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Sustainable Innovation Measurement: Approaches and Challenges

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Introduction

Many argue that innovation is becoming increasingly important for both long-term survival and growth in intensely competitive and uncertain environments (Gunday et al. 2011; Rennings 2000). In the light of increasing consumer awareness, tightening government regulations and growing stakeholder expectations in respect of sustainable development, management of innovation oriented to sustainability (or sustainable innovation) is becoming an important issue for both companies and policy makers (Adams et al. 2016; Doran and Ryan 2016).

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Sustainable innovation or the innovations that include environmental and societal dimensions alongside economic aspects (Adams et al. 2016) are a powerful tool for new firms to undermine the already established firms or for established players to strengthen their position in competitive markets (Doran and Ryan 2016). Through innovations, firms can find new markets or increase the market share in existing markets as technological developments and stiff global competition rapidly erode the value added to existing products and services (Gunday et al. 2011). On the other hand, policy makers can use regulations and other mechanisms to promote sustainable innovations and thereby reduce environmental problems, enhance social welfare and incentivize expenditure on research and development (Doran and Rayon 2016). Hence, sustainable innovation is a crucial tool to fulfil the responsibilities to the environment and society in the pursuit of sustainable development (Calik and Bardudeen 2016).

According to United Nations (UN) Sustainable Development Goal (SDG) No. 9, "build resilient infrastructure, promote sustainable industrialization and foster innovation", sustainable innovation is a key to the creation of more sustainable industries to increase resource-use efficiency and adoption of clean and environmentally sound technologies and industrial processes (UN 2018). However, to motivate investment in sustainable innovations, it is essential to assess their potential contribution to the achievement of SDGs. Concrete evidence-based impacts of sustainable innovation can spur further investment, policy-level support and stakeholder commitment. Sound theoretical and methodological approaches are therefore needed to monitor, measure, communicate and evaluate sustainable innovations in the achievement of sustainability goals. However, measuring sustainability performance is a complex process in the light of multitudinous expectations about the economic, social and environmental responsibilities (Bocken et al. 2014; Coccia 2009). However, measurement of sustainable innovation and their performance, and sustainability indicator frameworks globally remains at a rudimentary and fragmented level (Bocken et al. 2014; Krajnc and Glavič 2003; Spangenberg 2002). The purpose of this chapter is therefore to discuss the approaches to and challenges in the measurement of sustainable innovations and sustainable innovation performance.

The chapter also presents some practical solutions to overcome such challenges.

The rest of the chapter is organized as follows. Section "Sustainable Innovations" provides an overview of sustainable innovation since a sound understanding of the concept is essential when discussing its measurement aspects. Section "Measuring Sustainable Innovations" and "Sustainable Innovation Performance Indicators" presents the measurement and assessment of sustainable innovation while focusing specifically on performance measurement and indicators for sustainable innovations. Section "Sustainable Innovation Performance Measurement Challenges and Possible Solutions" critically discusses the challenges in the application of the measurement of sustainable innovations. It also deals with some possible practical strategies to overcome such challenges. The last section provides the conclusions and contributions of the chapter.

Sustainable Innovations

Understanding what constitutes sustainable innovation is essential for developing any system for its assessment or measurement. In the extant literature, two similar terms have been largely used interchangeably though their exact meaning is not the same. They are: eco-innovations (sometimes interchangeably referred to as green, ecological and environmental innovations) and sustainable innovations (sometimes referred to as sustainability-oriented innovations) (Adams et al. 2016; Rennings 2000). Eco-innovations primarily focus on the environmental sustainability pillar of sustainable development. On the other hand, sustainable innovations[1] include environmental innovations and additionally incorporate societal dimensions alongside environmental and economic aspects (Adams et al. 2016; Calik and Bardudeen 2016).

