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Dematerialization in Beijing from the perspective of material metabolism

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ABSTRACT

City has always been a concentrated area of consumption and pollution in a country or region. Solutions to the dematerialization of city would exert a profound impact on the entire socio-economic system. And the issue of resources and environment in Beijing, the center of China's politics, economy, and culture, becomes a focus of attention both domestically and internationally. In this paper, we used the economy-wide material flow analysis to describe the socio-economic development and the current situation of resources and environment in Beijing during the period 1992–2015. Based on this, Tapio decoupling model and the logarithmic mean divisia index method were used to analyze the level and influencing factors of dematerialization in Beijing. The results of the study showed that: From 1992 to 2015, GDP of Beijing increased from 61.25 billion yuan to 623.45 billion yuan, at the same time, direct material input and domestic processed output also increased from 139.88 million tons and 78.63 million tons in 1992 to 205.17 million tons and 166.27 million tons in 2015 respectively. Judging from the change of the decoupling relationship between economic growth and resources and environment, the level of dematerialization in Beijing was continuously increasing. And the dematerialization level of resource consumption was slightly better than that of pollution discharge. The high expansion of population and economy was not conducive to the realization of dematerialization in Beijing. However, the decrease of the intensity of material utilization played a crucial role in the process of dematerialization in Beijing. Moreover, increases in material circulation and social overall level of cleaner production were beneficial to the realization of dematerialization.

1. Introduction

Urbanization is a phenomenon that accompanies socio-economic development. When city provides great convenience for people's production and life, its development has also promoted social and economic growth. However, with the acceleration of urbanization, the problems of resources and environment in cities are becoming increasingly prominent, which has become the key factor restricting the sustainable development. Therefore, it has gradually become the focus of academic circles that how to reduce resource consumption and pollution emissions so as to achieve the healthy development of urban social economy. In October 2017, the 19th Session of National Congress of the Communist Party of China clearly stated that "we must vigorously promote the quality and efficiency of development to meet the growing ecological needs of the people on the basis of continuing to promote development." The issue of the balance between economic growth and ecological environment is particularly important in the new economic situation. While developing economy, we should not only pay attention to the growth of "quantity", but also to the improvement of "quality". In September 2017, "City Master Planning of Beijing (2016–2035)" was officially released, which clearly put forward "rigidly constraining and rationally planning the urban size based on the capacity of resources". In the process of social and economic development in Beijing, the importance of resource and environmental issues is obvious.

Dematerialization is a new research idea to solve the resource and environment problems. While the concept of dematerialization in early stage only emphasized the reduction of resource consumption (Colombo, 1988; Wernick and Ausubel, 2003), with the extensive development of related research, its concept has also been continuously enriched. Now this concept emphasizes reducing environmental pressures to the minimum while achieving

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economic growth (Chen et al., 2003). The reduction of environmental pressure in this area includes both the decrease of resource consumption and the decline of pollution discharge.

On the basis of the definition of dematerialization, many studies have explored issues related to dematerialization of the social economy. Ruth M examined the impact of dematerialization on energy use and CO_2 emissions from five metals sectors in the United States. The study found that improving energy efficiency and changing the fuel mix promoted the reduction of carbon emissions (Ruth, 1998). Sun and Meristo (1999) analyzed the dematerialization in the energy use of OECD from 1960 to 1995. They held the view that OECD had achieved significant dematerialization during the study period. Sun (2003) analyzed the dematerialization of energy use in Finland from 1972 to 1996, and indicated that although Finland had achieved good results in decarbonization and energy saving, it still lagged behind other developed countries. Dong et al. (2017) held the view that Japan had already begun to step into the dematerialization stage and the technology played a pivotal role. It can be seen from the above scholars' studies that significant achievements in dematerialization have been achieved in some developed countries. However, the degree of dematerialization is varied in different countries. Some scholars also made researches on the dematerialization of developing countries. For example, Li and Wang (2008) conducted multiple factors decomposition on the dematerialization of China's energy consumption from 1985 to 2006. The research showed that economic expansion was the dominant factor of energy consumption. Ru et al. (2009) discussed the dematerialization of China from 1952 to 2005. Their results demonstrated that China was already at a relative dematerialization level of carbon emissions. By material flow method, Wang (2015) analyzed the direct material input in China from 2000 to 2013 and its relationship with specific economic characteristics. Chiu et al. (2017) found that Philippines actually didn't fully achieved dematerialization compared with highly developed countries like Japan. As can be seen from the above scholars' research, developing countries still lag behind developed countries in terms of the dematerialization degree.

