that a systematic comparison and or assessment of the performance of the surveyed software is out of the scope of this review. This could be an interesting avenue for further research. To perform such an in-depth evaluation of the software options there are several possibilities. For instance, one can contact all software distributors, develop an exhaustive classification scheme and perform some benchmark tests. Alternatively, one can focus on the commercial publishers and ask their collaboration to define some minimal scheme of features, or one can analyse only open source or free software.

The survey carried out in this paper highlights an increasing availability of open source toolboxes and software for the implementation of many alternative or coincident efficiency models. Another interesting avenue for further research could be to foster the development of open sources available. Von Krogh and Von Hippel (2006) analysing the research on Open Source software identify different areas of its development, including *motivations of contributors* and including also *the process of innovation in open source software projects*. In addition, they consider also the *competitive dynamics enforced by open source software.* This latter option is, perhaps, the most important motivation for our analysis. The availability of new open software for carrying out PEA indeed can lead to improve the available tools at the benefit of the communities of users and interested policy makers at hand.

A crucial unanswered question posed by the evidence reported in this paper is the following: what is the ‘quality’ of these existing and available software tools? This is a relevant question to further address in future research. It is not an easy topic. For instance, Stamelos *et al.* (2002) propose three main steps for an open source code quality analysis, namely:

1. the definition of a set of ‘standard’ software rules,
2. a source code analysis to assess the code developed and verify conformance to the selected rules and
3. using the results of the assessment in the new release of the software.

The answer to this question would be important for the eventual development of an *Open Source Dynamic Digital Repository* of software for running PEA whose main features of the software and the respective maintenance could be made available to the community of practitioners and policy makers.

Acknowledgements

We acknowledge the constructive comments of a referee of this journal. We thank the participants of the EWEPA 2017 Conference held in June 2017 in London for helpful comments and discussions. In particular, we warmly acknowledge Gary Ferrier and Shawna Grosskopf for the information provided about some of the softwares reviewed. The usual disclaimer applies.

Notes

1. Toolboxes in progress but not yet released (e.g. Badin *et al.*, 2013) are not included.
2. Obviously, we know that a lot of researchers in the PEA area offer snippets of computer code in various languages on their web pages. Examples of such web pages include: S. Grosskopf (http://liberalarts.oregonstate.edu/spp/econ/shawna-grosskopf reporting the no longer supported OnFront software developed by EMQab: R. Fare, R. Althin, P. Roos and S. Grosskopf), O. Badunenko (https://sites.google.com/site/obadunenko), R. Sickles (http://rsickles.rice.edu/efficiency-software/, Sickles and Zelenyuk (2018) with the site https://sites.google.com/site/productivityefficiency/home), H.-J. Wang (http://homepage.ntu.edu.tw/~wangh/#professional), among others. However, we believe

that to systematically collect all such web sites and report results in a meaningful way is promising work for the future.
3. This is coherent with the main aim of this survey: that is, to present the state of the art of the existing software options, without entering into a full scale analysis of their performance.
4. For example, regression modelling, hypothesis tests, resampling simulations that support confidence intervals and the estimator's consistency, among others.
5. LIMDEP and NLOGIT have separate prices for government and non-profit organizations. NLOGIT includes all features of LIMDEP plus an estimation component for multinomial choice modelling.
6. An open source version is available: Octave.
7. AMPL code can be run in some open source MP solvers: see http://ampl.com/products/solvers/open-source/.

References

Aiello, F. and Bonanno, G. (2016) Efficiency in banking: a meta-regression analysis. *International Review of Applied Economics* 30(1): 112–149.

Aigner, D., Lovell, C.A.K. and Schmidt, P. (1977) Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics* 6(1): 21–37.

Akçay, A.E., Ertek, G. and Büyüközkan, G. (2012) Analyzing the solutions of DEA through information visualization and data mining techniques: SmartDEA framework. *Expert Systems with Applications* 39(9): 7763–7775.

Álvarez, I.C., Barbero, J. and Zofío, J.L. (2016) A Data Envelopment Analysis toolbox for Matlab. Universidad Autónoma de Madrid, Department of Economic Analysis (Economic Theory and Economic History), No. 2016/03.

Andersen, P. and Petersen, N.C. (1993) A procedure for ranking efficient units in data envelopment analysis. *Management Science* 39(10): 1261–1264.