Irrespective of whether it is an eco-innovation or sustainable innovation, it is not a prerequisite for them to be motivated primarily by environmental or social improvements (Carrillo-Hermosilla et al. 2010). They could also be a by-product of an economic motivation to reduce

Table 13.1 The typology of sustainable innovation

Sustainable innovation targets	Institutions Organizations and marketing	Primarily non-technological change			
	Processes and products	Primarily technological change			
		Modification	Redesign	Alternatives	Creation
		Sustainable innovation mechanisms			

Source Adapted from OECD (2009)

costs or improve market share (Horbach et al. 2012; Organisation for Economic Co-operation and Development [OECD] 2009). Hence, these innovations can be "sustainably motivated innovations" or "sustainably beneficial normal innovations" (Carrillo-Hermosilla et al. 2010). Nonetheless, sustainable innovations contribute to the achievement of sustainable development through the generation and creation of ecological and social improvements (Rennings 2000).

There are various types of sustainable innovations with different attributes, determinants and contributions to business performance (Adams et al. 2016). The typology provided by OECD (2009) for eco-innovation can be extended to systematically understand the different types of sustainable innovations (see Table 13.1).

With this brief overview of sustainable innovations, the next chapter focuses on the measurement aspects.

Measuring Sustainable Innovations

As mentioned at the beginning of this chapter, the measurement of sustainable innovation is still underdeveloped. This section first draws from the literature on eco-innovations in directing the discussion. The study of Arundel and Kemp (2009) can be regarded as the most prominent one that discusses the measurement aspects of eco-innovations (Calik and Bardudeen 2016; Cheng and Shiu 2012). Measuring eco (sustainable)-innovation is important for two reasons. First, it helps to identify the expected environmental and social benefits. Second, it

helps companies, countries or regions to gauge their ability to retain/gain competitiveness through eco (sustainable)-innovation (Arundel and Kemp 2009; Boons and Lüdeke-Freund 2013; Coccia 2009).

In extending the eco-innovation approach of Arundel and Kemp (2009) for incorporating sustainable innovations, there are three measurement aspects that can be identified at a macro-level: (a) *nature*, (b) *drivers and barriers* and (c) *effects of eco-innovation*. The nature of the sustainable innovation is the innovation target given in the OECD typology (see Table 13.1). Hence, it is the categorization of sustainable innovations into products, processes, organization, marketing and institutions. Alternatively, it can also focus on the mechanism through which innovation is introduced such as modification, redesign, alternative or creation. The second aspect of innovation measurement can focus on drivers such as regulation, demand from users, capturing new markets, cost reduction and image or barriers of eco-innovation such as technological, financial, labour force related, regulatory, consumer related, supplier related and managerial. The third aspect is the measurement of the effects of sustainable innovation. In line with the sustainable development notion, these impacts should be measured in terms of economic, environmental and social dimensions. In measuring these impacts of sustainable innovations, companies are interested in micro-effects whereas policy makers are interested in meso (sectors)- and macro-level impacts. Hence, there are no "comprehensive frameworks consisting of a limited number of selected indicators based on a standardized, transparent and methodologically sound basis" and "clearly defined policy targets in all … dimensions and on different levels of society (meta, macro, meso and micro levels)" (Spangenberg 2002: 296).

There are four categories of measures for eco-innovations (Acs and Audretsch 1993; Arundel and Kemp 2009): (a) *input measures* such as R&D expenditure and R&D staff, (b) *intermediate output measures* such as number of patents and number of scientific publications, (c) *direct output measures* such as number of innovations and sales of new products and (d) *indirect impact measures* such as changes in resource efficiency and productivity. Calik and Bardudeen (2016) suggest that these measures can be either measures of innovation capability or innovation

performance. Innovation capability-oriented measures focus on inputs and processes while performance-oriented models focus on output and results. Similarly, Alegre et al. (2006) opine that innovation performance is a construct with two different dimensions: *efficacy* and *efficiency*. They define innovation efficacy as "the degree of success of an innovation" and innovation efficiency as "the effort carried out to achieve that degree of success" (Alegre et al. 2006: 334). Hence, innovation efficacy measures are related to the innovation output/performance while innovation efficiency measures are related to innovation input/performance measures. These categories of measures are important when discussing sustainable innovation performance indicators. This aspect is discussed in the next section of the chapter.

