Renewable and Sustainable Energy Reviews 78 (2017) 61–71

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Application of computable general equilibrium (CGE) to climate change mitigation policy: A systematic review

Kazeem Alasinrin Babatunde[a,b,*], Rawshan Ara Begum[c], Fathin Faizah Said[a]

[a] School of Economics, Faculty of Economics and Management, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[b] Department of Economics, College of Management Sciences, Alhikmah University, Ilorin, Nigeria
[c] Institute of Climate Change (IPI), Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia

ARTICLE INFO

Keywords:
Computable general equilibrium
Climate change mitigation policy
Systematic review
DSGE
ABM

ABSTRACT

With the growing literature related to climate change mitigation measures and policy interventions, a systematic review of the application of computable general equilibrium (CGE) model is inevitable. Therefore, this article aims to characterise the relevant studies, define a comparative framework to identify the current state-of-the-art and the gaps in applied general equilibrium models. Firstly, the systematic review found a total of 301 research articles from Scopus and Web of Science databases and finally analysed 154 articles based on inclusion and exclusion criteria from 67 refereed journals. The review analysis found that application of CGE model is very vital in addressing climate change mitigation issues at the national, regional and global levels. However, China attracted the most substantial research interests followed by the USA, India and Australia, among others, which are in line with their share of greenhouse gas emissions in the world. Most of the research themes focus on the carbon tax, emission reduction target, emission trading, renewable energy, energy efficiency, and carbon capture and storage as primary drivers of low carbon economy. Nevertheless, there is a trend of employing more static CGE model compared to the dynamic CGE, although application of the latter has a limitation of providing right inputs to the macroeconomic policy. Finally, research directions and gaps envision other complementary models such as dynamic stochastic general equilibrium (DSGE) and agent-based model (ABM) for proper policy interventions.

1. Introduction

The greenhouse gas mitigation puzzle links the national policy dynamics directly with the global socio-economic and environmental policy issues. Hence, climate mitigation policy objectives and viewpoints blow hot and cold at global, regional, national and sectoral levels [1]. With global policy modellers seeking long-term climate change stabilization [2,3], regional policymakers are interested in addressing carbon linkages [4], border tax adjustment [5] and transboundary air pollution control [6]; national placing high preference on economic impacts of the transition pathways to low carbon economy [7,8], energy access and security as national goals [9,10], competitiveness and employment are the major policy thrust of the sectoral policy stakeholders. In response to the differences above, United Nation Framework Conference on Climate Change (UNFCCC) has shouldered the responsibility of harmonising climate change related problems at all levels, with its first victory recorded at Kyoto, Japan in 1997. Although, the victory was marred by controversies between developed countries (e.g. USA) and developing countries (e.g. China) about which economy should take the leading role in mitigating greenhouse gas. Since then, efforts have been geared towards having better global deals on climate change and global warming with the most recent conference of parties (COP 21) held in Paris in December 2015. The key outcomes of the conference were the unanimous agreement and a companion decision by party members [11], which has prompted the formal US President, Barak Obama to describe the deal as ‘the best chance to save the planet’.

How this breathtaking planet is to be saved is far from clear as many studies point to an increasing amount of energy use and corresponding GHG emissions being from electricity and manufacturing sectors. The US electricity generation, for instance, is responsible for about 39% of all its carbon emissions in 2014 – whose generator mainly relies on coal [12]. In many developing economies, where energy demand has been considerably varied, the noticeable improvement in industrial activities due to the accelerating growth of their economies has led to an unprecedented rise in energy consumption. In China, for example, manufacturing and power generation sectors accounted mainly for the CO_2 emissions with 47% and 32% of all

* Corresponding author at: School of Economics, Faculty of Economics and Management,Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.

http://dx.doi.org/10.1016/j.rser.2017.04.064
Received 21 August 2016; Received in revised form 5 February 2017; Accepted 27 April 2017
1364-0321/

China GHG emissions respectively [13]. China, the world's leading CO_2 emitter, however, has been reported as the real force behind the drop in world's carbon dioxide emissions by 0.6% in 2015 [14]. Conversely, India's carbon dioxide emissions have risen due to its power generation, even as global emissions rates dwindle. Therefore, a significant reduction in energy carbon emissions is vital if global CO_2 reduction targets are to be achieved. To do this, a combination of energy efficiency, renewable energy, fossil fuel switching, nuclear and carbon capture and storage (CCS) can lead to given low emissions concentration magnitude with renewables taking the lead [15–17].

As an outcome of the COP 21 in Paris, developed economies are to take full economy-wide mitigation targets, as developing countries are persuaded to gear towards economy-wide emissions reduction target with common core mitigation commitments. Hence, computable general equilibrium (CGE) models have been widely used in simulating the economy-wide effect of climate mitigation policy [18–26]. The literature indicates that bulk of carbon emissions come from the energy sector. Thus, considerable CGE mitigation modelling studies were channelled towards energy system. For example, energy tax [27–32] and energy security [10,33–36] have dominated the climate mitigation literature. However, limited CGE modelling efforts are devoted to other important GHG emitting sectors such as; agriculture with 7.10% of the studies, followed by forestry/forest with 5.20%, industry (3.90%), transport (3.30%), building (1.30%) and lastly, only one research article [37] explores through waste sector based on this review study (see Fig. 1).

