Journal of Cleaner Production xxx (2016) 1–17

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Enterprises' compliance with government carbon reduction labelling policy using a system dynamics approach

Rui Zhao [a,*], Xiao Zhou [a], Qiao Jin [a], Yutao Wang [b], Chengliang Liu [c]

[a] *Faculty of Geosciences and Environmental Engineering, Southwest Jiaotong University, Chengdu, 611756, China*
[b] *Institute of Ecology and Biodiversity, Shandong University, Jinan, 250100, China*
[c] *School of Urban and Regional Science, East China Normal University, Shanghai, 200062, China*

A R T I C L E I N F O

Article history:
Received 14 April 2015
Received in revised form
21 April 2016
Accepted 22 April 2016
Available online xxx

Keywords:
System dynamics
Carbon reduction labelling scheme
Carbon emissions
Governmental policy
Enterprises' compliance

A B S T R A C T

A carbon reduction labelling scheme is an effective policy tool for motivating enterprises or organizations to reduce their life-cycle-based carbon emissions to benefit the environment. This paper uses system dynamics to model enterprises' compliance with a combined government policy instrument for a carbon reduction labelling scheme, that is, government subsidies and economic sanctions. A case study of paper enterprises in China is provided to demonstrate the application of the proposed model in which two optional technological plans to reduce the enterprises' carbon emissions are examined. The technological plans are categorized as a low-cost and high-cost plan. The simulation results show that both the technological plans are vulnerable to the combined policy making, and the high-cost plan shows superior environmental performance for carbon emissions reduction. However, the enterprises are more inclined to choose the low-cost plan because of superior economic performance. The study offers insights to help enterprises select optimal actions on carbon emissions reduction and to inform government of possible sustainable policy design to promote low-carbon development. The model limitations are discussed as a basis for further improvements in low-carbon development.

1. Introduction

Over recent years, climate change has become a global issue and has been attracting increasing attention (Rose and Allen, 2013; Jiricka et al., 2016). In this context, sustainable development is deemed as a central component of greenhouse gas emission reduction to mitigate the climate change crisis (Uddin et al., 2015). Following the principle of sustainable development, cleaner production is considered a significant tool to promote emissions reduction and energy saving, in which carbon footprinting is involved to measure life-cycle-based carbon emissions for services or products (Zhao et al., 2013; Almeida et al., 2015).

A carbon reduction labelling scheme is expected to help individuals change their consuming behaviours to benefit the environment by providing carbon emissions information on products or services (Liu et al., 2016). Moreover, carbon labelling schemes have been introduced by a number of countries including France, Japan, Switzerland, and the UK. Such schemes help enterprises or organizations better understand their environmental impact and inform supply chain networks of ways to reduce their associated carbon emissions through improvements in product sustainability (Tan et al., 2014; Liu et al., 2016). With the development of green consumption, consumers' purchasing behaviour may be influenced by a carbon reduction labelling scheme (Zhao et al., 2012a). Recent investigation shows that 47% of people surveyed prefer to purchase carbon labelled products if they have the same quality as non-carbon labelled products. Particularly, 20% of people surveyed in the UK are willing to buy carbon labelled products even at a higher price (Messum, 2012).

Currently, the implementation of a carbon reduction labelling scheme is voluntary for enterprises (Shi, 2013; Tan et al., 2014). Business, in general, is driven by profit (Kane, 2010). Enterprises may consider assuming additional social responsibilities to improve their public image and to benefit from business opportunities from the sale of ‘green’ products with enhanced environmental awareness of consumers (Lin et al., 2013; Kolk, 2016). However, the additional cost of low-carbon certificated technologies required to improve the ‘green performance’ of products may cause uncertainty regarding commercial success (Bi et al., 2015).

* Corresponding author.
E-mail address: ruizhaoswjtu@hotmail.com (R. Zhao).

http://dx.doi.org/10.1016/j.jclepro.2016.04.096
0959-6526/

For this reason, government should assume a leading role in motivating technical innovation among enterprises through well-designed policies for improved product sustainability, thus to achieve a 'win–win' performance between the environment and the economy (Choi, 2015). However, there are a number of uncertainties involved in policy making for low-carbon development, for example, the extent to which the government should support the accreditation of the carbon reduction labelling scheme, the design of incentives and restraint mechanisms, and whether there will be any unintended consequences (Cohen and Vandenbergh, 2012; Zimmer et al., 2015). Given the complexity, policy design should also seek a balance between flexibility and certainty.

In this context, this paper uses system dynamics (SD) to model enterprises' response to integrated government policy making (e.g. combined subsidies and penalties combined) for the implementation of a carbon reduction labelling scheme. The synergy impact of subsidies and penalties on enterprises' economic return is investigated. Two optional technological plans for carbon emissions reduction for the enterprises are pre-defined to determine which plan is effective in promoting both economic and environmental performance under the integrated policy making. An optimal combination of policy design is suggested to drive carbon emissions reduction and, thus, promote low-carbon transition.