Sustainable Innovation Performance Indicators

As outlined in the previous section, *innovation performance*[2] is related to the innovation output/results or the degree of success of the innovation (Acs and Audretsch 1993; Alegre et al. 2006; Arundel and Kemp 2009; Calik and Bardudeen 2016). Accordingly, sustainable innovation performance is the output/results of sustainable innovations reflecting the degree of success of the innovation in achieving the expected economic, social and economic output/outcomes. As in the case of traditional performance measurement, it is necessary to measure sustainable innovation performance in terms of performance indicators also (Gunarathne and Peiris 2017).

The indicators for performance measurement of sustainable innovations can be of two types, according to the famous work of Kaplan and Norton's (1996) Balanced Scorecard approach. First, there are *the lagging (outcome) indicators* which enable management to monitor the achievement of company goals and objectives (Kaplan and Norton 1996; Langfield-Smith et al. 2012). Though these indicators provide information on results achieved, they are inadequate to assist managers to directly manage performance or provide guidance on how to navigate the future (Kaplan and Norton 1996). On the other hand, the second

type of indicators, *leading (driving) indicators*, focused on the factors that drive results. Improvements in leading indicators should result in improvements in lagging indicators over time (Langfield-Smith et al. 2012). In the context of sustainable innovations, the input measures which Arundel and Kemp (2009) suggest can be regarded as leading indicators as they are related to driving sustainable innovations. The other measurement categories of Arundel and Kemp (2009), i.e., intermediate output measures, direct output measures and indirect impact measures, can be regarded as lagging indicators as they produce the results of sustainable innovation outcome at various levels. As Kaplan and Norton (1996) recommend, it is necessary to have a mixture of leading and lagging measures even for sustainable innovations as both are vital for motivating and measuring sustainable innovations.

Another aspect to consider in setting indicators is representativeness, which can be addressed through the use of core and supplemental indicators. These indicators help overcome the difficulty of having a standardized set of indicators for the measurement of sustainable innovations due to the multidimensionality of sustainability (Arundel and Kemp 2009; Gunarathne and Peiris 2017; Veleva and Ellenbecker 2001). As a solution to this issue, Veleva and Ellenbecker (2001) suggest using a set of core and supplemental indicators. *Core indicators* represent a set of indicators that can be used in any situation by any entity, and they measure common aspects such as profit, water use, energy use, and employee satisfaction and welfare. *Supplemental indicators* are openly set and vary between companies/facilities. The purpose of supplemental indicators is to introduce flexibility by addressing additional production-specific aspects (Veleva and Ellenbecker 2001). The purpose of core and supplemental indicators should be to reflect the wholeness of the system while displaying the interaction among its subsystems (Gunarathne and Peiris 2017; Krajnc and Glavič 2003). For any of the above categories of sustainability measurement aspects, i.e., input or output measures or leading and lagging measures, a set of core and supplemental indicators can be used.

The next section of the chapter discusses the challenges associated with the performance measurement of sustainable innovation and some possible solutions to overcome them.

Sustainable Innovation Performance Measurement Challenges and Possible Solutions

There are three aspects regarding the challenges to the measurement of sustainable innovation performance:

- Problems associated with the conventional measurement of the performance of innovations,
- Problems associated with the measurement of sustainability and
- Unresolved problems associated with the traditional performance measurement.

These challenges are discussed below. The first challenge is related to the conventional problems of measuring the performance of innovations. As Calik and Bardudeen (2016) suggest, measurement of even normal/standard innovation, let alone sustainable innovation, is difficult. Second are the challenges to the measurement of sustainability since what is meant by sustainability and how it can be achieved are uncertain (Adams et al. 2016). The third challenge is the still unresolved problems associated with the traditional performance measurement of any organization, system or product. Since these measurement challenges are integrated, it is difficult to isolate them for discussion. Therefore, this section discusses these challenges without specifically referring them to their source of origin. These measurement challenges have to do with the identification of what constitutes sustainable innovations, identification and quantification of performance indicators, problems associated with the determination of system boundary and suitable time periods for measurement and performance comparisons. The rest of this section provides a critical discussion of these challenges while suggesting some practical remedies.

