REFLECTIONS ON DISCUSSIONS ABOUT TECHNICAL EFFICIENCY OF INNOVATIVENESS OF COUNTRIES

Wojciech NASIEROWSKI

Warsaw University of Technology, Faculty of Management, Department of Management Systems, Warsaw, POLAND

e-mail: nasierow@unb.ca; www.wnasierowski.pl

Abstract: The objective of this article is to outline various drawbacks of the studies on technical efficiency of pro-innovation activities at a national level. A better awareness of existing constraints may assist the readers and reviewers of the relative reports in a more critical assessment of the presented results and help in planning the research. This article outlines several methodological problems faced with conducting research on the technical efficiency of innovations. On the basis of the review of the subject-related literature, as well as press releases, numerous restraints prevailing in the currently used research approaches are presented. Some of these precincts are evidenced in the used methods: other may be rooted in the non-scientifically related intentions of the authors. Frequently, observations may drive the audience to the incorrect conclusions and opinions. The awareness of the consequences of these limitations may serve as a warning about the reliability of the results, their applicability for crafting policies, and country-to-country comparisons. However, various limitations originate from the very nature of the theme. Several propositions are specified about items to be kept in mind in order to minimize the negative impact caused by existing drawbacks. These may serve as a guide to formulate research questions and hypotheses for verification in further studies. While each of the propositions stated independently may be labeled obvious, their simultaneous review many contribute to the streamlining further research and in the improvement of the quality of suggestions arrived at. The conclusions from the article may also pinpoint to these methodological issues that cause some of the publications on the subject to be of questionable value.

Keywords: innovation, technical efficiency, methodology, research questions.

JEL: B41, Q3, M20.

1 Introduction

Innovations are considered key elements in a country's economic prosperity. Not surprisingly, they are of pivotal interest to governments, entrepreneurs, executives, and academics. Notions such as innovation, creativity, and competitiveness, accompanied by global political change, and technological progress and productivity have gained special attention. Providing references to publications on these subjects will produce a long list and will be incomplete. Despite a proliferation of studies on technical efficiency of innovations, there are several constraints that frequently are not acknowledged, yielding results with limited practical value. This article is based on the review of the subject-related reports. It presents some of the limitations that both researchers and those who choose to use these study results should be aware of. Some propositions worth further examination are outlined. No classical outline based on hypotheses testing is adopted. Instead, the following four sections illustrate problems experienced when investigating technical efficiency of innovations: definitions, data, methodology, and objectives. The conclusion summarizes suggestions for further ideas and investigation on the improvement of approaches to studies on technical efficiency of innovations.

2 Definitions of innovations/innovativeness

The concepts of innovations and innovativeness are debatable. What exactly constitutes an innovation, or how an innovation is defined, is not universally agreed upon (Nasierowski and Arcelus, 2012; INNO, 2006). According to Oslo Manual (OM, 2005) and Frascati Manual (FM, 2015), interpretations seemed to have dominated the European line of thinking about these constructs. They appeared to be a standard and a prerequisite of the academically accepted discussion on the subject there: other approaches prevail in many countries outside the European Union. Irrespective of the definition of innovation (invention, research and development (R&D), research and innovation (R&I), or the like), there are problems with operationalization of these concepts. It is probably impossible for an independent researcher to provide a definition for innovation, predisposed for operationalization, that will be widely accepted. Consequently, it is expedient to accept that the definition of innovation is an indicatum type because it is included in the description of the discussed object. It is a terminological, not an empirical definition (Nowak, 1965, pp.245-281). Under such constraints, intuitive understanding of the concept of innovativeness may be necessitated, although it may affect the precision of any discussion about this concept.

This situation is quite similar to psychological studies, in which the lack of a sharp definition for intelligence is pragmatically filled by equating intelligence with Intelligence Quotient (IQ) test results. The value of IQ is considered to be an objective measure. However, because intelligence is nearly impossible to define precisely, controversies surround the IQ tests. There is a debate about what exactly they measure, and whether or not they indeed measure any objective value. Researchers of innovativeness may be forced to accept that innovations are what composite indexes of innovativeness indicate, or what, for example, data series used to describe it indicate.

The notions of invention, and associated R&D, as well as innovation are becoming somewhat outdated and do not correspond to the contemporary challenges of changing technology and socioeconomic trends. Innovation versus invention is explained by the Oslo Manual and the Frascati Manual. When a thesaurus is referred to, these notions are listed as synonyms. There are also pivotal differences between technical efficiency and allocative efficiency. Distinctions are often overlooked, especially in publications and presentations that do not have a scientific and/or business background, or are directed to a broad audience. Such deficiency in precision and accuracy, if overlooked, may easily lead to misinterpretation of the results of the studies that have been carried out or, at a minimum, may create confusion. Furthermore, at times reports, and even composite indexes that have the word innovation in their title, use data mostly related to inventiveness (variety of R&D counts, patents) and not data directly related to innovations or innovativeness. Also there seems to be more focus on product-related data series, instead of on service or on non-technological developments. The number of doctoral degrees used to indicate dedication to innovativeness may serve as a casual example of such concerns. Solutions used on the rice fields in Vietnam or Indonesia are breathtaking. Probably these have been developed by people with no formal schooling, yet still exemplify innovative solutions. Outstanding financial and prestigious successes are at times achieved by entrepreneurs without university degrees: B. Gates and Microsoft, S. Jobs and Apple. Thus, the expectation of a certain level of various educational attainments to indicate the levels of innovativeness may be deemed incomplete. Although difficult to grasp, some data series related to levels of creativity, innovative drive in the society, and conditions that allow an outside the box thinking should be entered into any discussion on innovativeness.

