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The driving forces of material use in China: An index decomposition analysis

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ABSTRACT

Based on its economic development and population expansion, China has become one of the most important countries in terms of accounting for materials used worldwide. A deeper understanding of how material use has evolved in China is needed to devise appropriate policies in the future. This paper applied a logarithmic mean Divisia index (LMDI) to decompose the driving forces of changes in China's material use during the 2002–2012 period into five component effects: population, activity, structural, intensity and material structural effects. In addition, a decoupling index was used to further analyse the decoupling relationship between China's material use and gross output per capita. The results show that Chinese material use has risen from 11.8 billion tonnes in 2002 to 35 billion tonnes in 2012 and that the economic activity effect is the largest positive contributor to the growth in material use, followed by material structural effect, population effect and structural effects. The material intensity effect positively promoted the increase in material use during the 2002–2007 period, although it played a negative role during the 2007–2012 period. A province-level analysis reveals substantial heterogeneity. Some provinces exhibit falling material use, although in most provinces, material use significantly increases. The decoupling analysis indicates that relative decoupling and no decoupling effects characterize the main conditions across the provinces during the study period. Policy recommendations are then made based on our findings.

1. Introduction

In recent years, increasing economic development and urbanization along with a growing population have stimulated considerable use of raw materials on a large scale (Fishman et al., 2015). In 2002, 54 billion (metric) tonnes of raw materials were extracted for consumption or use in production processes. By 2012, this amount had risen to 80.4 billion tonnes. As globalization has progressed, China has played an important role in stimulating the provision and use of raw materials. As a country with high material intensity, China accounted for 19.7% of worldwide material extraction in 2002, and by 2012, that number had grown to 33.3% (as shown in Fig. 1). Meanwhile, various types of raw materials were characterized by different growth rates over this period. Biomass remained at the same level of extraction, while there was significant growth in non-metallic minerals extraction. Notably, China also dramatically expanded its material supply in relation to its increased extraction. Thus, it is necessary to investigate the current state of material use – particularly in China – to elucidate the relevant driving forces.

On a related note, issues of material use have rapidly become matters of primary importance in international policy debates (UN Environmental Program, 2011). Resource efficiency has been emphasized as one of seven flagship initiatives in the European Union's 2020 strategy for green and sustainable development (European Environment Agency, 2011). Considering the increased demand from the policy domain for robust indicators, it is imperative that we construct an appropriate assessment framework to measure material use and material intensity. Increased attention has been paid not only to materials and products that are directly used by a national economy but also to the indirect resource use that is required in supply chains and embodied in internationally traded products (Lutter et al., 2016).

Domestic material consumption (DMC), one of the most popular current indicators of material use, has been widely used across both fields and regions by numerous institutions (OECD, 2011; 2014; 2015; UN Environmental Program, 2013a). Meanwhile, certain scholars have comprehensively compared DMC on a global scale (Dittrich et al., 2012; Giljum et al., 2014; Steinberger et al., 2013). In addition, the concept of a material footprint (MF) has been devised and calculated to

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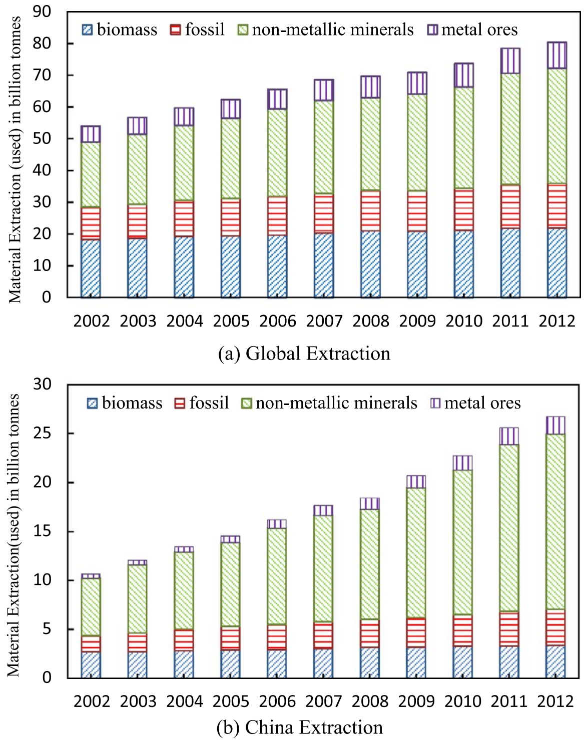

Fig. 1. Resource extraction across the globe and in China during the 2002–2012 period.
Data source: www.materialflows.net.

