Ecological Economics 153 (2018) 1–16

Contents lists available at ScienceDirect

Ecological Economics

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

Methodological and Ideological Options

Integrating Sustainability Into City-level CO_2 Accounting: Social Consumption Pattern and Income Distribution

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ARTICLE INFO

Keywords:
Sustainability
Social consumption pattern
Income distribution
CO_2 emissions
Semi-closed input–output model
Hypothetical extraction method
City

ABSTRACT

From a sustainability perspective, city-level CO_2 emissions require reconsiderations. Correspondingly, the economy-environment-society nexus should be incorporated into city-scale CO_2 accounting. Therefore, in this study, the semi-closed IO model is integrated with a HEM to calculate CO_2 emissions arising from the social consumption pattern and income distribution, and to explore economic drivers behind CO_2 variations. This method is applied to a case study of Beijing. Result demonstrate that Beijing in 2012 witnessed something different from that in 2005: (1) CO_2 emissions centred in the internal linkages of a broader class of consumption terms with high economic output, mainly driven by interprovincial exports; (2) imports increasingly helped decarbonize the mixed, net forward and backward CO_2 linkages of consumption items; and (3) income-driven CO_2 emissions excluding demand-side parts persisted, which were more obvious on the supply side where households have more economy-wide effects. Besides, urban households played an essential role in household-wide CO_2 reductions. This paper ended with corresponding conclusions, policy implications and directions for future work.

1. Introduction

1.1. Climate Change and Chinese Cities: A Sustainability Perspective

Climate change is a global issue in need of international collaboration, national planning and actions for mitigation and adaptation (Beg et al., 2002). More important are cities' proactive response and participation (Bai et al., 2018) when considering the high population concentration (Ürge-Vorsatz et al., 2018), emerging socio-economic dynamics (including urbanization, technology development, industrialization, and increasing energy demand) (Wang et al., 2017), growing contributions to CO_2 emissions (Bai et al., 2018), and greater vulnerability to global warming (Harlan and Ruddell, 2011). Meanwhile, climate change is closely correlated with sustainability. In detail, climate change is one of six major threats to sustainability across the world, with the rest involving deforestation, loss of biodiversity, population growth, poverty, and scarcity of drinking water (Stern, 2008). Though falling short of a clear and universally accepted definition (Mog, 2004), sustainability highlights the economy-environment-society nexus (Ciegis et al., 2009), and sustainable development is characterized by balancing the needs of both present and future generations without any compromise (Brundtland, 1987). Thus, a sustainability viewpoint could be conductive to grasping and coping with climate change by the joint efforts from economy, environment and society.

Sustainability is not only crucial to but also necessary for China nowadays. China has been in a dilemma in achieving the harmony among economy, environment and society, thereby striving to promote sustainable development. One evidence is that China has become the largest emitter since 2007 (Mi et al., 2016) and thereby has made efforts in climate change mitigation and adaptation (Ge et al., 2016),

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https://doi.org/10.1016/j.ecolecon.2018.06.019
Received 24 March 2017; Received in revised form 12 April 2018; Accepted 24 June 2018

accompanied by continual economic growth and emerging social problems such as regional disparities (Zhou et al., 2017), urban bias (Chen et al., 2012) and income inequalities (Xie and Zhou, 2014). Moreover, China, like most countries, prioritizes economic growth rather than environmental protection (Govindaraju and Tang, 2013). Consequently, climate change mitigation and adaptation policies should be improved to tackle climate change considering socio-economic factors (Li and Lin, 2013; Xu et al., 2016a).

Chinese cities are also plagued by the above-mentioned social-economic problems when reducing CO_2 (Wang et al., 2014). However, compared to low carbon development, sustainable development is more favorable in the context of Chinese cities (Baeumler et al., 2012). Therefore, sustainable low-carbon city development in China was investigated from a multidisciplinary perspective (Baeumler et al., 2012), which is a concern featuring a systematic thinking (Wang et al., 2017), because cities are a complex system facing CO_2 flows generated from both physical and monetary flows (Ji, 2011) but simultaneously vulnerable to climate change (Baeumler et al., 2012).To systematically analyze CO_2 emissions, Life-cycle Assessment (LCA) is powerful as its core concerns the system perspective (Zamagni, 2012) at different levels (e.g. products, processes, producers, and consumers). For instance, LCA is capable of tracking emissions directly and indirectly (Hellweg and Canals, 2014), ensuring the whole coverage of CO_2 emissions of scope 1 (direct GHG emissions from sources owned or controlled by the company), scope 2 (indirect GHG emissions from the generation of purchased electricity consumed by the company) and scope 3 (all other indirect emissions produced in the activities of the company, yet from sources not owned or controlled by the company) (Development and Institute, 2001). Meantime, LCA is a systematic process because it consists of inventory and impact analysis, as well as applications to practical improvements such as product development and public policy-making (Guinee et al., 2010).