In conclusion, dematerialization studies focus more on carbon emissions and energy consumption. Most studies only analyze some of the resource consumption (such as energy, metals) or partial of the pollution emissions (such as carbon emissions). However, the study of the relationship between the resource environmental pressure in the overall social and economic growth is still relatively limited. In addition, the dematerialization analysis focuses more on the research at the national level, and the research on dematerialization of cities is still not much. As the basic unit of production and living activities, the city is a concentrated area for resource consumption and pollution discharge. Therefore, it is of great significance to study the dematerialization of the city for the realization of the dematerialization of the entire economic system.

The purpose of dematerialization is to ease and gradually solve the increasingly severe resource and environmental problems. From the perspective of ecology, the resource and environment problems of urban development can be attributed to the dislocation or imbalance of the city's material metabolism in time or space (Lou, 2007). Material flow analysis is one of the main methods for the quantitative analysis of material metabolism in the world (Ma et al., 2007). Based on the conservation of matter, material flow analysis can quantitatively assess the systematic analysis of material flow and storage in a given system in a certain space-time. It also deals with various aspects of the source, path and sink of material flows (Brunner and Rechberger, 2004; Dai, 2015). According to different subjects, material flow analysis can be divided into substance flow analysis (SFA) and economy-wide material flow analysis (EW-MFA). EW-MFA can explore in-depth the relationship between socio-economic development and ecological environment. It can provide an effective path for solving the resource and environment problems in the process of socio-economic development (Dai et al., 2017a; Dai and Wang, 2017a).

In view of the above analysis, this paper took Beijing as an example and applied EW-MFA to establish the material metabolism model of its throughput state so as to objectively reflect the status quo of its resources and the environment. On this basis, the paper analyzed the problem of the city's dematerialization in Beijing from the perspective of material input and output. In this paper, the dematerialization and its influencing factors in Beijing were investigated, which provided scientific basis for the exploration of dematerialization in the city.

2. Methods and data

2.1. EW-MFA

In recent years, scholars have paid more attention to the study of dematerialization according to the index of material flow analysis. Canas et al. (2003) brought analytical value to the discussion on "dematerialization" considering direct material input (DMI) per capita as the dependent variable in a test of the environmental Kuznets curve (EKC). Shao et al. (2017) analyzed the relationship between economic recession and material use, measured as DMC during 1970–2010 of 150 economies, and found that dematerialization typically occurred under conditions of low or negative economic growth. Zhang et al. (2017) developed an integrated analytical framework of dematerialization analysis incorporating both material flow and stock indicators.

EW-MFA can quantitatively measure the impact of human activities on the natural environment from two aspects of material input and output, which provides the possibility for comprehensive dematerialization analysis. Direct material input (DMI) and domestic processed output (DPO) are two key indicators in economy-wide material flow analysis (Dai et al., 2017b): DMI index represents the material flow directly into the socio-economic system from the ecological environment system at the input end, which is used to reflect the resource consumption, and DPO index represents the material flow from the socio-economic system to the ecological environment system at the output end, which is used to reflect the pollution discharge.

2.2. The decoupling model

The dematerialization level of a country or region can be measured by the decoupling of economic development indicators from resource and environmental indicators (Wang, 2010). Tapio (2005) decoupling model combines two types of indicators, gross and relative variability. The model uses a time-scale elastic analysis method to reflect the decoupling relationship between variables. Thus, the objectivity and accuracy of decoupling relationship measurement and analysis are further improved (Peng et al., 2011). Therefore, this paper adopts Tapio (2005) decoupling model to measure the level of materialization in Beijing. The decoupling model is constructed as follows:

$$t = \frac{\%\Delta EP}{\%\Delta GDP} \tag{1}$$

In Eq. (1), t is the decoupling elastic coefficient; GDP is gross domestic product; EP is environmental pressure, and it refers to resource consumption (DMI index) and pollutant emission (DPO index). DMI and DPO indicators respectively reflect the impact of the socio-economic system on the eco-environment system in