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Review

A review on health cost accounting of air pollution in China

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ABSTRACT

Over the last three decades, rapid industrialization in China has generated an unprecedentedly high level of air pollution and associated health problems. Given that China accounts for one-fifth of the world population and suffers from severe air pollution, a comprehensive review of the indicators accounting for the health costs in relation to air pollution will benefit evidence-based and health-related environmental policy-making. This paper reviews the conventional static and the new dynamic approach adopted for air pollution-related health cost accounting in China and analyzes the difference between the two in estimating GDP loss. The advantages of adopting the dynamic approach for health cost accounting in China, with conditions guaranteeing its optimal performance are highlighted. Guidelines on how one can identify an appropriate approach for health cost accounting in China are put forward. Further, we outline and compare the globally-applicable and China-specific indicators adopted by different accounting methodologies, with their pros and cons being discussed. A comprehensive account of the available databases and methodologies for health cost accounting in China are outlined. Future directions to guide health cost accounting in China are provided.

Our work provides valuable insights into future health cost accounting research in China. Our study has strengthen the view that the dynamic approach is comparatively more preferred than the static approach for health cost accounting in China, if more data is available to train the dynamic models and improve the robustness of the parameters employed. In addition, future dynamic model should address the socio-economic impacts, including benefits or losses of air pollution polices, to provide a more robust policy picture. Our work has laid the key principles and guidelines for selecting proper econometric approaches and parameters. We have also identified a proper estimation method for the Value of Life in China, and proposed the integration of engineering approaches, such as the use of deep learning and big data analysis for health cost accounting at the fine-grained level (city-district or sub-regional level). Our work has also identified the gap for more accurate health cost accounting at the fine-grained level in China, which will subsequently affect the quality of health-related air pollution policy decision-making at such levels, and the health-related quality of life of the citizens in China.

1. Introduction

Over the last three decades, rapid industrialization in China has caused significant air pollution and health challenges (Diamond, 2005; Lagorio, 2010; Lim, 2007). The mean annual $PM_{2.5}$ concentration in China's major cities reported to be 43 μg/m^3, had exceeded 4 folds based on the threshold of 10 μg/m^3 annual mean concentration set by the World Health Organization in 2017 (Chan and Danzon, 2005; MEEPRC, 2017). Serious air pollution has created severe health risks (Dockery and Pope, 1994; Dockery et al., 1992, 1989), raising increasing concerns in China (Wang, 2016). People's quality of life has deteriorated continuously with increasing rates of morbidity and mortality. Pollution has also affected tourism negatively, and triggered people to move out of the polluted cities in China (Liang and Zhao, 2015).

Against such background, quantification of air pollution-related health costs is needed for reviewing how much air pollution in China has costed the health of its own citizens, and how serious the problem is, before any sound and justifiable health-related environmental policy measures can be designed. Thompson et al. has conducted a quantitative study and suggested that the costs of United State's carbon policies could be offset by 26% to 1050% due to air pollution control policies in the states that improve air quality and reduce health costs, indicating those policies are worthy of implementation (Thompson et al., 2014).

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Another study in China has shown that various polluted provinces in China should closely cooperate in order to minimize the regional health costs due to $PM_{2.5}$ (Wu et al., 2017). Given that China hosts one-fifth of the world's population and is a key contributor to global air pollution (Kaiman, 2013), The beneficiaries of developing reliable and precise health cost accounting methodologies for China's air pollution will not be restricted to Chinese policy-makers, but also researchers who are interested in air pollution-related health policy studies globally (OECD, 2014).

Existing methodologies concerning air pollution-related health cost accounting research have not been studied thoroughly. First, a number of models and economic hypotheses have been proposed to evaluate the health burden of air pollution in China, but no systematic research has been conducted regarding how the accounting of economic loss differs across different methodologies. The basis for selecting a particular accounting methodology is not well established (D.-S. Huang and Zhang, 2013; Huang et al., 2012b; Kan and Chen, 2004; Wenbo and Shiqiu, 2010; Zhang et al., 2010). Secondly, various indicators have been proposed for health cost accounting in China. Some of them are global indicators, while others are China-specific. Inconsistency occurs when one type of indicator is preferred to another (see Section 3.2), but not much has been documented with reasonable justification. Thirdly, as the health cost accounting with respect to China's air pollution has become a heated discussion, scholars have attempted to acquire the needed data from various sources (Ding et al., 2016; Li et al., 2017; Lv et al., 2017; Pandey et al., 2004; QOEDC, 2017; Xie et al., 2015; J.Y. Zhu et al., 2017), a comprehensive review of open data resource is needed in order to assist researchers seeking for good quality data. Last but not the least, a comprehensive literature review that reveals changes in research focus and trends of development in this field is still lacking.