Argyrioy, G. and Sifaleras, A. (2013) An AMPL optimization software library for Data Envelopment Analysis. XI Balkan Conference on Operational Research (BALCOR 2013), Belgrade-Zlatibor, Serbia

Arickx, F., Broeckhove, J., Dejonghe, M. and van den Broeck, J. (1997) BSFM: a computer program for Bayesian stochastic frontier models. *Computational Statistics* 12(3): 403–421.

Badin, L., Daraio, C. and Simar, L. (2013) CONDEFF: A Toolbox for Conditional Efficiency Measurement, XIII EWEPA 2013, Helsinki, June.

Badunenko, O. and Mozharovskyi, P. (2016) Nonparametric frontier analysis using Stata. *Stata Journal* 16(3): 550–589.

Badunenko, O., Kolomiytseva, Y. and Mozharovskyi, P. (2017) Package 'npsf'. Available at https://cran.rproject.org/web/packages/npsf/npsf.pdf. Accessed 9 February 2017.

Banker, R.D., Charnes, A. and Cooper, W.W. (1984) Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science* 30(9): 1078–1092.

Barr, R.S. (2004) DEA software tools and technology. In W.W. Cooper, L.M. Seiford and J. Zhu (eds.), *Handbook on Data Envelopment Analysis* (pp. 539–566). Boston: Kluwer.

Barr, R.S. and Durchholz, M.L. (1992) Parallel software for large-scale Data Envelopment Analysis. In Joint National Meeting of ORSA and TIMS, San Francisco.

Battese, G.E. and Coelli, T.J. (1988) Prediction of firm level technical inefficiencies with a generalised frontier production function and panel data. *Journal of Econometrics* 38(3): 387–399.

Battese, G.E., Coelli, T.J. and Colby, T.C. (1989) Estimation of frontier production functions and the efficiencies of Indian farms using panel data from ICRISAT's village level studies. *Journal of Quantitative Economics* 5(2): 327–348.

Belotti, F., Daidone, S., Ilardi, G. and Atella, V. (2013) Stochastic frontier analysis using Stata. *Stata Journal* 13(4): 718–758.

Bogetoft, P. and Otto, L. (2010) *Benchmarking with DEA, SFA, and R*. New York: Springer.

Bogetoft, P. and Otto, L. (2015) Package 'Benchmarking'. Available at ftp://sunsite2.icm.edu.pl/packages/cran/web/packages/Benchmarking/Benchmarking.pdf. Accessed 30 January 2017.

Bravo Ureta, B., Solís, D., Moreira López, V.H., Maripani, J.F., Thiam, A. and Rivas, T. (2007) Technical efficiency in farming: a meta-regression analysis. *Journal of Productivity Analysis* 27(1): 57–72.

Ceyhan, M.E. and Benneyan, J.C. (2010) Data envelopment analysis spreadsheet software for conventional DEA models and estimated proportions. In Proceedings of the IIE Annual Conference. Institute of Industrial Engineers-Publisher.

Chang, Y.L. and Sueyoshi, T. (1991) An interactive application of data envelopment analysis in microcomputers. *Computational Economics* 4(1): 51–64.

Charnes, A., Cooper, W.W. and Rhodes, E. (1978) Measuring the efficiency of decision making units. *European Journal of Operational Research* 2(6): 429–444.

Charnes, A., Cooper, W.W., Golany, B., Seiford, L.M. and Stutz, J. (1985) Foundations of data envelopment analysis and Pareto-Koopmans empirical production functions. *Journal of Econometrics* 30(1–2): 91–107.

Charnes, A., Cooper, W.W., Lewin, A.Y. and Seiford, L.M. (1994) DEA software packages. In A. Charnes, W.W. Cooper, A.Y. Lewin and L.M. Seiford (eds.), *Data Envelopment Analysis: Theory, Methodology, and Applications* (pp. 89–94). New York: Springer.

Chatzigeorgiou, A. and Stiakakis, E. (2011) Benchmarking library and application software with Data Envelopment Analysis. *Software Quality Journal* 19(3): 553–578.

Chen, Y. and Zhu, J. (2004) Measuring information technology's indirect impact on firm performance. *Information Technology and Management Journal* 5(1–2): 9–22.

Cheng, G. (2014) *Data Envelopment Analysis: Methods and MaxDEA Software*. Beijing: Intellectual Property Publishing House Co. Ltd.

Cheng, G. and Qian, Z. (2011) *MaxDEA manual*. Peking University, Beijing, China.