At present, the concept of the responsible R&I challenges our way of thinking about technological progress: from science in society to science for society, with society (Owen, et al., 2012). However, there is no universal interpretation of R&I, and as a consequence, there is no unequivocal guide to how to interpret and operationalize the concept.

Proposition 1: Semantic (terminology, definitions) differences mean that the discussion on efficiency of innovations will be plagued with imprecision and controversies.

Proposition 2: As a consequence of the context, country-to-country comparisons may bring limited advantages. Policies of innovation management intended to improve the technical efficiency are difficult to transfer across cultural and economic borders. This reflection does not preclude the usefulness of such discussions. One perspective may enrich another view. The expectation that arguments about the issue will bring ready-to-be-used practical blueprints is flawed.

3 Data used in the studies on technical efficiency of innovations

Research on technical efficiency of innovations has to be based on data – inputs that describe investment in innovations and outputs that describe produced results. One of the key concerns rests with the dilemma of what data series should be used. The question is the consequence of the imprecision of definitions addressed in the earlier section. On the output side, the question can be answered from the perspective of the objectives of the study (or some aspects of allocative efficiency that will be concisely mentioned in Section 5). By their nature, as evidenced in many reports on the subject, either set of these data are aggregated and have some historical nature. This situation poses several queries.

3.1 Historical data

"How old is outdated?" When talking about innovations, two types of situation may ensue. The first deals with traditional, conservative, stable sectors referred to at times as low R&D intensity sectors, where progress is recorded slowly and the experience from the past can be extrapolated into a future. Then, data from statistical offices may be of a great value.

The second deals with fast-growing sectors. Inventions/innovations occur there rapidly, frequently in new market niches that call for prompt reactions to create an opportunity to have the benefit of first mover advantages. To this end, one may resort to the use of BIG data, which is also an emerging concept when investigating efficiency of innovations at the country level (EISb, 2018).

Proposition 3: The use of new concepts for data collection – BIG data, for example – may be needed to explore issues of innovativeness in the fast-growing sectors. Historical data may be almost useless in this area.

3.2 Slack

What is the delay between data collection and production of results that may be used for practical purposes? Normally, current efforts do not contribute instantly to the current results. In most of the composite indexes about ranking countries (e.g., WCY, 2018; GCR, 2018; GII, 2018; KAM, 2019), and on innovativeness (e.g., European Innovation Scoreboard [EIS]), the "current" inputs are matched with "current" outputs, which is fundamentally incorrect. The notion of a slack is difficult to grasp: e.g., how far into the past it should be examined. For example, data normally used in indexes of innovativeness/competitiveness use education expenditures as one of the input data. Indeed, investment in basic schooling, extended to graduation, and then to acquiring skills needed as an independent researcher may exceed 25 years. Generally, investigating time slacks at a country level seems to be a fruitless effort. At the company level, such slack can, in some instances, be documented. Caballero (2014) investigated the slack between R&D personnel as an input and the total number of patents and registered trademarks and observed a 2-year delay.

Proposition 4: Even though the issue of slack is difficult to grasp, it should not be ignored.

3.3 Aggregated data

The available data series are at a high level of aggregation, making pin-pointing suggestions as to what specifically should be improved nearly impossible. For example, the doctoral degree counts are used as a measure of a level of innovation capacity. However, normally, doctoral degrees in music or political sciences have a different impact on innovations than doctoral degrees in biology or electronics. All such degrees may shed light on innovativeness of the society but not on the propensity for developing a commercial application of new ideas. This leads to the situation where suggestions arrived at are very general. Should detailed data become available, the results of simulation experiments with possible solutions may highlight means and areas that may call for special attention in an attempt to improve technical efficiency of innovations.

The use of an aggregate of some inputs may create further confusion because there is no chance to link these expenditures directly to future contributions to innovations. This may be particularly acute in the case of:

1) Education – deciding which specific courses and which teaching methods have the greatest impact on the development of innovative/creative skills and which stimulate attitudes. mathematics, physics, informatics, biology, chemistry, and logics in preuniversity education may be assumed to be among disciplines that contribute to enhanced desires and skills in innovativeness. Knowledge and appreciation of these disciplines form the foundation that assists future inventors, innovators, and entrepreneurs. However, it is more a hypothesis than a scientifically and practically evidenced assumption. Furthermore, in some composite indexes, EIS, for example, counts of foreign students and graduates are used. It should be remembered that the choice of an overseas location for studies depends on many criteria selected by students and the assessment of appeal of the location; and

2) R&I (R&D) – which may focus on commercial results or look for prestigious types of scientific outcomes. As well, concentration on product or process innovations may be a reflection of varying attitudes of researchers and priorities of strategic economic outcomes.

Proposition 5: The use of aggregate data prevents the formulation of suggestions for policy improvement in the area of innovation management because of a very different pattern of R&I present in different countries and economic sectors.

3.4 Measuring innovations

Suggestions as to how to measure and collect data about innovativeness have been presented, for example, by Borrás and Edquist (2016), Gault (2013), OECD (2008, 2010), and Arundel and Hollanders (2005). The easily accessible data about innovations can be found, for example, in rankings of countries that allow the development of composite indexes of innovations. Frequently used sources include EISa (2018), World Competitiveness Yearbook (WCY, 2017), Global Competitiveness Report (GCR, 2018), Global Innovation Index (GII, 2018), Human Development Index (HDI, 2014), and Knowledge Assessment Methodology (KAM, 2019), to name only a few. There are also specific innovation measurement frameworks developed in South Korea, China, Japan, Germany, as well as the Global Innovation Index (EISa, 2018, pp.9-24). These scales are not free of drawbacks (even if the issue of missing values is overlooked), but they have been recognized as options used within the field. Data series are at times flawed with critical errors. In some instances, systems responsible for data collection can be questioned, as observed with respect to the World Competitiveness Yearbook (WCY, 2017), for example. On other occasions, as noticed in EIS, when new data series are entered to the index, some countries, such as Cyprus, Malta, and Turkey, report values for data that are vastly different from observable patterns, which is difficult to explain.

Proposition 6: There is no consistent framework for measuring innovations. It may be helpful to use one, or to develop another one, following a clear definition of what is measured (innovation) and what is its purpose for the presentation of the results.

3.5 Outliers

One of the dilemmas in an attempt to use findings from studies on efficiency of innovations to craft policy-related suggestions deals with the homogeneity – comparability – of countries in the examined set of countries. The problem stemming from outliers is one of the elements responsible for such a problem. The issue of outliers may be especially visible in terms of comparisons from the viewpoint of size (e.g., GDP or population counts – Germany vs. Iceland), and wealth (e.g., PPP – Luxemburg vs. Bulgaria). The answer to related questions may lead to a discussion on the selection of countries that are somewhat similar (because of size, wealth). Within studies on technical efficiency size, wealth, experience may be irrelevant to the assessment of efficiency. There is not a convincing argument as to whether "big" or "small" countries should be removed and which criterion can be decisive to do so. It may be questioned whether China and Iceland, for example, could be compared in a single study under the assumption that the size may be associated with benefits stemming from organizational synergies.

A related issue can be traced to comparisons of different provinces in Canada, Germany, or China as reported in some composite indexes.

Proposition 7: The issue of outliers (here: countries with very big/small values of some indicators) should be taken into account, especially with respect to the existence of possible synergies affecting innovativeness activities. The impact of outliers may be regarded as marginal in the case of technical efficiency. When examining the allocative efficiency, the issue of outliers must not be overlooked.

3.6 Distinguishing inputs from outputs and grouping of data pertinent to innovations

Indiscriminately adding standardized values of data, irrespective of whether they indicate inputs to or outputs from innovation as is practiced in composite indexes may be convenient for public relations purposes. It is not useful as a means to support any policy-type initiatives. The unequivocal distinction between inputs and outputs is prone to creating controversies. What is an input and what is an output may also depend on the objectives of the study. For example, employment in R&D may be an output, a consequence of investment in R&D, and, concurrently, an output in terms of creation of commercial results.

A similar problem arises when grouping variables for the purpose of the assessment of technical efficiency, for instance, whether inputs or outputs must be grouped in order to facilitate computations of nonparametric tests. At times, "name of data series driven" grouping is used (e.g., EIS methodology). In an unreported report, the factor analysis with Oblimin rotation was used to identify such groups. Elements (data series) with values lower than 0.5 in the anti-image correlation matrix were eliminated. Standardized values of data $[(x - x_{min})/(x_{max} - x_{min})]$ were used, and any value greater than 1 (along with the examination of scree plots) was set as the benchmark to identify the acceptable number of factors. This approach has not produced convincing results, but the results provide some guidance to group data into inputs and outputs.

Probably, the most important aspect of studies on innovativeness rests with compliance of pro-innovation policies and activities, with the National Innovation System (NIS), of a country, irrespective whether such a system is documented or not. NIS can be defined as "a network of agents and set policies and institutions that affect the introduction of technology that is new to the economy" (Dahlman, 1994, p.541). There is no single definition for NIS (OECD, 1997, 1999; Freeman, 1987; Lundvall, 1992; Nelson, 1993; Patel and Pavitt, 1994; Metcalfe, 1995). Since its emergence as a topic in management literature in the late 1980s, the concept of NIS has undergone significant changes and has been "further elaborated and theoretically underpinned in the early 1990s" (Balazat and Pyka, 2005, p.5). At the outset, NIS served to define the key players related to the innovation process and the scope of their activities. Works by Nelson (1993), Lundval (1992), Dosi, et al. (1988), and Freeman (1995) have not used a standardized structure of presentation of NIS and have dealt with many countries independently, without an attempt to make country-to-country comparisons.