To date, there is a lack of systematic literature reviews on the CGE modelling and climate change mitigation policy, despite their rapidly growing literature and debates over the policy intervention becoming unendingly polarised and politicised [38]. Based on the preceding, this article aims to review systematically the relevant literature regarding the application of CGE models on climate change mitigation policy and to characterise the relevant studies, defining a comparative framework to identify the current state-of-the-art and the gaps.

2. The computable general equilibrium (CGE) model

A CGE model is a computer-based simulation which makes use of a system of equations that describe the whole economy and their sectoral interactions. As a multi-sector model, CGE is based on real world data of a single country or a group of national economies. The CGE simulation usually begins with a general equilibrium condition (a business-as-usual) followed by the introduction of a policy shock (e.g. carbon tax or emission trading scheme for climate change mitigation) which by this, the model generates a new general equilibrium reality.

The term ‘computable’ in this model emphasizes the capacity of the model to quantify and ascertain the economy-wide effects of a policy shock via computer simulations. Economists generally rely on a priori information to anticipate the direction of economic policy. However, policy makers may want to know the magnitude of the shock on an economy.

Equilibrium is a household economic jargon which signals a relatively stable economic state. For instance, fluctuations in the supply

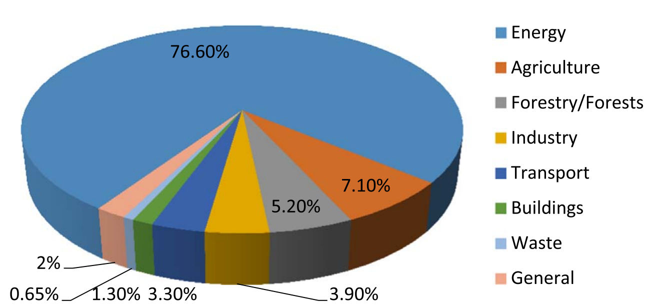

Fig. 1. Applications of CGE on climate change mitigation across sectors.

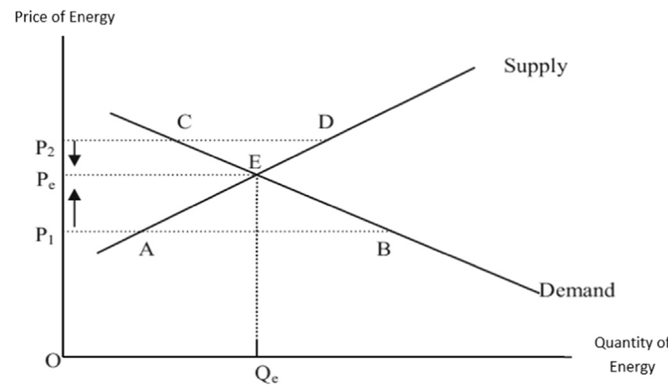

Fig. 2. Market equilibrium.

of and demand for energy (conventional) instigate a change in energy prices and in turn affect the composition of greenhouse gases: when the supply of energy falls short of its demand, energy price goes up; and vice versa. As economic theory posits, the supply and demand over time will converge to a steady state and hence the price of energy will be relatively stable at point E in Fig. 2. Therefore, point E is called the equilibrium in the conventional energy market. But, this graph only reveals the equilibrium in a single market. In reality, several markets are linked and interconnected with one and another. For example, fossil fuel energy market and renewable energy market are closely related. If there is sudden fall in the supply of renewables, their price will increase. With this situation, people tend to use more non-renewable energy and buy fewer renewables. As a consequence, the initial equilibrium in the conventional energy market is affected by the situation in the renewable market. Hence, equilibrium can only be achieved in an economy when all (i.e., general) markets are in equilibrium. Another classical way to understand the interrelationships in a computable general equilibrium model is to view them as a circular flow of spending and income in an economy [39].

2.1. Standard CGE model

A standard CGE model consists of two main components: Model structure and database. As previously argued, the structure of CGE model is a system of equations that take into cognisance all the economic interrelationships in the real world. The economic system comprises different components and thus become very complex in reality. Meanwhile, all sectors and subsectors are directly or indirectly related to demand for and supply of goods and services. All these are fundamental to CGE model. An economic system in a standard CGE model is depicted in Fig. 3 where the key components are those in double lined rectangular text boxes. Capital, labour and intermediate resources are inputs for producing a good or service. At equilibrium, different users such as household, government, investor, intermediate, and foreign, buy this good or service. As shown at the bottom of Fig. 3, these five consumers (demands) represent an important part of the economic system, as all other components are linked to them in multitude ways.

As a data-rich model, CGE database is made up of two parts: the flow of spending and income in an economy and the parameter values. Modeller assigns and fixes the parameter values to the equations while the model is being run. The spending and income flow data for a standard CGE model are usually from the demand for and supply of goods and services. The National statistical department produces these type of data in the form of input-output (I-O) tables. However, for an extended CGE model in which the modeller interest is not limited to the production and consumption activities but also the interrelationship and interconnection between sectors and institutions, more data are needed. Hence, social accounting matrix (SAM) accommodates or allows access to these data [39].