Coelli, T. and Henningsen, A. (2013) Package 'frontier'. Available in ftp://gnu.cs.pu.edu.tw/network/CRAN/web/packages/frontier/frontier.pdf. Accessed 1 February 2017.

Coelli, T.J. (1996a) A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation, Working Paper 96/7, Centre for Efficiency and Productivity Analysis – CEPA, Department of Econometrics, University of New England, Armidale, NSW, Australia.

Coelli, T.J. (1996b) A guide to DEAP version 2.1: a data envelopment analysis (computer program), Centre for Efficiency and Productivity Analysis – CEPA, Department of Econometrics: Working paper 96/08, University of New England, Armidale.

Coelli, T.J. (1997) A Guide to TFPIP Version 1.0: A Total Factor Productivity Index (Computer) Program. Department of Econometrics, University of New England, Armidale.

Coelli, T.J., Rao, D.S.P., O'Donnell, C.J. and Battese, G.E. (2005) *An Introduction to Efficiency and Productivity Analysis*. 2nd ed., New York: Springer.

Cooper, W.W., Seiford, L.M. and Tone, K. (2006) *Introduction to Data Envelopment Analysis and Its Uses: With DEA-Solver Software and References*. New York: Springer.

Dakpo, K.H., Desjeux, Y. and Latruffe, L. (2016) Package 'Productivity'. Available at https://cran.rproject.org/pub/R/web/packages/productivity/productivity.pdf. Accessed 9 February 2017.

Daouia, A., Laurent, T. and Laurent, M.T. (2015) Package 'frontiles'. Available at https://cran.r-project.org/web/packages/frontiles/frontiles.pdf. Accessed 2 December 2016.

Daouia, A., Laurent, T., and Noh, H. (2017) Package 'npbr'. Available at https://cran.r-project.org/web/packages/npbr/npbr.pdf. Accessed 20 May 2018.

Daraio, C. and Simar, L. (2007) Advanced Robust and Nonparametric Methods in Efficiency Analysis. *Methodology and Applications*. New York: Springer.

Del Gatto, M., Di Liberto, A. and Petraglia, C. (2011) Measuring Productivity. *Journal of Economic Surveys* 25(5): 952–1008.

Deprins, D., Simar, L. and Tulkens, H. (1984) Measuring labor-efficiency in post offices. In: M.G. Marchand, P. Pestieau and H. Tulkens (eds.), *The Performance of Public Enterprises: Concepts and Measurement* (pp. 243–267). Amsterdam: Elsevier.

Desjeux, Y. (2017) Package 'sfadv'. Available at https://cran.r-project.org/web/packages/sfadv/sfadv.pdf. Accessed 20 May 2018.

Diaz-Martinez, Z. and Fernandez-Menendez, J. (2008) The DEA package. Version 0.1–2. Available at http://cran.rproject.org/web/packages/DEA/DEA. Accessed 2 December 2016.

Emrouznejad, A. (2005) Measurement efficiency and productivity in SAS/OR. *Computers and Operations Research* 32(7): 1665–1683.

Emrouznejad, A. and Thanassoulis, E. (2009) Managing performance of organisational units with PIMsoft: a new DEA software. 23rd European Conference on Operational Research, Bonn, Germany.

Fernández-Montes, A., Velasco, F. and Ortega, J.A. (2012) Evaluating decision-making performance in a grid-computing environment using DEA. *Expert Systems with Applications* 39(15): 12061–12070.

Ferrara, G. and Vidoli, F. (2015) Package 'semsfa'. Available at https://cran.rproject.org/web/packages/semsfa/semsfa.pdf. Accessed 30 January 2017.

Ferris, M.C. and Voelker, M.M. (2002) Slice models in general purpose modeling systems: an application to DEA. *Optimization Methods and Software* 17(6): 1009–1032.

Fisher, I. (1922) *The Making of Index Numbers: A Study of their Varieties, Tests, and Reliability*. Boston: Houghton Mifflin.

Fusco, E. and Vidoli, F. (2015) Package 'ssfa'. Available at https://cran.r-project.org/web/packages/ssfa/ssfa.pdf. Accessed 30 January 2017.

Green, R.H. (1996) DIY DEA: implementing data envelopment analysis in the mathematical programming language AMPL. *Omega* 24(4): 489–494.

Greene, W. (1995) *LIMDEP (Version 7): User's Manual and Reference Guide*. New York: Econometric Software Inc.