There is a question of measuring and assessing NIS, identification of NIS subsystems, and thereafter their quantification for the purpose of studies on technical efficiency of innovations (Nasierowski and Arcelus, 2003; Kravchenko, 2011). The identification of groups of inputs may be an akin to the specification of NIS subsystems. Such subsystems have been named by several authors as reported by Nasierowski (2009). These are:

- governance of NIS; that is, crafting policies, regulations, and priorities that support innovation, accompanied by assumptions regarding innovation underpinnings within the economy of a country and the society,
- funding of research, commercialization of results, and regulations that foster transfer of technologies to practice,
- improving the quality of human capital (labeled frequently as education) that tailor education systems to produce graduates with entrepreneurial, creative skills,
- direct and indirect supports for innovations via Small and Medium Size Enterprices (SMEs), as

well as accounting and legal practices that stimulate the flourishing of innovation.

These subsystems are consistent with the European Union research and innovation strategy (EU, 2014). Identification of data series to describe such subsystems for a number of countries is a disputable element (also as a consequence of definition-related quandaries). While most subsystems can be somewhat quantified, the problem remains with respect to the governance/management of NIS and with respect to the governance and the policy of technological development of a country and its role in the strategies of sociopolitical development. The task is exceptionally complex and any results disputable. In this area, isolation of issues important to the country-specific economic, social, and cultural characteristics is critical and very diversified. Technical efficiency score – technical efficiency – EFF – in the Data Envelopment Analysis (DEA) calculations may be recommended as a proxy of the quality of governance. Nevertheless, EFF, to a large extent, assesses the quality of the pro-innovation efforts and the integrity of the NIS. Subsequently, the measure of technical efficiency of pro-innovation attempts will become an item used in its measurement.

For inputs, selection of data and grouping them may be regarded as reasonably uncontroversial. Innovations are undertaken as a means to accomplish objectives, but there is a broad range of objectives, and the outcomes that may be desired and are described by different data series. Metrics to describe outputs and the selection of the NIS subsystems may depend on each country's specific policies of economic development, the corresponding priorities, and expected gains from innovations. It may be bewildering complex to identify a set of meaningfully clear objectives common to a variety of countries. These may be among the reasons for problems with the identification of outputs experienced by EIS, as evidenced by frequent changes to data that denote outputs between 2005 and 2017. The set of 5 outcomes, as used by EIS (2018), may not reflect the diversity of objectives followed by the diverse range of countries examined in the report.

Proposition 8: The distinction of what is an input or an output may depend on the objectives of the study, thus grouping data may be examined along the line of thinking about objectives.

Proposition 9: The technical efficiency – EFF (in the DEA methodology) – may be used as a proxy to quality of governance.

A similar problem of grouping data exists when grouping countries in order to show some similarities in their performance results.

Proposition 10: In the case of grouping countries based on an above/below arbitrarily set value of an indicator, it may be worthwhile to use cluster analysis. Such methodology will also facilitate the formulation of more adequate suggestions for crafting policies in countries that are somewhat similar.

3.7 Context

Context within which innovations are developed is an item that gains recognition in the examination of efficiency of innovations. Data that describe context are at times referred to as moderators, or enablers. These are data about existing and difficult to change characteristics of the country (or a situation), where innovations are formed. The examination of such contextual elements is important because similar levels of inputs may produce different levels of outputs subject to the conditions where they are developed. The efficiency can be assessed properly only then when such conditions are taken into account (EISd, 2018).

There is a need to clarify:

- which aspects indeed impact on technical efficiency of innovations and to what extent; and
- which data are or may become available or can be used as a proxy of data that are needed.

The incorporation of enablers (context-related data) into the study marks a relatively new view and is disputed. Also, it may be worth further examining whether "enablers" can form a separate group of inputs or be considered as an element that moderates input–output relationships.

Proposition 11: It is recommended to incorporate the context-related data into any examination of technical efficiency of innovations in order to arrive at results that take into account the conditions where innovations are produced.

3.8 Cross-relationships

There may be cross-relationships among data series used. The use of correlation coefficients to eliminate redundant data series (that essentially report the same aspect) may not be enough. The issue may be that "a" impacts on "b" directly and also indirectly on "b" via "c." Again, keeping other limitations of the study (data series used, their reliability, aggregate format) in mind, resolving quandaries in this area may remain a purely theoretical concept without any promise to yield practical gains worth the effort, yet the problem may exist. Structural equation modeling offers some assistance to cope with this drawback. Furthermore, many elements, such as multicollinearity, measurement error, and omitted variables in the statistical data series used, can weaken the precision of parameter estimates (i.e., any of the examined elements that describe innovations; Chapple, et al., 2005).

Proposition 12: While concern relative to cross-relationships is valid, in light of other dilemmas related to innovation measurement, it may be regarded as negligible.