One of the first challenges that impede the measurement process is to identify sustainable innovations. Similar to other innovations, sustainable innovations lack a standard definition (Kesidou and Demirel 2012; Boons and Lüdeke-Freund 2013). An accepted definition or a framework such as the OCED (2009) typology can be a useful

reference point in this identification process. As discussed in section "Sustainable Innovations", according to the OECD (2009) typology, there are different types of sustainable innovations such as product, process, organization, marketing and institutions. While product and process innovations are more observable and easy to evaluate, measurement of the other types of sustainable innovations is difficult (Calik and Bardudeen 2016). On the other hand, sustainable business models are important in driving the corporate innovations for sustainability (Bocken et al. 2014; Boons and Lüdeke-Freund 2013). Hence, there is a need for a creative approach informed by these definitions or typologies.

Another challenge is to identify areas for the development of sustainable innovation performance indicators in the economic, environmental and social spheres. As Bocken et al. (2014) put it, "it is not always so clear how delivering social and environmental value might translate into profit and competitive advantage for the firm" (p. 44). Since sustainability is a multidimensional concept, its measurement should consider and integrate economic, social and environmental aspects (Pope et al. 2004). Due to the multitude of sustainability aspects relevant to organizations and for which organizations are accountable, the measurement aspect can become complex (Gunarathne and Peiris 2017; Keeble et al. 2003). The areas in which the economic performance should be measured can be identified fairly easily (Keeble et al. 2003). Areas of several environmental domains such as energy and carbon, water, waste and materials too can be easily identified. However, identifying areas of biodiversity can be quite challenging. Similarly, the measurement areas in the social dimension of sustainable innovation performance can be difficult to identify because of the unclear nature of what is social sustainability (Krajnc and Glavič 2003; von Geibler et al. 2006).

One solution would be to use some accepted frameworks or internationally recognized standards in defining the dimensions of sustainability. For instance, ISO 14000, the Global Reporting Initiative (GRI), the Global Compact and WBCSD Eco-Efficiency Metrics can inform the identification of sustainable innovation performance indicators (Calik and Bardudeen 2016; Keeble et al. 2003). On the other hand, Coccia (2009) suggests a technometric technique to measure the impact of technological innovations on geo-economic environment.

Another solution is to use concepts such as "*the environmental space concept*" which uses a combination of system-specific measures with their inter-linkages (see Spangenberg 2002). Though these standards/frameworks can be a useful point of reference, there should be manager participation to plant a sense of ownership in the measurement process. The outcome of this exercise is a standard set of *Key Performance Indicators* (KPIs) in the economic, social and environmental spheres. (See Table 13.2 for some examples). These selected indicators should reflect the business realities, values and culture of the organization. Another aspect can be the engagement of stakeholders involved in and affected by the sustainable innovations. However, there can be a conflict between the indicators suggested by internal and external stakeholders. Hence, it will be necessary to strike a balance that reflects the concerns of various stakeholders (Keeble et al. 2003). Once the areas for performance measurement are determined, it will be pertinent to identify the materiality of the sustainability-related issues. Again, frameworks such as GRI offer some guidelines to identify the sustainability-related materiality issues for an organization, which should then lead to the development of relevant KPIs.

Even if these areas are identified, another practical and theoretical challenge is the quantification of sustainable innovation performance in the chosen areas. Frameworks, standards and methodologies can help to standardize measurement and accounting in certain areas such as water, energy and carbon. For instance, for the calculation of carbon footprint ISO/TS 14067:2013 standard information is available. However, such widely accepted frameworks for measurement are not available for many of the other environmental areas and social dimensions such as employee morale, community and engagement due to the lack of available markets of exchange (Coccia 2009).