Greene, W. (2002) *NLOGIT: Version 3.0: Reference Guide*. New York: Econometric Software Inc.

Greene, W. (2007) *LIMDEP 9.0 reference guide*. Plainview, NY: Econometric Software Inc.

Griffin, J.E. and Steel, M.F. (2007) Bayesian stochastic frontier analysis using WinBUGS. *Journal of Productivity Analysis* 27(3): 163–176.

Herrero, I. and Pascoe, S. (2002) Estimation of technical efficiency: a review of some of the stochastic frontier and DEA software. *Computers in Higher Education Economics Review* 15(1): 38–43.

Higgins, J.P. and Green, S. (eds.), (2011) *Cochrane Handbook for Systematic Reviews of Interventions*. London: John Wiley & Sons.

Hollingsworth, B. (1999) Data envelopment analysis and productivity analysis: a review of the options. *Economic Journal* 109(456): F458–F462.

Hollingsworth, B. (2004) Non parametric efficiency measurement. *Economic Journal* 114(496): F307–F311.

Hussain, A. and Jones, M. (2001) *An Introduction to Frontier Analyst*. Kendal: Banxia Software.

Iliyasu, A., Mohamed, Z.A., Terano, R. and Malaysia, S.M. (2015) Data envelopment analysis models and software packages for academic purposes. *Pertanika Journal of Scholarly Research Reviews* 1(1): 27–32.

Jablonsky, J. (2014) MS Excel based software support tools for decision problems with multiple criteria. *Procedia Economics and Finance* 12, 251–258.

Ji, Y.B. and Lee, C. (2010) Data envelopment analysis. *Stata Journal* 10(2): 267–280.

Johnson, A.L. and McGinnis, L.F. (2011) Performance measurement in the warehousing industry. *IIE Transactions* 43(3): 203–215.

Johnson, A.L., Chen, W.-C. and McGinnis, L.F. (2010) Large-scale Internet benchmarking: technology and application in warehousing operations. *Computers in Industry* 61(3): 280–286.

Kalvelagen, E. (2002) *Efficiently Solving DEA Models with GAMS*. Washington: GAMS Development Corporation.

Korösi, G., Matyas, L. and Székely, I. (1993) Comparative review of some econometric software packages. *Journal of Economic Surveys* 7(1): 105–118.

Kumbhakar, S.C. and Wang, H.J. (2015) Estimation of technical inefficiency in production frontier models using cross-sectional data. In S.C. Ray, S.C. Kumbhakar and P. Dua (eds.), *Benchmarking for Performance Evaluation: A Production Frontier Approach* (pp. 1–73). New Delhi: Springer.

Kumbhakar, S.C., Wang, H.J., and Horncastle, A.P. (2015) *A Practitioner's Guide to Stochastic Frontier Analysis Using Stata*. Cambridge: Cambridge University Press.

Lai, M.-C., Wang, W.-K., Huang, H.-C. and Kao, M.-C. (2011) Linking the benchmarking tool to a knowledge-based system for performance improvement. *Expert Systems with Applications* 38(8): 10579–10586.

Ley, E. (1996) Data screening and data envelopment analysis. In H. Varian (ed.), *Computational Economics and Finance: Modelling and Analysis with Mathematica* (pp. 120–130). New York: Springer-Telos.

Li, R.C., Tangsoc, J.C., See, S.L., Cantor, V.J.M., Tan, M.L.L. and Rachelle, J.S.Y. (2016) A DEA-based performance measurement mathematical model and software application system applied to public hospitals in the Philippines. *DLSU Business and Economics Review* 25(2): 166–196.

Lim, D. and Anderson, T. (2012) An introduction to technology forecasting with a TFDEA Excel Add-in, 1293–1298. In PICMET'12: Technology Management for Emerging Technologies.

Lim, D.-J. (2016) Package 'DJL'. Available at https://cran.r-project.org/web/packages/DJL/DJL.pdf. Accessed 16 February 2018.

Malmquist, S. (1953) Index numbers and indifference surfaces. *Trabajos de Estatistica* 4, 209–242.

Meza, L.A., Biondi Neto, L., Mello, J., Gomes, E.G. and Coelho, P.H.G. (2004) FSDA–Free Software for Decision Analysis (SLAD–Software Livre de Apoio à Decisão): a software package for data envelopment analysis models. In Congreso Latino-Iberoamericano De Investigación Operativa–Claio.

