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Measuring interregional spillover and feedback effects of economy and CO_2 emissions: A case study of the capital city agglomeration in China

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ABSTRACT

Interregional trade not only contributes to economic output but also causes a large amount of CO_2 emissions. We measure the spillover and feedback effects of economy and CO_2 emissions in the capital city agglomeration of China by a four-region input-output model. The results reveal that the contribution of spillover effects on both economic output and CO_2 emissions is remarkable. First, both of net economic and CO_2 emissions spillovers flow from Beijing to Hebei and Tianjin. Second, net economic spillovers flow from Hebei to Tianjin, however net CO_2 emissions spillovers flow from Tianjin to Hebei. Thirdly, there are some sectors, such as mining and washing of coal sector, whose economic and CO_2 emissions net spillovers flow in opposite directions between any two cities. The results indicate that the economic driving function from Tianjin to Hebei needs to be strengthened, and Tianjin should assume part of the CO_2 emissions responsibility for Hebei. The most important is that cities should work together to replace coal with clean energy technologies such as those based on wind and solar.

1. Introduction

Since the initiation of reforms and the associated changes in policies, China has exhibited a high rate of economic growth. China became the second largest economy in 2009. International and domestic trade is an important driving force for this great achievement. International trade leads to economic growth and causes environmental impacts (Zhao et al., 2017, 2016; Tian et al., 2017; Chen and Chen, 2013). Similarly, interregional trade has both economic and environmental impacts. Previous studies reveal that interregional spillover and feedback effects contribute to regional economic development (Pan, 2015; Bai et al., 2012). Spillover and feedback effects are important interregional interactions. The spillover effects can be traced back to the theories of economic equilibrium and non-equilibrium development. In the 1950s, economists focused on the growth pole and put forward the spillover effects of the center to the periphery. With the development of new economic growth theory, Romer (1986) and Robert (1988) proposed that the spillover effects are the exogenous economic essence. The economic spillover effects refer to the unidirectional influence of the economic development of one region on the economic development of other regions. The feedback effects are the influence of other regions on the development of the region (Pan and Li, 2007).

Initially, the study of the effects of interregional spillover and feedback concentrated on the economic field and then gradually expanded to the study of resources and the environment (Wood et al., 2018; Zhao et al., 2018; Wang et al., 2018; Chen et al., 2018; Hossein and Kaneko, 2013; Wang and Chen, 2016). The spillover and feedback effects of CO_2 emissions are a type of environmental effects embodied in interregional economic interactions. Economic development requires energy consumption, therefore, interregional economic interactions can lead to spillover and feedback effects of energy consumption and CO_2 emissions (Su and Ang, 2014; Meng et al., 2013; Zhang et al., 2013, 2016; Zhang, 2017).

The existence of spillover and feedback effects, on the one hand, has strengthened the economic links among regions. On the other hand, there has been a close correlation between inter-region CO_2 emissions and a requirement for regional cooperation to reduce emissions. It is needed to clarify the interregional influence of CO_2 emissions in order to cooperate in emissions reduction between regions. Moreover, each region should assume the responsibility of CO_2 emissions reduction as well as obtain the economic benefits. The purpose of this study is to

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Fig. 1. Location and range of the capital city agglomeration.

measure and compare regional economic and CO_2 emissions spillover and feedback effects, in order to provide a reference for cooperate in CO_2 emissions reduction among different cities, based on the case of a capital city agglomeration in China.

The reason for choosing the capital city agglomeration as a case is as follows: First, the city agglomeration has close economic ties. Second, the city agglomeration has great differences in development. Thirdly, the city agglomeration is the implementation zone of the "Beijing-Tianjin-Hebei collaborative development strategy", facing the dual task of economic and environmental cooperation.

The capital city agglomeration in China includes Beijing, Tianjin, and the cities of the Hebei Province, which includes Shijiazhuang, Baoding, Langfang, Cangzhou, Qinhuangdao, Tangshan, Zhangjiakou, Chengde, Hengshui, Xingtai and Handan (as shown in Fig. 1). In 2015, the city agglomeration occupied approximately 2% of China's territory, accounted for 8% of China's population, contributed 10% to China's GDP, and consumed 10% of China's energy.

