Science of the Total Environment 637–638 (2018) 91–103

Contents lists available at ScienceDirect

Science of the Total Environment

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

The assessment framework of provincial carbon emission driving factors: An empirical analysis of Hebei Province

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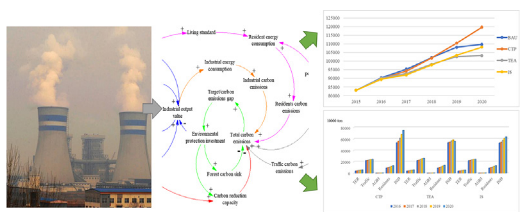
HIGHLIGHTS

- A provincial assessment framework of carbon emission driving factors was constructed.
- Carbon emissions in different fields of a province were clearly shown.
- Carbon trading, carbon sinks and other measures were included in the model.
- The overlapping effects of different scenarios and policies were reflected.
- Specific emission reduction measures were put forward for Hebei and other provinces.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 7 December 2017
Received in revised form 16 April 2018
Accepted 30 April 2018
Available online xxxx

Editor: Simon Pollard

Keywords:
Carbon emission
System dynamics
Driving factors
Scenario analysis
China

ABSTRACT

The achievement of emission reduction targets in each province is necessary for Chinese government to reach its international obligations. Research on the detailed disaggregate driving factors based on provincial carbon emission changes could inform better carbon emission reduction policies. This paper establishes an assessment framework of provincial carbon emissions drivers using system dynamics modelling and makes an empirical analysis of Hebei Province. The model attempts to simulate the dynamic relationship between carbon emissions generation and suppression through seven subsystems including population economy, secondary industry, and policies. In addition, carbon sinks and carbon markets are also incorporated into this framework. Based on the socio-economic conditions, policy guidance and emission reduction targets of Hebei Province, we analyze the impact of single-factor changes and make a four scenario evaluation to explore the mitigation strategies in the light of provincial level. The simulation results are acquired as listed; (1) The impact of technology and energy structure on emission reduction is seen to be obviously, and excessive reliance on carbon emissions trading could not be generated conducive to emission reduction. (2) The combined effectiveness of driving factors is not equal to the aggregation of simple summation of each single factor. (3) The role of carbon sinks in reducing emissions should not be ignored. Therefore, the results of empirical analysis show that targeted emission reduction measures should be formulated according to the actual carbon emission sources. Policy implications in terms of our study results are recommended alternatively.

1. Introduction

The IPCC's Fifth Assessment Report confirms that global carbon dioxide concentration has risen to the highest levels and that greenhouse gas emissions have been the leading cause of global warming since the mid-20th century (Stocker.Tomas et al., 2014). The research from

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https://doi.org/10.1016/j.scitotenv.2018.04.419

the World Meteorological Organization (WMO) and the report of the Global Carbon Project (GCP) also support this view (Quéré et al., 2016). Global warming has become an indisputable fact that requires people to fully understand the urgency of curbing carbon emissions. The reality is that China, the world's biggest emitter of carbon emissions, accounts for 28% of the global total. The global carbon reduction trend is heavily dependent on China (Stocker.Tomas et al., 2014). Although the Chinese government has made tremendous efforts to reduce carbon emissions, including actively fulfilling the emission reduction obligations stipulated in the "Paris Agreement" and putting forward the "13th Five-year Plan for Controlling Greenhouse Gas Emissions", China still faces the problem of enormous pressure. Therefore, such pressure cannot be mitigated by relying solely on the measures taken by the central government (Xie et al., 2017; Zhang, 2015).

The achievement of emission reduction targets in every province is necessary for the Chinese government to reduce emissions. In fact, the Chinese government does indeed have a clear division of provincial emission reduction responsibilities. The documents issued in recent years, such as "Work Plan on Greenhouse Gas Emissions in Hebei Province" and "13th Five-Year Plan for Natural Gas Development in Hebei Province", contain quantifiable emission reduction targets and define the emission reduction responsibilities of Hebei. These documents include many quantitative responsibilities, such as: In 2020, carbon dioxide emissions per unit of GDP in Hebei Province will drop 20.5% as compared with that in 2015. The proportion of non-fossil energy consumption will increase from 2015 3.05% to 7%. More specific expressions could be seen in Section 5.1.