However, though sustainability and LCA are crucial to climate change for Chinese cities, two considerations deserve extra attention:

(1) The environment-economy-energy nexus in CO_2 accounting has been preferred in academia (de Carvalho et al., 2016). In contrast, a sustainability perspective (i.e., the economy-environment-society nexus) is relatively absent (Zamagni et al., 2013);
(2) LCA is not compatible with sustainability to some degree. For example, LCA mainly covers environmental issues yet fails to simultaneously assess environment and society, impeding a comprehensive knowledge of achieving sustainability (Hellweg and Canals, 2014).

1.2. Integrating Sustainability Into City-level CO_2 Accounting

To solve the above-mentioned problems, we integrate sustainability into city-level CO_2 accounting. In detail, conflicts between sustainability and LCA are identified in terms of households and the social consumption pattern. Correspondingly, LCA is modified for city-level CO_2 accounting.

1.2.1. Identifying Conflicts Between Sustainability and LCA

1.2.1.1. At the Household Level. Households are important sectors in socio-economic sustainability with reference to poverty elimination (Mog, 2004), life standard improvement and social equality (Wang et al., 2016). Besides, household lifestyle and behaviors are vital to sustainable consumption at the household level (Hubacek et al., 2007; Liu et al., 2010).

For city-scale CO_2 accounting, household CO_2 emissions (HCE) have increasingly gained attention from different aspects. To illustrate, urban and rural CO_2 emissions (Lavers et al., 2017; Wang and Yang, 2016), direct and indirect CO_2 emissions (Dias et al., 2014; Lin et al., 2013) are classified. Together with other conventional and hidden factors (Ponce de Leon Barido and Marshall, 2014; Shen et al., 2018), income distribution and household consumption pattern have been explored (Lavers et al., 2017). During this process, studies at the country level serve as the precautionary signal to ensure climate change mitigation and adaptation. Generally, these studies focus on leapfrogging strategies for developing countries in pursuit of clean energy and sustainable lifestyle (Burke, 2010, 2013; Hubacek et al., 2007), rebound effects and backfire varying with how household consumption treated technological innovation (Throne-Holst et al., 2007), distributional effects of climate change measures (e.g., carbon tax (Büchs et al., 2011), carbon revenue (Grainger and Kolstad, 2010) and carbon trading (Asafu-Adjaye and Mahadevan, 2013)). Among all the studies, however, there are two general problems:

(1) Many studies regard households as independent parts unaffected by the intermediate input–output system, rather than closely correlated;
(2) The household impacts of different income levels on CO_2 emissions caused by social consumption pattern, themselves and their counterparts are not classified.

1.2.1.2. At the Social Consumption Level. In contrast to regarding consumption and production as separate parts, sustainable consumption stresses the simultaneous sustainable development between consumption and production (Liu et al., 2010) to pursue a more equitable consumption distribution and environmental benefits (Hertwich and Katzmayr, 2004). By using input-output analysis (IOA)-based LCA, sustainable consumption can be fulfilled to make polices, identify sustainable measures, and influence public awareness (Hertwich, 2005).

Accordingly, the social consumption pattern (in this paper) based on IOA-based LCA is the combination of production and consumption in the whole economic system. For China, the combination of consumers and producers, at the country level, answers for why the problems of consumers appear (Liu et al., 2010). On top of that, China's climate change mitigation policies have already been pushed to a consumption level to grasp consumers' role and ensure high quality of life (Wang et al., 2014). However, consumption's role in city-level CO_2 emissions calls for further improvements because:

(1) The understanding of consumption is limited to either household consumption (Ramaswami et al., 2008) or the link between sectors and final demand categories (Mózner, 2013), rather than the natural tie between consumption and production;
(2) The interactions within the social consumption pattern are not considered sufficiently.

1.2.2. Modifying LCA for CO_2 Accounting

With these conflicts between sustainability and LCA, modified LCA is given by integrating the semi-closed input-output (IO) model with hypothetical extraction method (HEM) at the household level and modified HEM at the social consumption pattern level.

Frist, the semi-closed IO model is determined with reference to three considerations: (1) LCA depends on careful but parallel interpretation given still existing debates over how to choose among process-based LCA, IOA-based LCA, and hybrid LCA for the environmental impacts analysis (Rowley et al., 2009). In other words, no kind of LCA is designed for all the purposes, so a feasible LCA relies on the analysis of the reality (Erickson et al., 2012; Munksgaard et al., 2005); (2) compared with the conventional IO model, the semi-closed IO model, prioritizing endogenous effects of household income-expenditure relationship and pioneered by (Batey et al., 1987), is more feasible at the city level, because regional economy tends to be more open than national (Chen et al., 2015); and (3) through introducing household income and expenditure into the intermediate system, this semi-closed IO model can touch on the changes of household consumption triggered by the labor input originating from changed output (Tian et al., 2017).