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National pathways to the Sustainable Development Goals (SDGs): A comparative review of scenario modelling tools

Cameron Allen[a,*], Graciela Metternicht[a], Thomas Wiedmann[b,c]

[a] Interdisciplinary Environmental Studies (IES), School of Biological, Earth and Environmental Sciences, UNSW Australia, Sydney, NSW 2052, Australia
[b] Sustainability Assessment Program (SAP), School of Civil and Environmental Engineering, UNSW Australia, Sydney, NSW 2052, Australia
[c] ISA, School of Physics A28, The University of Sydney, NSW 2006, Australia

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ABSTRACT

The recently-adopted global Sustainable Development Goals (SDGs) will have significant implications for national development planning in both developed and developing countries in the post-2015 period to 2030. Integrated, nationally-owned SDG strategies will be at the centre of national efforts to implement the new sustainable development agenda. The long-run processes and systems perspective that are inherent in the SDGs present complex analytical problems for policymakers and analysts. Scenario analysis and quantitative modelling will be important analytical tools to support national sustainable development planning, and there is an increasingly sophisticated suite of models available to decision makers. This paper reviews and assesses a broad range of different quantitative models that have the potential to support national development planning for the SDGs. The study develops a typology and inventory of 80 different models, and then reviews the comparative strengths, weaknesses and general utility of different models through an initial screening and subsequent multi-criteria analysis of short-listed models. Current gaps in model capabilities are highlighted in the context of providing analytical support for national development planning for the SDGs. While some existing models are particularly relevant, it is unlikely that an ideal model can analyse all SDG targets and variables of interest within a single modelling framework. Top-down 'macro framework' models are likely to be more useful for undertaking system-level or economy-wide scenario analysis driven by the national long-term goals and targets, and for exploring trade-offs and synergies among sectors. Bottom-up sectoral models will be able to support far more detailed option-level impact analysis of concrete interventions, technologies and investments. Combining both approaches within an analytical framework will provide a robust approach for analysis and decision-making. The results highlight a range of potential gaps in current modelling capabilities, and provide some new tools to assist with model selection.

1. Introduction

1.1. The Sustainable Development Goals

In September 2015 the global community adopted the 2030 Agenda for Sustainable Development, which includes a set of 17 Sustainable Development Goals (SDGs) and 169 targets. The new goals aim to build on the achievements of the Millennium Development Goals (MDGs) and set a transformative agenda that emphasizes integration and balance among economic, social and environmental aspirations.

The SDGs are set to become a critical component of the new international development framework for all countries and will have major implications for national development planning efforts in the post-2015 period. While the goals themselves will be universal, it will be left to countries to select national targets and ultimately determine their own priorities and level of ambition in terms of the scale and pace of transformation. Integrated, nationally-owned SDG strategies will be at the centre of national efforts.

Compared with the MDGs, the SDGs represent a far broader and more integrated, complex and challenging agenda for countries to implement. They also apply to both developing and developed

* Corresponding author.
E-mail addresses: Cameron.allen@abs.gov.au, cameron.allen@unep.org (C. Allen), g.metternicht@unsw.edu.au (G. Metternicht), t.wiedmann@unsw.edu.au (T. Wiedmann).

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countries. The timeframe for achieving the goals will be medium- to long-term, with most goals and targets corresponding to a 2030 time horizon.

Governments will face many challenges in choosing realistic yet ambitious national targets and setting out the most cost-effective and appropriate pathways towards achieving them. Given the broad scope of the SDGs, policy-makers will need to be able to easily assess the economic, social and environmental implications of their strategies in an integrated way over the long-term.

With national implementation of the SDGs commencing in early 2016, this paper explores the strengths and weaknesses of contemporary modelling tools and gaps in current modelling capabilities in the context of national development planning for the SDGs, using a novel policy screening and criteria-based approach.

1.2. Modelling approaches and types of models: challenges in the context of the SDGs

In response to the perceived limitations of traditional approaches to economic development planning based on cost-benefit analysis and macroeconomic modelling (Barker, 2004; Daly and Farley, 2011; DeCanio, 2003; Scrieciu, 2007; Söderbaum, 2008), research activities in several disciplines have increasingly aimed at developing quantitative tools for the analysis of trade-offs and synergies among the three sustainable development dimensions. These approaches build upon a long tradition of modelling in economics, engineering and other disciplines which has resulted in the emergence of a suite of more sophisticated tools that are helping decision-makers to deal with the complexity that is inherent in sustainable development (Connolly et al., 2010; Howells et al., 2013; Joshi et al., 2015; Pedercini, 2011; Turner et al., 2011).