2. Literature review

In this section, the existing literature on related policy instruments incentivizing low-carbon development is given, and a review of SD application to policy making is provided.

2.1. Policy incentives for low-carbon development

A number of policy instruments have been proposed to promote low-carbon development, for example, price mechanisms (Zhou et al., 2010; Brauneis et al., 2013; Shahnazari et al., 2014) and finance and taxation (Brand et al., 2013; Wang and Chang, 2014). However, studies have confirmed that government incentive mechanisms, for example, subsidies, may have a greater impact than regulatory or voluntary approaches to low-carbon development (Zhang et al., 2010).

Diamond (2009) examined the possible impact of government incentives for the adoption of hybrid electric vehicles, which suggested that a subsidy with payments upfront were the most effective. Sawangphol and Pharino (2011) indicated that stimulation of renewable energy development by offering government subsidies was effective in reducing the cost of technological innovation while private investment in renewable energy industry was encouraged. Shukla and Chaturvedi (2012) presented a targeted approach by incorporating solar, wind, and nuclear technologies into the Indian electricity generation sector, which identified that a governmental subsidy was necessary when the carbon price was comparatively low. Ehrig and Behrendt (2013) demonstrated that the subsidy for co-firing systems in Belgium and the UK had a high level of significance while supporting carbon-intensive supply chains. Tian et al. (2014) investigated green supply chain management diffusion (GSCM) among Chinese manufacturers, for which the subsidies for manufacturers were more effective than subsidies for consumers. Li et al. (2014) suggested that a carbon subsidy could be a supplementary strategy to carbon tax because of its effect in increasing carbon emissions reduction and economic profits in a supply chain. Tang et al. (2015) proposed a multi-agent-based model to investigate the possible influences of various carbon emissions trading mechanisms, and a financial subsidy was identified as an effective policy instrument for reducing carbon emissions. The authors also found that economic penalties should be employed with caution to balance economic development and carbon emissions reduction. Wang et al. (2016) examined both the economic and environmental impacts of a reduction in water and electricity subsidies in Abu Dhabi using a computable general equilibrium (CGE) analysis. The study indicated that the reduction of an electricity subsidy was more effective than a reduction in a water subsidy in increasing GDP and reducing CO_2 emissions.

Considering their effectiveness in reducing carbon emissions, individual policy instruments, that is, government subsidies, have a significant impact on low-carbon development. However, integrated policy making for low-carbon development is still in progress and is considered more effective (Kounetas and Tsekouras, 2008; Tsou and Wang, 2012; Wang et al., 2014). For instance, Tsou and Wang (2012) proposed a bi-level mixed-integer nonlinear programming (BL-MINLP) model to encourage enterprises to minimize carbon emissions related to recycled products. The model indicated that subsidies and penalties implemented simultaneously triggered greater carbon emissions reduction. The study is set in this context to investigate the synergy effects of the implementation of a carbon reduction labelling scheme. Moreover, an optimal combination of the two important policy indicators is suggested to provide financial balance for governments and, ultimately, to help enterprises achieve long-term commercial success.

2.2. SD for policy simulation on low-carbon development

SD was proposed by Professor Forrester in 1956 and is a modelling approach for the development of complex system simulation. The approach combines qualitative and quantitative analysis to understand dynamic complexity in the internal mechanisms of a system (Zhao and Zhong, 2015). It has been widely applied to policy making in areas such as water resources management (Feng et al., 2008; Dai et al., 2013), urban development (Han et al., 2009; Sabounchi et al., 2014), and energy management (He and Zhang, 2015).

For low-carbon development, Trappey et al. (2012) constructed an SD model for the evaluation of Taiwan's green transportation policies for policy makers. Cheng et al. (2015) further introduced an investigation of policy effectiveness in the promotion of a sustainable urban transportation system using an SD approach. Simulation results indicated that a fuel tax and parking management policies were both equally potentially effective in reducing fuel consumption and CO_2 emissions. Xu et al. (2014) designed an SD-based industrial restructuring optimal model to seek sustainability in economic, environmental, and social dimensions. Franco et al. (2015) proposed an SD model to investigate the long-term impact of various policy instruments on electricity market reform, through which the carbon price floor, feed-in tariff (FIT), and capacity mechanisms were useful for the transition. Particularly, Ahmad et al. (2015) evaluated FIT policy making on solar PV (photovoltaic) investments in Malaysia using an SD approach. The results reflected that the scenarios with higher FIT rates resulted in the installation of higher PV capacity, thus reducing CO_2 emissions.

Focussing on an integrated policy, Jaber et al. (2013) identified a carbon tax and an emissions penalty, as an effective method of reducing carbon emissions within a supply chain network. A similar implication was obtained by Cardenas et al. (2016), who applied an SD approach to show that low-carbon policies (i.e. carbon taxes and subsidies) have a great impact on both carbon emissions reduction and the diffusion of clean technologies. These studies had suggested that policies should encourage environmental investment for renewable energy development. Shale gas (SG), as renewable energy, was investigated by using an SD approach to show its associated competitiveness influenced by