Meza, L.A., Biondi Neto, L., Mello, J.C.C.B.S. and Gomes, E.G. (2005) ISYDS-Integrated System for Decision Support (SIAD-Sistema Integrado de Apoio à Decisão): a software package for data envelopment analysis model. *Pesquisa Operacional* 25(3): 493–503.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D.G. and Group, P. (2009) Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 6(7): e1000097, 1–6.

Morgunov, E.P. (2005) Theory and practice of computer technologies used for creating DEA software. Siberian State Aerospace University, Krasnoyarsk, Russia. Available at http://morgunov.org/docs/paper36.pdf. Accessed 9 February 2017.

Murillo-Zamorano, L.R. (2004) Economic efficiency and frontier techniques. *Journal of Economic Surveys* 18(1): 33–77.

Odeck, J. and Bråthen, S. (2012) A meta-analysis of DEA and SFA studies of the technical efficiency of seaports: a comparison of fixed and random-effects regression models. *Transportation Research* 46A(10): 1574–1585.

O'Donnell, C.J. (2008) An Aggregate Quantity-Price Framework for Measuring and Decomposing Productivity and Profitability Change. Centre for Efficiency and Productivity Analysis Working Papers WP07/2008. University of Queensland.

O'Donnell, C.J. (2010) DPIN version 1.0: a program for decomposing productivity index numbers (No. WP012010). School of Economics, University of Queensland, Australia.

Oh, D.-H. and Suh, D. (2013) Package 'nonparaeff'. Available at https://cran.r-project.org/web/packages/nonparaeff/nonparaeff.pdf. Accessed 30 January 2017.

Olesen, O.B. and Petersen, N.C. (1996) A presentation of GAMS for DEA. *Computers and Operations Research* 23(4): 323–339.

Parmeter, C.F. and Kumbhakar, S.C. (2014) Efficiency analysis: A primer on recent advances. *Foundations and Trends in Econometrics* 7(3–4): 191–385.

Pasupathy, K.S. and Medina-Borja, A. (2008) Integrating excel, access, and visual basic to deploy performance measurement and evaluation at the American red cross. *Interfaces* 38(4): 324–337.

Pavlyuk, D. (2016) Package 'spfrontier'. Available at https://cran.r-project.org/web/packages/spfrontier/spfrontier.pdf. Accessed 30 January 2017.

Petticrew, M. and Roberts, H. (2006) *Systematic Reviews in the Social Sciences: A Practical Guide*. Malden: Blackwell.

Pitt, M.M. and Lee, L.F. (1981) The measurement and sources of technical inefficiency in the Indonesian weaving industry. *Journal of Development Economics* 9(1): 43–64.

Podinovski, V.V. (2004) Production trade-offs and weight restrictions in data envelopment analysis. *Journal of the Operational Research Society* 55(12): 1311–1322.

Puthanpura, A.K. (2018) Package 'Compind'. Available at https://cran.r-project.org/web/packages/Compind/Compind.pdf. Accessed 20 May 2018.

Ramanathan, R. (2003) *An Introduction to Data Envelopment Analysis: A Tool for Performance Measurement*. New Delhi: Sage.

Reifschneider, D. and Stevenson, R. (1991) Systematic departures from the frontier: a framework for the analysis of firm inefficiency. *International Economic Review* 32(3): 715–723.

Rosko, M.D. and Mutter, R.L. (2011) What have we learned from the application of stochastic frontier analysis to U.S. hospitals? *Medical Care Research and Review* 68(1S): 75S–100S.

Samoilenko, S. and Osei-Bryson, K.-M. (2013) Using Data Envelopment Analysis (DEA) for monitoring efficiency-based performance of productivity-driven organizations: design and implementation of a decision support system. *Omega* 41(1): 131–142.

Scheel, H. (2000) EMS: Efficiency Measurement System User's Manual. *Operations Research and Wirtschaftsinformatik*. Germany: University of Dortmund.

Sena, V. (1999) Stochastic frontiers estimation: a review of the software options. *Journal of Applied Econometrics* 14(5): 579–586.

Shott, T. and Lim, D.-J. (2015) Package 'TFDEA'. Available at https://cran.r-project.org/web/packages/TFDEA/TFDEA.pdf. Accessed 30 January 2017.

Sickles, R.C. and Zelenyuk, V. (2018) *Measurement of Productivity and Efficiency: Theory and Practice*. Cambridge: Cambridge University Press, *forthcoming*.