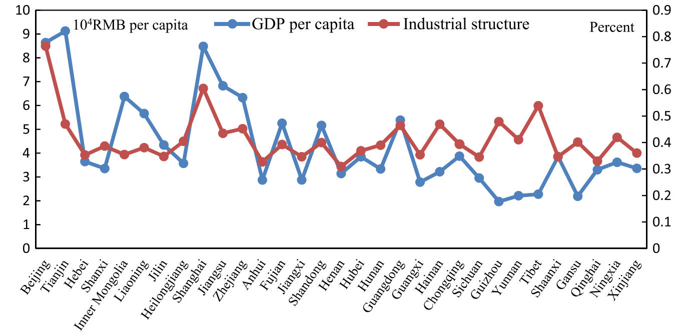

Fig. 2. The distribution of gross domestic product (GDP) per capita and industrial structure of provinces in 2012.
Data source: China Statistical Yearbook (2013). Note: industrial structure refers to the proportion of tertiary industry output accounted for the total industry output.

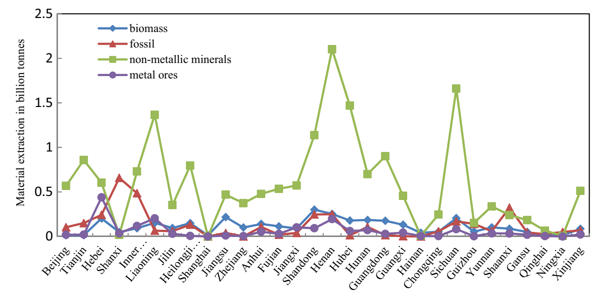

Fig. 3. Four types of material extraction of 30 provinces in 2012.
Data source: www.materilaflows.net and calculated based on our study.

measure direct and indirect material consumption, commonly known as raw material consumption (RMC) (Bruckner et al., 2012; Kovanda and Weinzettel, 2013). RMC is defined as the global allocation of raw material extraction used in the final demand of an economy (Wiedmann et al., 2015). In contrast to DMC as an economy-wide material indicator, the MF focuses more on upstream material flows that are associated with internationally traded products, thus illustrating the volume of materials that are required for specific products along their entire supply chains, from resource extraction to final demand.

Given that demand for raw materials derives from production and consumption, we investigate material use rather than extraction. We define material use as the regional material consumption which equals regional extraction plus material inflows minus material outflows and materials are directly employed by sectors in the production process and by final consumers, both regional extraction and inflows. Compared with DMC, material use is an indicator which measures the utilization of materials at the beginning of the value chain and a large share of materials is used in the production process and not consumed directly as final demand (Pothen and Schymura, 2015). Biomass, fossil materials, non-metallic minerals and metal ores together constitute raw materials (excluding water and air). Material use is closely linked to local economic development and geophysical factors, including land area per capita and climate change (Steinberger et al., 2010) and China's provinces exhibit extremely uneven economic development, industrial structure and resource endowment, as shown in Fig. 2 (National Bureau of Statistics of China) and Fig. 3 (this calculation is based on this study data). As raw materials are the fundamental resource of the industrial sector, rapid raw materials extraction along with a growing population, poor material resource management, and even spatial distribution have resulted in frequent and severe material-related issues in China (Li et al., 2015; Li and Dewan, 2017; Yu et al., 2015). Accordingly, it is essential for policy makers to obtain a clear understanding of raw material use to address current material issues and to enact effective material resource policy in China.

Certain studies have empirically investigated the drivers of material use. In fact, the choice of methods is closely related to the driving factors. These studies can be primarily divided into three groups based on the methodology employed to examine the drivers of material use, i.e., structural decomposition analysis (SDA), index composition analysis (IDA), and econometric techniques. The SDA approach decomposes index changes by using the input-output tables in specific years depending on the input-output model that is used in the quantitative economics. Numerous scholars have applied SDA to analyse CO_2 emissions (e.g., Chang et al., 2008; Tian et al., 2013; Geng et al., 2013; Su and Ang, 2012). Considering the similarity between carbon emissions and material use, the SDA approach has also been widely employed to expose the drivers of material use. Muñoz and Hubacek (2008) applied the SDA method to investigate Chile's material use from 1986 to 1996. The changes in material flow accounting were decomposed into five driving effects: material intensity, structural change, changes in the mix, category and level effects. Wood et al. (2009) used the SDA method to analyse the drivers of material use in Australia. The results showed that the major positive drivers of changes in material use were the level of exports, export mix, industrial structure, affluence, and population. Weinzettel and Kovanda (2011) applied the SDA method to expose the driving forces of material use change in the Czech Republic during the 2000–2007 period. The changes of individual material categories were broken down into three driving forces: technology, product structure of the final demand, and volume of the final demand for individual final demand categories.

Compared to the SDA approach, the IDA method requires only aggregated data of departments and is suitable for time series decompositions that contain few factors. Hence, the application of IDA proves more widely, which mainly contains the Laspeyres and Divisia index approaches. LMDI has been employed in IDAs to explore the driving forces of various indexes due to its inherent advantages regarding path independence, its ability to handle zero values with no unexplained residual terms and its consistency in aggregation (Ma and Stern, 2008). The LMDI application appeared in 2001 in the literature in which the method was applied as a perfect decomposition tool for analysing