There are huge differences in the economic development within this region. Beijing and Tianjin generated more than twice the per capita GDP of Hebei in 2015. High-tech industries and modern service sectors are dominant in Beijing. The leading sectors in Tianjin are transforming from traditional manufacturing to emerging industries, such as equipment manufacturing, electronic information, aerospace, new energy, and new materials. Hebei has abundant mineral and energy resources, therefore, traditional industries with high-energy consumption and low-value addition are well developed in this region. These differences between the economies of the above regions promote frequent trade between cities (Zheng et al., 2018). Cities of Hebei often provide Beijing and Tianjin with steel, cement, coal, and other industrial raw materials. Thus, CO_2 emissions embodied in trade among these cities can't be ignored. If ignored, it is not fair to Hebei province. That is to say, Hebei would undertake more CO_2 emissions reduction tasks but obtain relatively small economic benefits.

China's Work Program for Controlling Greenhouse Gas Emissions During the Period of the Thirteenth Five-year Plan released in 2016 which states that in 2020, the CO_2 emissions per unit of GDP will drop by 18% compared with that in 2015. Meanwhile, the goals of the provinces are divided into five categories. Among them, Beijing, Tianjin and Hebei have the same CO_2 emissions intensity target, namely a decrease of 20.5% respectively. However, the above target on CO_2 emissions intensity reduction only takes into account the CO_2 emissions and GDP generated by local production activities, while insufficient attention is paid to CO_2 emissions from interregional trade flows. In order to achieve this goal, all the provinces are formulating their own policies without regard to reducing CO_2 emissions through economic cooperation. This study attempts to clarify the economic relationship among Beijing, Tianjin and Hebei through the analysis of spillover and feedback effects, as well as the involved CO_2 emissions, so as to provide the basis for working together to reduce CO_2 emissions intensity between cities.

The remainder of this paper is organised as follows. Section 2 presents the methodology used in the study. The steps for establishing the multi-regional input-output model and measurement of spillover and feedback effects are presented in this section. The empirical results are discussed in Section 3. The main conclusions of this study and policy implications are presented in Section 4.

2. Methodology

2.1. Measurement of interregional economic spillover and feedback effects

Interregional economic impacts have attracted much attention (Bai et al., 2012; Brun et al., 2001; Chen, 2007; Li, 2014; Wang, 2016). Some scholars have constructed econometric models to study interregional spillover effects (Groenewold et al., 2007; Xi and Li, 2015; Zhang and Felmingham, 2002; Zhu et al., 2016). However, the methods used in these studies can only measure the elasticity of interregional spillover effects without a scientific standard for selecting variables.

The multi-regional input-output (MRIO) model is widely employed to quantify interregional or inter-industrial impacts. Based on the model, certain researchers have measured interregional impacts of resources use, mainly including water withdrawals, energy consumption, and land use (Oppon et al., 2018; Zhao et al., 2018; Zhang and Anadon, 2014). Numerous studies have calculated interregional environmental impacts by using the MRIO model (Yang et al., 2018; Martinez et al., 2018; Weinzettel and Wood, 2018; Wang et al., 2017). CO_2 emissions linkage is one of the most popular issues (Tian et al., 2018; Wang and Ang, 2018; Chen et al., 2017; Jiang et al., 2016), which directly affects the CO_2 emissions responsibilities identified in international negotiations. In comparison with the econometric method, the MRIO method has a more unified form. Moreover, the MRIO method can quantify interregional feedback effects (Moran et al., 2018; Geoffrey et al., 1999; Pan and Li, 2007; Wu and Zhu, 2010; Zhang and Zhao, 2006), which can not be calculated by the econometric method. Therefore, we use an MRIO model to measure interregional economic spillover and feedback effects.

Miller (1963) introduced a decomposition algorithm of the MRIO model for two regions and analysed interregional economic feedback effects. Based on this model, Pyatt and Round (1979) put forward a framework for measuring spillover and feedback effects. Subsequently, Round (1985) separated the interregional spillover effects from the feedback effects. Based on the method of Miller (1963) and Round (1985), this study develops a four-region MRIO model, which includes Beijing, Tianjin, Hebei and the other provinces in China, and excludes Hong Kong, Macau and Taiwan because of no available data. The basic form of the input-output decomposition model is as follows:

$$AX + Y = X \tag{1}$$

where A, X and Y is the input-coefficient matrix, the total output and