Simm, J. and Besstremyannaya, G. (2016) Package 'rDEA', Version 1.2-5. Available at https://cran.r-project.org/web/packages/rDEA/rDEA.pdf. Accessed 16 February 2018.

Soteriades, A.D. (2017) Package 'additiveDEA'. Available at https://cran.r-project.org/web/packages/additiveDEA/additiveDEA.pdf. Accessed 8 August 2017

Stamelos, I., Angelis, L., Oikonomou, A. and Bleris, G.L. (2002) Code quality analysis in open source software development. *Information Systems Journal* 12(1): 43–60.

Stevenson, R.E. (1980) Likelihood function for generalized stochastic frontier estimation. *Journal of Econometrics* 13(1): 57–66.

Straub, A. (2015) Package 'sfa'. Available at https://cran.rproject.org/web/packages/sfa/sfa.pdf. Accessed 2 December 2016.

Tauchmann, H. (2012) Partial frontier efficiency analysis. *Stata Journal* 12(3): 461–478.

Thanassoulis, E. (2001) *Introduction to the Theory and Application of Data Envelopment Analysis: A Foundation Text with Integrated Software*. New York: Springer.

Tone, K. (2001) A slacks-based measure of efficiency in data envelopment analysis. *European Journal of Operational Research* 130(3): 498–509.

Tone, K. and Tsutsui, M. (2009) Network DEA: a slacks-based measure approach. *European Journal of Operational Research* 197(1): 243–252.

Tone, K. and Tsutsui, M., (2010) Dynamic DEA: a slacks-based measure approach. *Omega* 38(3–4): 145–156.

Tone, K. and Tsutsui, M. (2014) Dynamic DEA with network structure: a slacks-based measure approach. *Omega* 42(1): 124–131.

Törnqvist, L. (1936) The Bank of Finland's Consumption Price Index. *Bank of Finland Monthly Bulletin* 10: 1–8.

Tranfield, D., Denyer, D. and Smart, P. (2003) Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management* 14(3): 207–222.

Van Eck, N.J. and Waltman, L. (2010) Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84(2): 523–538.

Van Eck, N.J. and Waltman, L. (2014) Visualizing bibliometric networks. In Y. Ding, R. Rousseau and D. Wolfram (eds.), *Measuring Scholarly Impact* (pp. 285–320). Springer.

Vidoli, F. and Fusco, E. (2018) Package 'MultiplierDEA'. Available at https://cran.r-project.org/web/packages/MultiplierDEA/MultiplierDEA.pdf. Accessed 20 May 2018.

Von Krogh, G. and Von Hippel, E. (2006) The promise of research on open source software. *Management Science* 52(7): 975–983.

Wang, W.K. (2005) A knowledge-based decision support system for measuring the performance of government real estate investment. *Expert Systems with Applications* 29(4): 901–912.

Wei, Q., Zhang, J. and Zhang, X. (2000) An inverse DEA model for inputs/outputs estimate. *European Journal of Operational Research* 121(1): 151–163

Wilson, P.W. (2008) FEAR: a software package for frontier efficiency analysis with R. *Socio-Economic Planning Sciences* 42(4): 247–254.

Wilson, P.W. (2014) Package 'FEAR'. Available at http://www.clemson.edu/economics/faculty/wilson/software/FEAR/Compiled/2.0.1/FEAR-manual.pdf. Accessed 30 January 2017.

Worthington, A.C. (2014) A review of frontier approaches to efficiency and productivity measurement in urban water utilities. *Urban Water Journal* 11(1): 55–73.

Yousefi, A. and Hadi-Vencheh, A. (2010) An integrated group decision making model and its evaluation by DEA for automobile industry. *Expert Systems with Applications* 37(12): 8543–8556.

Zhu, J. (2014) *Quantitative Models for Performance Evaluation and Benchmarking Data Envelopment Analysis with Spreadsheets*. 3th ed. New York: Springer.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Online Appendix
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Table 2A. Comparative Analysis based on available documentation
Table 1B. Keywords Occurrences and Link Strength in the Documentation Network
Table 1C. 34 Original Relevant Documents (expert-based). Descriptive Information from Google Scholar (Last updated: Feb 9, 2017)
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Figure 1B. Clusters of Key Terms and Expressions related to Table 1 and 2 documents
Figure 2B. Density Map of Key Terms and Expressions related to Tables 1 and 2 documents