Another challenge is to devise a system for the measurement of sustainable innovations (Keeble et al. 2003). Sustainable innovation measurement can be done at establishment, firm, industry, country and regional levels. When the scope is broadened, there will be additional measurement challenges. Conversely, even if the system boundary is limited to a unit/department of an organization, there will be challenges. This is because sustainable innovation is a result of interaction

Table 13.2 Examples of KPIs for sustainable innovation performance

Dimension		
Economic	Social	Environmental
% of annual sales/profits from the new products (for the last three years)	Increase in income of employees from new products	Amount of energy saved from a new processes
% of R&D (innovation) projects on budget	The number of accidents reduced by introducing a new production process	Carbon tonnes reduced/increased by introducing new products
Amount of additional taxes paid to government on new products	The number of new suppliers engaged through the new products developed	Waste generation/savings from a new production processes
Annual sales growth of new products developed	The number of stakeholder contacts made	Amount of water consumption reduced through a new production system
% of cost savings from the adoption of new technologies/processes	Number of new employment opportunities (direct and indirect) created due to the new products introduced	% of hazardous waste recycled from the new recycling plant

among many units in an organization (Calik and Bardudeen 2016). Hence, the demarcation of sustainable innovation performance among the various entities is challenging. Related to this issue are the challenges arising from the transdisciplinary nature of sustainability (Hadorn et al. 2006; Schaltegger et al. 2013). This requires a joint definition of sustainable innovation performance in a cross-disciplinary context with the focus on real word connection (Schaltegger et al. 2013). Hence, a single team or department is not capable of identifying, measuring and reporting sustainable innovation performance. As Schaltegger et al. (2013) put it, "understanding transdisciplinarity requires, in addition to an interdisciplinary scientific exchange, the collaboration of science and extra-science partners with the ultimate aim to develop knowledge that is actionable and relevant in practice" (p. 223). The involvement of various external parties such as academics and practitioners can accumulate new knowledge and create openness to innovation (Richter 2013). However, in the assessment of sustainable innovation performance measurement process, this will inevitably invite additional complexity, cost and time. This necessitates an organization to have a right mix of accuracy and practicability in the process of measurement.

Another issue related to measuring the sustainable innovation performance lies with determining the time period. Since many of the financial, environmental and social impacts of sustainable innovations are felt over a period of time, it is necessary to account for a reasonable time period rather than only focusing on a short period (Gunarathne and Peiris 2017; Bocken et al. 2014). For instance, sustainable innovations such as hybrid cars were not viable when they were first introduced but may become so in the future due to the changes in the business environment (Bocken et al. 2014). Many scholars therefore emphasize the use of full life cycle analysis in this regard (Kemp and Pearson 2008). However, when the sustainability performance over a long time period is measured, many other economic, marketing and other factors come into play (Calik and Bardudeen 2016). Hence, the isolation of the impacts of sustainable innovation performance will continue to be a challenge. Also, another question is to decide whether the innovation impacts should be measured ex-post or ex-ante (see Coccia 2009 for more details). The above techniques should therefore be applied before

Table 13.3 Sustainable innovation performance measurement challenges and solutions

Challenge	Source/s of the problem	Solution/s
Identification of what constitutes sustainable innovations	Lack of a standard definition for sustainable innovations	Following an accepted definition/framework for sustainable innovation identification E.g., *OECD* (2009) *typology*
Identification of sustainable innovation performance indicators in economic, environmental, and social spheres	Multidimensionality of the concept of sustainability	Use some accepted frameworks or internationally recognized standards for defining the dimensions of sustainability E.g., *ISO 14000, the Global Reporting Initiative (GRI), the Global Compact and WBCSD Eco-Efficiency Metrics* *Technometric techniques for technological innovations or "the environmental space concept"* Stakeholder engagement for identification of material sustainability issues
Quantification of sustainable innovation performance indicators	Lack of widely accepted frameworks for measurement E.g., *Measurement of community engagement and biodiversity*	Develop in-house performance indicators and use them consistently over time to identify the relative changes