Very limited literature has systematically studied carbon emission driving factors from the provincial level. Currently, most research focuses on country or city emission reduction (Wang et al., 2017; Wang et al., 2012; Xu et al., 2016). A few provincial studies only focus on carbon emissions from several sectors in one province or carbon emissions from energy consumption. Based on the "energy-economy carbon emissions" hybrid input-output analysis framework, Wang et al. (2017) conducted structural decomposition analysis (SDA) on carbon emissions influencing factors in Guangdong Province. Tang et al. (2016) used LMDI to assess the relative contribution of different factors to emission variability in Jiangsu Province. Lia et al. (2017) studied the data from various provinces in China and analyzed the effects of common carbon emission factors. In fact, the above-mentioned studies in recent years still have the following three defects: (1) The current research focuses on the national level and the urban level. In fact, the socio-economic disparities in various parts of China are very large. Studies at the national level have led to insufficient specificity of carbon emissions in different regions. However, the study scope at the city level is small and contains too many specialties. Therefore, the current lack of provincial research just meets the balance of commonality and individuality. (2) The existing research does not clearly quantify the intrinsic link between provincial-level carbon emission drivers and social economy, but instead simply carries out factor decomposition. However, it is difficult for us to see in such decomposition the social and economic factors that follow what path has had an impact on carbon emissions. (3) The current article does not systematically study new factors that may have a major impact on carbon emissions (such as carbon emissions trading, forestry carbon sinks, and carbon taxes). Those common factors (such as GDP, energy structure, industrial structure, etc.) are usually ignored when these new factors are studied separately. Or that all factors have not been included in the unified system for research. This may underestimate the complexity of the socio-economic and carbon emissions as a system and make the effects of such factors as carbon emissions trading, forestry carbon sinks, and carbon taxes misinterpreted.

However, identifying key carbon emission factors may directly affect China's carbon emission reduction measures, policies, and strategies (Shuai et al., 2018). At present, various emission reduction measures have been widely used, such as carbon trading, forestry carbon sinks, and so on. The research does not consider the effects of these measures; especially the carbon sequestration of forestry is often ignored. As the largest carbon storage in terrestrial ecosystems, forests play an important role in reducing carbon emissions and maintaining carbon balance (Xia, 2016). In addition, carbon emissions trading in China has just passed the experimental stage and is being carried out in a wider range. Before the launch of China's unified carbon trading market at the end of 2017, China began conducting long-term carbon trading pilots in seven provinces and cities including Shenzhen and Shanghai from 2013. From the "National Carbon Emission Trading Market Construction Plan (Power Generation Industry)", although the Chinese government has announced that the national carbon market is "starting", it still needs a large amount of basic research to establish the necessary system and support system. The official market transaction is expected to start at a price of 50–70 yuan/ton, and the expected transaction price is 300 yuan/ton.

In summary, the actual research itself has a certain research gap. Under such mixed research conditions, the provinces are already pushing hard to reduce carbon emissions. Due to the lack of basic research on the drivers of carbon emissions in actual emission reduction work, some provinces may blindly formulate unrealistic emission reduction measures. This also reflects another research gap in the current study. The purpose of this paper is to fill up the above research gap by using system dynamics modelling to construct a framework for assessing provincial carbon emission drivers.

To accomplish this purpose, we attempted to design the next study in such a way. First, build a complete SD model that includes socio-economic, energy, carbon emissions, and policy approaches. The model will use a variety of subsystems to fully present the complex feedback of the economic society and carbon emissions system. Second, a scenario analysis of the SD model is an important part of this study. In order to observe the effect of a single emission reduction method and the comprehensive use of different emission reduction measures. Finally, according to the results of empirical analysis, reasonable and effective emission reduction policy recommendations are given.

The SD model will include a number of subsystems such as the population economy, the three major industries, the residents' lives, and traffic travel and emission reduction policies. Each subsystem has its own "task" that will work together to sort out the inherent complexity of carbon emissions and their influencing factors. The population economics subsystem will provide the model with a basis that can shed light on the details of carbon emissions in all areas of society and economy. The goal of the three major industries is to meticulously portray the economic-energy carbon emission process in economic activities. The two sub-systems of residents' life and transportation will calculate their own carbon emissions. Their purpose is to improve the system of carbon emission accounting and clarify the carbon emission responsibilities that this department undertakes. The setting of the policy subsystem is to provide feedback to other subsystems through different means of emission reduction so as to observe the effects of different emission reduction policies. Based on this model, we have extensively collected policy documents on economic transformation, energy conservation, and emission reduction in China and Hebei Province in recent years. From the above, we have extracted the expected target data for technical reduction, carbon trading market, and forest carbon sink that the government has focused on. Based on this, scenarios such as Business As Usual (BAU), Carbon trading and Further Policies (CTP), Technology and Energy Structure Adjustment (TEA), and Integrated scenarios (IS) were set up. It can be seen from the name that different scenarios have their own priorities. BAU will continue to observe the current development trend to observe the carbon emissions expected by Hebei Province (2020). The model will focus on regulating carbon emission through policy measures and depressing carbon emissions through technical measures under the CTP and TEA scenarios, respectively. The IS scenario is a comprehensive application of the above methods.