Scenario analysis has emerged as a method that is particularly well-suited to the task of taking a long-term view and attempting to harmonize socioeconomic and environmental goals (Kok et al., 2007; Miller et al., 2014; Raskin et al., 2010). Combined with quantitative modelling, it has become a widely-used approach for exploring possible or plausible future pathways and their potential outcomes and implications (Hertwich et al., 2015; Schandl et al., 2015; Swart et al., 2004; Vergragt and Quist, 2011).

Despite these advancements, policy-relevant modelling for sustainable development remains a challenge, and the gap between the outputs from commonly-used economic growth models and the advice needed to support decision making for the SDGs may be extremely large. To understand this gap, further research on the strengths and weaknesses of different modelling approaches and available models is needed.

Top-down modelling approaches can support national-scale, macro-framework analyses of interactions and feedbacks across a range of sectors; whereas bottom-up approaches can assist in detailed technological assessment and meaningful evaluation of alternatives at the sectoral level. Combining these into hybrid approaches facilitates complementary analyses that balance the strengths and weaknesses of different approaches (Hourcade et al., 2006; van Vuuren et al., 2009)

The 'types' of models is another aspect that needs consideration in national policy for sustainable development. Input-output models are a useful descriptive tool for a national economy and form the basis for many advanced models, however their static nature limits their value in terms of long-term scenario modelling (Catenazzi, 2009; Herbst et al., 2012). Macro-econometric models are dynamic and based on a large amount of historical data, though they are of limited value for long-term analysis (Hedenus et al., 2013; Pollitt et al., 2010; Van Beeck, 1999). Dynamic computable general equilibrium (CGE) models are well-suited for scenario analysis using a consistent theoretical framework and feedbacks across sectors, however their theoretical underpinnings may render them less suitable for modelling sustainable development transitions (Barker, 2004; Bhattacharyya and Timilsina, 2010; Scrieciu, 2007). System dynamics models are also suited to all types of scenario analysis and comparative assessment of alternatives, however the definition of correct boundaries and feedback loops can be problematic (Hjorth and Bagheri, 2006; Nicholson, 2007; Pedercini, 2003, 2011; Turner et al., 2011). Bottom-up optimisation and simulation models are more useful for sector-based planning due to their more limited scope and detailed coverage of technologies and alternatives, however they generally lack feedback loops with other sectors in the broader economy (Herbst et al., 2012; Nicholson, 2007; Pollitt et al., 2010). Multi-agent models are promising in the context of sustainable development (Boulanger and Bréchet, 2005), though they are highly complex and remain experimental, with limited practical application (Wieland and Gutzler, 2014). Finally, hybrid and integrated assessment models are leveraging the strengths of multiple modelling methodologies, addressing some of the weaknesses related to the aforementioned categories and providing a more flexible and tailor-made approach (Bazilian et al., 2011; Herbst et al., 2012; Hourcade et al., 2006).

This evidences the absence of unique modelling approaches and model types that will address all analytical requirements underpinned by the new SDGs. Rightly, Nicholson (2007) points out the lack of a single universal methodology suited to all problems; with the utility of modelling approaches dependent on the nature of the system of focus, and the type of prediction desired. Likewise, the choice of modelling tools depends on the priority sectors of concern, the availability of expertise and data, cost and time limitations, amongst other factors (Böhringer and Löschel, 2006; Börjeson et al., 2006; Höjer et al., 2008).

1.3. Model types: state-of-the-art

A considerable volume of academic literature has emerged over the past ten years as international interest in models has grown along with their level of sophistication and computing power. This has included a number of evaluative or comparative reviews of different types of models in the context of a specific policy issue or research question, including sustainable development. For a brief summary of 40 past reviews of models drawn from the literature, refer to Table A in the Supplementary material (SM).

While not exhaustive, this provides a useful starting point for an initial comparative analysis of models in the context of the SDGs. A review of this literature highlights several research gaps. Firstly, with the emergence of a large volume of modelling tools adopting various methodologies over the past decade, there is a lack of a consolidated inventory or list of models from which decision makers can select a tool that best suits their analytical needs, and which facilitates an informed choice.

Secondly, there is no standardized approach for categorizing the various models, which makes it difficult to explore model strengths and weaknesses and provide an intuitive framework for such an inventory. As Nicholson (2007) again points out, "there exist a plethora of model types, and perhaps only a slightly smaller number of model classification schemes".

Thirdly, while the literature provides numerous critiques of specific models as well as broad model categories, there is limited consideration of the utility of different models to support national sustainable development planning. Finally, there is no literature at this stage that considers these questions specifically in the context of the new global SDGs.

The methodologies used in the literature to comparatively assess different models generally fall into two approaches: