



Composite innovation metrics: MCDA and the Quadruple Innovation Helix framework



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ABSTRACT

Innovation is a complex, dynamic, socio-technical, socio-economic and socio-political phenomenon which needs to be approached in a holistic manner to be properly measured and assessed. In this paper, we revisit the national and regional Innovation Scoreboards using a multiple criteria decision analysis (MCDA) approach in the context of the Quadruple Innovation Helix (QIH) framework. We deploy an MCDA approach combining AHP and TOPSIS methods which merges data from Government, University, Industry, and Civil Society sectors (the four QIH actors or helices) and overcomes limitations of the existing Innovation Scoreboard approach by incorporating the different preference systems of the QIH Helix actors. The findings illustrate the power and promise of our approach as an alternative composite innovation metric. Estimating the different preferences of innovation stakeholders gives the ability to develop policies and practices oriented towards specific QIH actors. Estimating the importance that each QIH actor assigns to different innovation aspects is critical policy-wise and practice-wise as it provides a perspective on relative efficacies and potential ways and means to calculate differential efficacies for alternative configurations of resource allocations. These results underlie specific policies, practices, and priorities therein based on the relative re-distribution of weights.

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1. Introduction

Innovation is considered as a key driver to economic growth and competitiveness. Traditional industrial economies are now transformed to knowledge economies where innovation is considered to one of the main drivers for sustained economic growth, if not the single one (Grupp and Mogee, 2004). Policy makers need efficient and effective tools to measure and monitor the innovation related performance so that they develop new measures, policies, and evaluate current approaches.

In order to understand the innovation concept and model the innovation process, initially a linear approach has been considered for several years, including a sequence of research (basic and applied) and commercialization (market test and diffusion). This linear approach was later changed with the introduction of a dynamic/systemic behaviour in the chain-link model of innovation (Kline and Rosenberg, 1986). In this direction different actors are considered to be interacting into non-linear path characterized by feedback mechanisms. In this framework a systems approach is applied for describing the knowledge

creation ('Mode 1' to 'Mode 2' (Gibbons et al., 1994) or even 'Mode 3' (Carayannis and Campbell, 2006, 2009) (Carayannis et al., 2016a). In particular, 'Mode 1' knowledge production is associated with the linear model of innovation (i.e., invention-innovation-diffusion), where there is a sequential 'first-then' relationship between basic research (knowledge production) and innovation (knowledge application). This approach has been challenged by the concept of 'Mode 2' of knowledge production (Gibbons et al., 1994), which is related to a context-driven research (i.e., knowledge application and knowledge-based problem-solving in a context of application), while 'Mode 3' knowledge production (Carayannis et al., 2016a) focuses on and leverages higher order learning processes and dynamics that allow for both top-down government, university and industry policies and practices as well as bottom-up civil society and grassroots movements initiatives and priorities to interact and engage with each other toward a more intelligent, effective, and efficient synthesis (see also (Carayannis and Campbell, 2006, 2009, 2012)).

An innovation systems approach at a national level was introduced (Lundvall, 1992; Nelson, 1993) defining a complex set of relationships at a country level. Specifically, a National Innovation System (NIS) is defined as consisting of a network of institutions whose activities initiate, import, modify and diffuse new technologies and which provide the framework within which governments form and implement policies to influence the innovation process (Freeman, 1987; Metcalfe, 1995).

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The NIS concept has since then been used as a tool for analyzing country specificities in the innovation process in a globalized economy, as well as a guide for policy formulation (OECD, 1999). This systematic approach has been extended to regional level and the concept of a Regional Innovation System has been introduced in the research and policy agendas (Cooke, 2001; Cooke et al., 1997). Regional concepts are considered as tools to generate an effective national innovation system (Chung, 2002) as in the globalized knowledge-based economies the region state is becoming the focal point of the economic activity instead of the nation state. Regions are more dynamic and responsive than nation states, regions can better exploit knowledge advantages and stocks, and they can focus on region specific capabilities, while interaction and co-operation (and clustering) are feasible at the regional level. As (Hajek et al., 2014) note, the benefits of spatial proximity are realized at regional level, and the benefits are reflected in the effective formal and informal cooperation among regional actors (investors, entrepreneurs, researchers, enterprises, public institutions, and consumers). In turn, policy formulation should focus on regional specificities and capabilities so as to optimize the results (see also the smart specialization concept). In this National/Regional innovation systems framework, four main interacting actors are involved, this leading to the concept of the Quadruple Innovation Helix (QIH) framework. Within the QIH framework, academia and industry interact and collaborate while government coordinates and facilitates applying top-down policy instruments according to visions and perspectives for the future, while civil society forms the fourth helix interacting with all the above in a bottom-up fashion. Given that innovation is a complex dynamic socio-technical, socio-economic and socio-political phenomenon, civil society plays a central role in driving user-centric innovation that serves both the society and the economy (social innovation *inter alia*).

Within this framework several approaches have been applied in order to measure innovation-related performance. An indicator approach (single, multiple or composite) has been mostly followed; the need for international comparisons have led to the use and the development of internationally comparable indicators. In general, the single indicator approach (e.g., R&D expenditures, number of patents) has been found to offer only a limited view of such a broad and complex concept such as innovation (Tidd and Bessant, 2013); therefore the role of composite indicators has been significantly enhanced in recent years (Carayannis and Grigoroudis, 2016; Carayannis and Provance, 2008; Paas and Poltimäe, 2010). Sub-indicators used in these approaches and related surveys have been following the evolution of the innovation concept with the introduction of the idea of incremental innovations, the introduction of non-technological innovation, the focus on co-operation co-opetition and recently on open innovation (Chesbrough, 2006), as well as targeted open innovation (Carayannis and Meissner, 2016; Carayannis et al., 2016c; Meissner et al., 2016). Innovation scoreboards, based on multiple indicators have been developed aiming at facilitating evaluation, benchmarking and policy formulation. Among the most widely used instruments are the European Innovation Scoreboard¹ (EIS) and the Regional Innovation Scoreboard² (RIS).³ IUS and RIS are considered to be the central authoritative sources for the European Commission and other EU as well as national policy making bodies (Adam, 2014). EIS is composed of 25 indicators covering 8 dimensions structured under 3 main blocks/pillars. In a similar approach, RIS is composed of 12 indicators (existing also at the EIU).

Although these innovation scoreboards are major attempts to grasp the multiple facets of innovation, they have received significant criticism on how the composite index is calculated (Archibugi et al., 2009; Grupp and Mogege, 2004; Grupp and Schubert, 2010), as well as due to the equal weighting scheme (Adam, 2014; Grupp and Mogege, 2004;

Schubert, 2006) applied in indicator aggregation. It should be noted that equal weighting does not imply the absence of weighting, because the former implies an explicit judgment on the weights being equal. Its effect also depends on how component indicators are divided into categories or groups: weighting equally categories (composed of different sub-indicators) could disguise different weights applied to each single sub-indicator (Goletsis and Chletsos, 2011; OECD, 2008).

In order to address the above criticism in our work we apply a multiple criteria approach for estimating the different innovation indicators' weights and constructing country and regional rankings. Although multiple criteria decision analysis (MCDA) manages to effectively capture the multiple dimensions of the evaluation problem, as well as the existence of multiple stakeholders, there are limited applications focusing on innovation; most of them apply MCDA for innovation planning (e.g., (Meesapawong et al., 2014)), technology roadmapping (see e.g. (Cho and Lee, 2013)). Recently, MCDA has been applied to assess the competitiveness of nations (Perez-Moreno et al., 2016). A multiple criteria method (namely TODIM) has been applied by Paredes-Frigolett et al. (2014) to rank innovation systems of Latin America and Iberian Peninsula countries; in their approach they suppose that preference weights are already known to the decision maker.

Our approach is based on combining AHP (Saaty, 1990) and TOPSIS methods (Hwang and Yoon, 1981). Specifically, in our approach the weighting issue is addressed through the application of the Analytical Hierarchy Process (AHP) method. In the first step the AHP method applies pairwise comparisons to hierarchical structures. Although it is usually applied in ranking problems, in the current application, the AHP method provides a structured framework for setting priorities on each level of the hierarchy. Given the hierarchy implied in the scoreboard indicators, we apply AHP for weight elicitation. The AHP method has been effectively applied in numerous MCDA applications with intangible criteria, while Saaty (Saaty, 2005) notes that using pairwise comparison measurements, the AHP method is able to provide relative measurements. In the second step, the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is applied in order to evaluate the innovation performance of countries and regions. TOPSIS' basic principle is that the chosen alternatives should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. As Tavana and Hatami-Marbini (2011) note, TOPSIS has been shown to be one of the best MCDA methods in addressing the rank reversal issue. This consistency feature is largely appreciated in practical applications. Another relative advantage of TOPSIS is its ability to identify the best alternative quickly (Parkan and Wu, 1997).

The proposed MCDA approach overcomes the need for conversion into a single metric (Cherchye et al., 2004) which can raise significant criticism especially in the case of aggregation of monetary with non-monetary outcomes (e.g., patents with employment and high tech exports). Through the TOPSIS application we also overcome the constraint for mutual independence of preferences that could occur if we applied a weighting average approach into the scoreboards' sub-indicators (see (Keeney and Raiffa, 1976) for further discussion).

The evaluation of criteria (or attributes) weights is one of the major issues discussed in the MCDA literature, particularly in aggregation procedures using an additive model. A detailed overview on weights elicitation methods for additive models can be found in (Eisenführ et al., 2010)), while it should be noted that this problem can be examined by different perspectives. For example, (Keeney and Raiffa, 1976) present and discuss the trade-off elicitation procedure, while experimental analysis has been also used in several studies (see for example (Borcherding et al., 1991; Weber and Borcherding, 1993)). Also, rank ordering criteria methods have been widely used for evaluating weights in an MCDA context (see (Ahn and Choi, 2012)). Additional literature in weight elicitation includes the works of (Grupp and Mogege, 2004), who use a heuristic approach, while (Cherchye et al., 2008; Saisana and Tarantola, 2002) use models based on linear programming.

¹ https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

² https://ec.europa.eu/growth/industry/innovation/facts-figures/regional_en

³ Other approaches include the Global Innovation Scoreboard, the Global Innovation Index, etc.

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