4 Methodology in the studies on technical efficiency of innovations

When investigating issues of assessment of innovativeness, composite indexes are often used to present the dedication of governments to these initiatives and to rank countries. While such approaches are widely publicized and serve well in media-type/publicity messages, from a practical viewpoint, their usefulness is limited. They also carry serious methodological constraints. Rankings by composite indexes can be interpreted as a proxy of results of assessment of technical efficiency of innovations using DEA. Development of these indexes has powerful and wealthy sponsors such as the World Bank, European Union Commission, United Nations Development Programme, Institut Européen d'Administration des Affaires (INSEAD), and International Institute for Management Development (IMD) to name only a few. Composite indexes algorithms command the forefront of attention. Publications and discussions, whether lauding their merits or panning their shortcomings, are abundant (e.g., Fagenberg, 1994; Freudenberg, 2003; Grupp and Schubert, 2010; Adam, 2014). These indexes contribute to an explanation of how countries are evaluated and ranked, often for public relation purposes. Similar data series and methodology are used to rank a country's dedication to wealth, standard of living, expenditures for education or R&D, and longevity and quality of life and produce statistically similar findings (Nasierowski, 2016).

Technical efficiency of innovations denotes how effectively a country transforms inputs into results. Innovation efficiency can be measured as the ability of firms and agencies in countries to translate inputs into outputs profitably. A country may produce many important innovations but may not meaningfully implement them into products or services, or it may dedicate excessive resources to achieve insufficient outcomes. The assumption behind composite indexes formulation is that some metrics of innovativeness are created based on the data series. Then, each component enters the index with the same weight of importance for all countries. This implies that the process of computation of the index of innovativeness includes the belief that all countries are equally efficient in transforming inputs into outputs. However, it is possible for countries to use varying amounts of resources to produce equivalent amounts of outputs, without the difference being reflected on the index of innovativeness.

Proposition 13: While composite indexes leading to the ranking of countries from the viewpoint of their dedication to pro-innovative activities may be accepted for public relations purposes, the use of methodology that uses efficiency (productivity) measures offer more opportunities to guide policies in support of innovations.

4.1 Calculation of scores

Composite indexes use a list of pre-set data series and then add standardized values of variables to present some result. It is difficult to interpret such a result – what does a sum of inputs and outputs denote? It is reasonable to expect that an object (country) that scores high on inputs will score high on outputs, and, cumulatively, on the final score. Even if the output is somewhat proportionally lower, the sum will still be high, irrespective of whether it denotes contribution to the expected benefits of investment in innovations. Parenthetically, for public relations purposes, it may be enough to sum up inputs or outputs, whichever is more convenient to prove the positive results in terms of innovativeness improvement. The use of a ratio of inputs to outputs is also a choice (a sort of a productivity measure), for example, Edquist (2016), or in a more sophisticated format of DEA results, in order to discuss the merits of pro-innovation initiatives from technical efficiency point of view. It may be more appropriate to depart from a cursory examination of a ratio of inputs to outputs and examine "best-practice frontiers" using the non-parametric DEA method. This means that the measure of technical efficiency (the Farrell Input Saving Measure of Technical Efficiency) is examined as the greatest proportion of inputs that can be reduced and still produce the same output (Färe and Grosskopf, 1998, p.14). Several papers have reported results based on the use of this approach (e.g., Nasierowski, 2010; Nasierowski and Arcelus, 2003; Hollanders and Esser, 2007).

Proposition 14: The development of formulae for productivity measures is the prerequisite for any discussion about technical efficiency of innovations, and the use of DEA methodology is highly recommended.

4.2 Weights of importance

The data series used in composite indexes enter the calculation with the same weight of importance. Such a method is at best imperfect. It is impossible to provide evidence that all types of investment are equally important – for example, that investment in education is equally important to the number of foreign doctoral students (as in the list of variables used in EIS). One of the proposed solutions to this problem rests with the employment of a variety of weighting approaches, such as Panel Data estimations, Analytical Hierarchy Process, Economic Development-Based method (EISa, 2018, pp.51-64). These expert-type approaches can be used to assess how important varying data series are. Despite professionalism and fairness in the expert assessments, there is a serious flaw in such a concept. The opinions, at the country level, will be impacted by the context within which experts operate (e.g., wealth or the size of the country), the evaluation perspective (e.g., economic sector of innovations), and areas of economic priorities of the country they represent (e.g., structure of GDP by economic sector).

Proposition 15: Despite the advantages of employment weighting methods with respect to the data used in composite indexes, the sole idea of weighting will remain controversial. The use of an approach that largely eliminates the need for such a dispute would be recommended: for example, the use of the nonparametric DEA method to measure the technical efficiency of innovations.

4.3 Changes in data series used to measure innovations

The salient objective of the development of composite indexes and rankings of countries refers to the impact of policies on the improvement or the deterioration of a position of a country in comparison to other countries in terms of accomplishments in innovation. The starting point for disagreements rests with objectives set and, therefore, measures taken to achieve them. There is a difficulty in identifying what these objectives are (even if these are described for PR purposes) and quantification of the alleged policies.

Furthermore, there is a problem of changes in the set of data series used in composite indexes for the purpose of ranking. With frequent changes in the set of data series used, it is not possible to use time series examinations. Such a set of persistently used data series can be indicated by an independent researcher, but it is unlikely that it will be broadly accepted as a correct one. This concern is not very precise with respect to general indexes that, by their nature, measure "everything"; however, it is valid with respect to indexes that intend to indicate a specific phenomenon – for example, EIS as a "measure" of innovativeness of the EU countries. These changes in the data series used prevent the use of time series analyses and thus prevent pinpointing the true impact of investments on outcomes.