(continued)

Table 13.3 (continued)

Challenge	Source/s of the problem	Solution/s
Problems associated with the determination of system boundary measurement and performance comparisons	Difficulty in determining the system boundary for sustainable innovation performance. Transdisciplinary nature of sustainability	Use of a mutually agreed system boundary E.g., *Consideration of sustainability impacts only at department level* Maintaining a right mix of accuracy and practicability in the process of measurement
Determination of the suitable time period for measurement	Long-term nature of the impacts of sustainable innovations Problems in deciding ex-post or ex-ante	Use of a reasonable time period for performance measurement E.g., *Use three years rather than only focusing on one year in sustainable agriculture innovations* Use of time value of money techniques and apply them ex-ante and ex-post E.g., *Net Present Value (NPV) or Internal Rate of Return (IRR) in a full life cycle analysis*
Benchmarking of sustainable innovation performance	Differences in the industries, companies or even departments (system boundaries)	Develop a set of core and supplemental indicators E.g., *Use of core indicators for comparison and supplemental indicators to capture the differences*

and after the sustainable innovation investment to enable ex-ante and ex-post evaluations.

Comparing sustainable innovation performance against other innovations can be another challenge. As discussed in the previous section, due to the differences in the industries, companies or even departments (system boundaries), it is necessary to have a set of core and supplemental indicators (Veleva and Ellenbecker 2001). While a comparison among the entities is possible by using core indicators, they will not necessarily capture the differences in the systems. The supplemental indicators introduced as a solution to overcome this issue will make it difficult to make comparisons as they will be entity specific. Hence, in the comparison or assessment of sustainable innovation performance, it will be necessary to maintain a right balance between the system representation and comparability.

Table 13.3 provides for a summary of these challenges, their sources of origin and possible solutions.

Conclusions

Sustainable innovation measurement remains at a rudimentary stage. This chapter aimed to discuss the approaches, challenges and possible solution for the measurement of sustainable innovations and innovation performance. The challenges and issues rooted in the measurement of sustainability, innovations and traditional performance pose a number of challenges to sustainable innovation performance measurement.

The discussion provided in this chapter has several implications for practitioners and researchers. The lack of a common source of information acts as a deterrent for researchers and practitioners to get an overview of this field and it in turn "limits research, education and training in this subject area, and hence limits practical experimentation and implementation in industry" (Bocken et al. 2014: 44). For practitioners, it is pertinent to understand that sustainable innovation measurement process is a dynamic learning process that informs decision-making rather than an end in itself. Once a small set of KPIs are established and agreed on (some possible examples are presented in Table 13.2), a

review process should be in place for continuous improvement. This would allow practitioners to develop a more robust set of indicators that accurately measure the sustainable innovation performance towards the expected objectives. Since the field is still developing and evolving, inter-industry and intra-industry benchmarking of measurement practices can also offer practical solutions. For researchers, sustainable innovation measurement offers wide opportunities for developing and testing theory. In parallel with the development of theory in this area, more research will be needed on the application of theory in the future, particularly on how to build a link between sustainable innovations and business models in research (Bocken et al. 2014; Boons and Lüdeke-Freund 2013). Also, it will be necessary to develop industry- and country-specific measurement indicators to reflect the differences in industries, regions and level of socio-economic development of countries.

Notes

1. *Sustainable innovations* are "any new or significant improvement of products, services, technological or organizational processes, commercialized or internally implemented that not only provide economic benefits but also generate positive social and environmental impacts" (Calik and Barbudeen 2016: 449).
2. According to the Oxford Dictionary (2018), *performance* is "a task or operation seen in terms of how successfully it is performed" or "the capabilities of a machine, product, or vehicle [or innovation]". Hence, the definition we choose for sustainable innovation performance is consistent with the traditional literal meaning of the term.

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