This paper studies the pros and cons of the traditional and new methods of health cost accounting in China, attempts to fill the research gaps and to provide valuable insights into how our future air pollution-related health cost accounting should be, both for China and the rest of the world. Our paper is structured as follows: Section 2 outlines the static and the dynamic model employed in health cost accounting research, identifies the discrepancies in their estimated GDP losses, and the rationales for indicators selection. Section 3 summarizes the indicators employed in different models. The sets of indicators integrated and standardized at the global scale and those designed specifically for China are introduced and compared. Section 4 provides an overview of the accessible data needed for the air pollution-related health cost accounting in China. Section 5 conducts a historical review of the academic articles covering the health cost accounting methodologies published in China in the last 30 years and identifies the research trend. Finally, our conclusion section charts the future directions of health cost accounting research in China.

2. Models and methods for health cost accounting of air pollution in China

2.1. The static accounting model vs. the dynamic accounting model

Two models are most commonly utilized for health cost accounting of air pollution: the static model and the dynamic model. Each type can be subdivided into different hybrid versions. Fig. 1 presents the typical structures of both models:

The static model follows a linear process. First, it measures the dose-response relationship between air pollutants and their health endpoints, such as premature deaths and incidents of respiratory illness (Kahn and Yardley, 2007), based on epidemiological literature; second, it monetarizes the health burdens based on market or survey data (Zhang et al., 2017a).

The dynamic model has been increasingly adopted recently, characterized by a thorough examination on the dynamics of the health industry (Wu et al., 2017), and the long-term or cross-period effects of economic loss (Böhringer and Rutherford, 2008; Clarke et al., 2009; Dai et al., 2017; Karplus et al., 2016; Li et al., 2012; Qi et al., 2014; van Ruijven et al., 2012; Wang et al., 2016; Yang et al., 2005; Zhang et al., 2013; L. Zhu et al., 2017). The dynamics are principally captured by diversified Computable General Equilibrium (CGE) models (Bollen and Brink, 2014; Matus et al., 2012; Nielsen and Ho, 2013; Saari et al., 2015; Wu et al., 2017; Xie et al., 2016). As shown in Fig. 1, a typical dynamic model is configured as a closed loop model. In particular, instead of merely considering the industry's impacts on health costs, the negative feedback of health loss on the resource allocation and market demands will be taken into account (Matus et al., 2012). By taking the bidirectional influences into account, the model can capture the general equilibrium after running multiple iterations (when key parameters converge), yielding the solution in the form of a final cost (Zhang et al., 2017a). Usually, five sub-models are nested in a complete dynamic model. First, a sub-model obtains the air pollution emission inventory through industry data (e.g. energy use); second, with reference to the transmission model and the chemical reactions theories, another sub-model predicts air quality distribution from the emission data; followed by the third and fourth sub-models that monetize the health costs by multiple dose-response equations and econometric methods; and the final sub-model calculates the influence of health damage on the industry iteratively, eventually reaching the general equilibrium across all sectors (Zhang et al., 2017a). Table 1 presents a dynamic model of an energy sector for air pollution-related health impact analysis (Karplus et al., 2016; Kishimoto et al., 2017; Luo et al., 2016; Zhang et al., 2013, 2017a).

2.2. Economic methods in the models and their estimation results

Various economic methods have been adopted in health cost accounting models, including the Direct Market Method, Surrogate Market Method, Contingent Value Method and Benefit Transfer Method are most commonly used (Chen et al., 2014). The following section will elaborate the four methods, and present the estimation value of models that are designed mainly based on each method.

2.2.1. Direct Market Method

The Direct Market Method (DMM) aggregates the market prices of goods or services that are curtailed directly by air contamination. It includes Market Value Approach (MVA), Opportunity Cost Approach (OCA), Human Capital Approach (HCA), Cost of Illness (COI) and Dose-response Technique (DRT) (Chen et al., 2014). Among these approaches, COI mainly focuses on estimating the cost of morbidity (Huang et al., 2012b). It can be used to substitute the Willingness To Pay (WTP) approach since COI data is easier to be obtained (see Section 2.2.3 for WTP). The description, sample calculation formula and data required for each approach are listed in Table 2.

DMM is the dominant econometric method for health cost accounting in China, and the MVA, HCA, COI and DRT are most widely used. For instance, the WRF-Chemical model shows that in China, health cost due to outdoor $PM_{2.5}$ pollution was reported to be about USD 151.1 to USD 176.9 billion in 2006 (Miao et al., 2017). Similar air pollution-related health cost studies focusing on metropolises such as Beijing (Li, 2012), provinces and cities in southern China (Wang and Qu, 2002), and the northern inland areas can be found (Han and Ma, 2001; Li, 2012; Zhou and Li, 1999). Besides assessing the economic loss due to air pollution-related health degradation, DMM has been used to calculate the economic gain of ambient air quality improvement. For example, the aggressive emission control policies introduced during the Asian Games in Guangzhou in 2010 was estimated to avoid 106 premature deaths, 1869 cases of hospital admission, 20,026 cases of outpatient visits, with an overall economic gain estimated to reach CNY 165 million (Ding et al., 2016). Similarly, using the HCA and DRT accounting, it was estimated that the energy reform introduced in