Proposition 16: A specific index that describes input–output structure immune to changes in data can be developed, yet it will be specific. Because of the set of variables used, it will not mirror observations provided by a well-established, recognized indexes and, therefore, will be exposed to criticism.

4.4 Congestion-related controversies

When using DEA to investigate technical efficiency, the technical efficiency (EFF) is examined as a function of Returns to Scale (RS), Congestion (CON), and Pure Technical Efficiency (PTE) – EFF = RS*CON*PTE. A more precise interpretation of RS and CON in the context of innovations is still missing. Reasons for congestion in pro-innovation efforts and its interpretation are not easy to explain. Congestion refers to additional resources needed to eliminate excess inputs that could have otherwise been used to generate more outputs. In other words, CON exists when increases in one or more inputs can be associated with decreases in one or more outputs. A low CON index, therefore, represents overinvestment or a waste of resources. The value of CON may be a result of overinvestment/underinvestment, ineffective use of resources, and quality of NIS (e.g., organizational aspects related to coordination of various pro-innovation efforts and degree of compliance of educational programs with pro-innovative priorities).

It would be worthwhile to determine to what extent overinvestment, deficient organizational solutions, and the like contribute to congestion. Further to this concern, it is worth mentioning that, at times, solutions considered standard in one country may be regarded as a luxury in another or an unnecessary waste in another. Such interpretations may be sought in the level of wealth, tradition, and accepted cultural and legal norms. The explanation to related questions may be sought by incorporating "enablers" to the study, and a drive to use less aggregate data yet may arrive at the results focused on a narrowly defined segment of the economy or questions related to very specific aspects of innovativeness.

Proposition 17: Examination of congestions and interpretation of its value calls for special attention. A solution or an expenditure that can be regarded standard, that is, typical in one country, may be interpreted as extravagant or a bad solution in another. Such an interpretation may also be the consequence of the contextual situation and be impacted by the level of available resources.

Proposition 18: Both composite indexes and a technical efficiency approach as a basis to rank levels of innovativeness have merits. Adding values of "inputs" to "outputs" – without any weights of importance – results in an intriguing measure that has no resemblance to any interpretation of productivity or efficiency. Such measures, often offered in the composite indexes, can readily be used for public relation purposes. The outcomes achieved with the use of the concept of technical efficiency (DEA) may be used for public relation purposes as well, but it also facilitates the identification of weak points in the current policies.

5 Objectives of the study on technical efficiency of innovations

It is warranted to underline that it is impossible, certainly very difficult, to isolate the impact of innovations from market, political, social, and economic developments on economic growth. It is also important to link concepts of pro-innovative initiatives to the objectives of socioeconomic developments. The separation of discussion on technical efficiency from discussion on allocative efficiency is the first step to introduce clarity. It is assumed that crafting pro-innovation policies may contribute to economic progress and the improvement of competitiveness. The investigation of related issues can be achieved only if data allow such deliberations.

Outcomes of any study on technical efficiency of innovations will depend on the objectives of the study. There are distinctions between academic type approaches versus business-like benefits versus policy-making focus. Each will call for a development of the specific topic-related methodology. Entrepreneurs frequently know how to change ideas into gains and do it. Politicians and governmental officials shape the climate (through policies, rules, and priorities); provide means and, at times, resources to solve problems; and contribute to economic betterment. Each perspective may be associated with different objectives and requires different methodology and data to carry on the study.

When composite sources are used to depict aspects of pro-innovation activities, the above pattern may not be an issue. Such composite indexes will show that "good is good," followed by some ranking based on arbitrarily selected historical data. Essentially, these will have no impact on setting policies. The use of DEA forces more reflection on formulating study objectives. These objectives may call for specific data series that almost certainly will not be available for a broader number of Decision Making Units (DMUs), for example, countries.

Proposition 19: The results from a discussion of technical efficiency in country-to-country comparisons are of limited use because of very different country policies of socioeconomic development, different constraints and context of operation, and priorities of the current governments (which frequently change).

Proposition 20: Similarly, as with differences among countries, patterns of technological development differ substantially between economic sectors. The distinction in high-low R&D sectors may be mitigated by increased lifting of inventions from one sector to another (innovation).

6 Conclusions

A problem occurs in the effort to pinpoint what are indeed the results from the multitude of studies on innovations. Even though the objectives of such studies are spelled out, the precision of the outcomes presented may be challenged. More specifically, what do current results indicate? How can they be translated to guide the application of suggestions to the policies of each country when countries differ greatly from one another, operate in a different context, and may have different objectives.

There are a number of pitfalls when designing a study on innovativeness and when interpreting the results obtained. One of the principal suggestions rests with a clear identification of the purpose of the study – which objectives the results are intended to serve. Definition of the examined object, followed by clearly defined objectives, may drive the selection of variables to be used in the study. The root problem may be in the outdated approaches use aggregate, historical data whereas innovation, in many sectors, calls for a quick response, forward looking, instead of backward-looking thinking to extrapolate toward future needs and goals. One of the issues that exemplify this phenomenon is manifested by the more frequent use of the notion of R&I, to replace R&D normally used for statistical reporting practices.

The presented areas of problems and limitations of studies on efficiency of innovations pose valid questions regarding the usefulness and credibility of the multiplicity of contemporary studies' results. There are problems and limitations that are difficult to resolve, yet these could be explained in order to provide an adequate perspective to the offered outcomes. On the research venue side, several hypotheses worth verification can be presented and the results can be examined before attempts at formulating comprehensive programs for the improvement of methodologies are made. However, even with the current limitations, further efforts in the investigation of technical efficiency of innovations are worth continuing. They broaden our understanding of the complexity and the importance of the subject. This article does not propose ready-to-use suggestions or solutions. It highlights several areas that create problems when investigating innovativeness. At minimum, exposing these quandaries may facilitate how to present and use outcomes, while remaining aware of the kinds of limitations many current reports produce.

7 References

[1] Adam, F., 2014. *Measuring National Innovation Performance*. Heidelberg: Springer Briefs in Economics.

[2] Arundel, A., Hollanders, H., 2005. *Policy Indicators and Targets: Measuring the Impact of Innovation Policies*. Brussels: European Commission.

[3] Balzat, M., Hanusch, H., 2004. Recent Trends in the Research on National Innovation Systems. *Journal of Evolutionary Economics*, 14(2), pp.197-210.

[4] Balzat, M., Pyka, A., 2005. *Mapping National Innovation Systems in the OECD Area* [online] Available at: http://webdoc.sub.gwdg.de/ebook/serien/lm/vwl_diskussionsreihe/279.pdf [Accessed February 1, 2019].

[5] Borrás, S., Edquist, Ch., 2016. *Conceptual Underpinnings for Innovation Policy Design: Indicators and Instruments in Context*. Unpublished paper prepared for the *OECD* Blue Sky Conference III, September 19-21 2016, Ghent, Belgium.

[6] Borrás, S., Edquist, Ch., 2013. *The Choice of Innovation Policy Instruments*. CIRCLE - Center for Innovation, Research and Competences in the Learning Economy. Lund: Lund University.

[7] Caballero, J.R., 2014. *Measuring Innovation Efficiency in Europe. A Färe-Primont TFP Index Approach*. Barcelona: Universitat Autònoma de Barcelona, Department D'Economia Aplicada.

[8] Dahlman, C.J., 1994. Technology Strategy in East Asian Developing Countries. *Journal of Asian Economics*, 5(4), pp.541-572.

[9] Dosi, G., Freeman, C., Nelson, R., Silverberg G. and Soete L., 1988. *Technological Change and Economic Theory*. London: Pinter Publishers.

[10] Edquist, Ch., Zabala Iturriagagtia, J.M., 2018. *Outputs of Innovation Systems: a European Perspective.* Centre for Innovation, Research and competence in the Learning Economy (CIRCLE), Lund University, [online] Available at: https://www.researchgate.net/publication/ 228365493 Outputs_of_ innovation_ systems_ a_European_perspective [Accessed Jan 6, 2019].

[11] Edquist, Ch., 2016. The Swedish National Council: Innovation Policy Governance to Replace Linearity with Holism. *Papers in Innovation Studies,* Paper No. 2016/24, CIRCLE, Lund University, Lund.

[12] EIS, 2005 to 2018. *European Innovation Scoreboard 2017 – Comparative Analysis of Innovation Performance*. Brussels: European Commission, European Trend Chart on Innovation.

[13] EISa, 2018. European Innovation Scoreboard 2018. Discussion Paper. *Workshop on the European Innovation Scoreboard: Perspectives for 2020 and Beyond*. November, European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Brussels.

[14] EISb, 2018. European Innovation Scoreboard 2018. *Exploratory Report B: Toward the Incorporation of Big Data in the European Innovation Scoreboard*, 19 June, European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Brussels.

[15] EISc, 2018. European Innovation Scoreboard. *Workshop on the European Innovation Scoreboard: Perspectives for 2020 and Beyond. Key Takeaways*. November, Brussels: European Commission.

[16] EISd, 2018. European Innovation Scoreboard 2018. *Exploratory Report C: Supplementary Analyses and Contextualization of Innovation Performance Data.* Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs. June, Brussels: European Commission.

[17] EU, 2014. *Research and innovation: Pushing Boundaries and Improving the Quality of Life*. Directorate-General for Communication. Brussels: European Commission.

[18] Fagerberg, J., 1994. Technology and International Differences in Growth Rate. *Economics of Innovation and New Technology*, 32(3), pp.183-200.

[19] FM (Frascati Manual), 2015. *Guidelines for Collecting and Reporting Data on Research and Experimental Development.* In series: The Measurement of Scientific, Technological and Innovation Activities. Paris: OECD.

[20] Freudenberg, M., 2003. Composite Indicators of Country Performance: A Critical Assessment. *STI Working paper*, *2003/16*, Industry Issues, OECD JT00153477.

[21] Gault, F., 2013. *Handbook of Innovation Indicators and Measurement*. Cheltenham: Edward Elgar.

[22] GCR, 2018. *The Global Competitiveness Report 2017-18,* K. Schwab, ed. World Economic Forum, Geneva, [online] Available at: https://www.weforum.org/reports/the-global-competitiveness-report-2017-2018 [Accessed February 10, 2019].

[23] GII, 2018. *Global Innovation Index 2018.* Eds.: Soumitra, D., Bruno, L., Wunsch-Vincent, S., [online] Available at: https://www.globalinnova tionindex.org/gii-2018-repor [Accessed February 10, 2019].

[24] Grupp, H., Schubert, T., 2010. Review and New Evidence on Composite Innovation Indicators for Evaluating National Performance. *Research Policy*, 39(1), pp.67-78.

[25] Grupp, H., Mogee, M.E., 2004. Indicators for National Science and Technology Policy: How Robust are Composite Indicators? *Research Policy,* 33(9), pp.1373-1384.

[26] *Handbook on Constructing Composite Indicators*, 2008. Paris: OECD.

[27] HDI, 2014. *Human Development Index, 2014*. United Nations Development Programme. New York: Published for the United Nations Development Program.

[28] Hollanders, H., Esser, F.C., 2007. *Measuring innovation efficiency.* ProInno Europe – InnoMetrics.

[29] INNO, 2006. What is Innovation?, [online] Available at: http://www.hi.is/~joner/eaps/innodd.htm [Accessed March 6, 2017].

[30] KAM, 2019. *Knowledge Assessment Methodology and Knowledge Economy index: Knowledge for Development Program, The World Bank Institute, [online] Available at:* https://estadisticas.pr/files/Biblioteca Virtual/estadisticas/biblioteca/BM/BM_KAM_2008.pdf [Accessed February 10, 2019].

[31] Katz, S., 2006. Indicators for Complex Innovation Systems. *Research Policy*, 35(7), pp.893-909.

[32] Kravchenko, N.A., 2011.The Problem of Measuring and Assessing National Innovation Systems. *Problems of Economic Transition*, 53(9), pp.61-73.

[33] Lundvall, B., 2007. National Innovation Systems - Analytical Concept and Development Tool". *Industry and Innovation*, 14(1), pp.95-119.

[34] Lundvall, B.A (ed), 2007. *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, Pinter Publishers, London.

[35] Metcalfe, S., 1995. The Economic Foundations of Technology Policy: Equilibrium and Evolutionary Perspectives. In: P. Stoneman (ed.), *Handbook of the Economics of Innovation and Technological Change*. Oxford (UK)/Cambridge (US): Blackwell Publishers.

[36] Murillo-Zamorano, L.R., 2004. Economic Efficiency and Frontier Techniques. *Journal of Economic Surveys*, 18(1), pp.33-77.

[37] Nasierowski, W., 2010. About Technical Efficiency of Efforts to Enhance Innovativeness in European Union. *International Journal of Innovation and Technology Management*, 7(4), pp.389-404.

[38] Nasierowski, W., 2009. A Conceptual Framework for Formalization of National Innovation Systems. *Foundations of Management*, 1(2), pp.159-166.

[39] Nasierowski, W., 2016. Composite Indexes of Economic and Social Performance: Do they Provide Valuable Information. *Foundations of Management*, 8(1), pp.167-174.

[40] Nasierowski, W. and Arcelus F., 2012. What is Innovativeness: Literature Review. *Foundations of Management*, 4(1), pp.63-74.

[41] Nasierowski, W. and Arcelus F., 2003. On the efficiency of National Innovation Systems. *Socio Economic Planning Sciences*, 37, pp.215-234.

[42] Nowak, S., 1965. *Metody badań socjologicznych* (Methods of Sociological Research). Warszawa: PWN.

[43] OECD, 2008. *Handbook on constructing composite indicators: Methodology and user guide*. Paris: JRC European Commission.

[44] OECD, 2010. *Measuring innovation: A new perspective*. Paris: OECD Publications.

[45] OECD, 1997. *National Innovation Systems.* Paris: OECD Publications.

[46] OECD, 1999. *Managing National Innovation Systems*. Paris: OECD Publications.

[47] OM (Oslo Manual), 2005. *Guidelines for collecting and interpreting innovation data*, 3rd edition Paris: OECD Publications.

[48] Owen, R., Macnaghten, P. and Stilgoe, J., 2012. Responsible Research and Innovation: from Science in Society to Science for Society, with Society. *Science and Public Policy*, 39(6), pp.751-760.

[49] Patel, P., Pavitt, K., 1994. The Nature and Economic Importance of National Innovation Systems. *STI Review*, No. 14. Paris - OECD Publications.

[50] Schibany, A., Streicher, G., 2008. The European Innovation Scoreboard: Drowning by Numbers? *Science and Public Policy*, 35(10), pp.717-732.

[51] Sharif, N., 2006. Emergence and Development of the National Innovation System Concept. *Research Policy*, 35, pp.745-766.

[52] WCY, 2017. *World Competitiveness Yearbook*. Lausanne.