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Dynamics of material productivity and socioeconomic factors based on auto-regressive distributed lag model in China

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ABSTRACT

Material productivity (MP), measured as economic output (such as Gross Domestic Product, GDP) per corresponding material input, is gained significant interest of becoming a widespread environmental sustainability indicator. The study of MP's dynamics is very important for policy-making on how to improve MP. This paper applies the auto-regressive distributed lag (ARDL) model to investigate the dynamic impacts of energy intensity for secondary industry (SEI), tertiary industry value added per GDP (TVA), trade openness (TO) and domestic extraction per capita (DEC) on MP in the case of China during the period from 1980 to 2010. The validated and robust results of the model confirm the existence of cointegration among the variables both in the long and short run. The impacts of selected socioeconomic factors can be summarized as follows: 1) In the long run, an SEI decrease driven by technology improvement is found to be the main driver of MP, and a 1% decrease in SEI results in a 0.432% increase in MP; 2) The magnitude of the impact of TVA on MP is higher over the short run than over the long run; 3) TO can reluctantly promote MP both in the long and short run; 4) DEC exhibits fundamentally different behaviors in the long and short run. DEC is not a strongly significant factor for MP, and the magnitude of the impact is very weak in the long run. However, it has the greatest negative impact on MP in the short run, as a 1% increase in DEC results in a 0.519% decrease in MP, which demonstrates that the marginal revenue of resource input has already dramatically declined. These insights from the study could be considerably helpful for sustainable resource management and material productivity enhancement.

1. Introduction

The transformation and flow of natural resources function as the material foundation for the world economy as well as the link between human activities and environmental impacts (Bringezu et al., 2004). However, since industrialization, natural resource consumption has risen sharply and thus has currently become a principal constraint to sustainable development. Meanwhile, excessive and insufficient material utilization lead to serious environmental issues such as climate change, air and water pollution, desertification, biodiversity loss and ecosystem degradation (Behrens et al., 2007). Material productivity (MP), measured as economic output (such as Gross Domestic Product, GDP) per corresponding material input, now becomes a widespread environmental sustainability indicator for the measurement and description of national material utilization efficiency in academia (Steinberger and Krausmann, 2011). And it has to be acknowledged that material productivity also has the limitations similar to other efficiency indicators which may lead to the Jevons paradox (Alcott, 2005; Polimeni et al., 2008). Nevertheless, as an integrated quantitative evaluating indicator, it has been as a popular topic that recently gained significant interest in societal and governmental documents (Austrian Federal Government, 2002; European Commission, 2005; Ministry of the Environment of Japan Government of Japan (2008); OECD (Organisation for Economic Co-operation and Development), 2013; The State Council of the People's Republic of China (2011)). Improving material productivity can create more economic benefits with less natural resources which to some extent could be an appropriate way to solve

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Acronyms

GDP	Gross Domestic Product
ARDL	Auto-regressive distributed lag
IDA	Index decomposition analysis
MFA	Material flow analysis
GCI	Growth competitive index
DMC	Domestic material consumption
EW-MFAcc	Economy-wide material flow accounting
ECM	Error correction model
UCB	Upper critical bound
LCB	Lower critical bound
SERI	Sustainable Europe Research Institute
NBS	National Bureau Of Statistics
VAR	Vector autoregression
T-Y	Toda-Yamamoto

Nomenclature

MP	Material productivity, US $/ton
SEI	Energy intensity for secondary industry, 10 000 ton of standard coal equivalent
TVA	Tertiary industry value added per GDP, %
TO	Trade openness, US $
DEC	Domestic extraction per capita, ton/person

collisions between future increasing demand and limited natural resources (Gan et al., 2013).

There is no doubt that energy as the most significant type of natural resource has an extremely important strategic position in the national economy. Hashimoto et al. (Hashimoto et al., 2008) have stated that reduction in energy intensity means that goods and services must be produced with less energy use and thus probably affected Japanese material productivity. Furthermore, a decline of energy intensity can partly characterize technological improvements in a broader sense (Hashimoto et al., 2008; Bleischwitz et al., 2009). Economic structure, which generates very different amounts of value added per ton of resource input, is another main factor in what might have changed national material productivity (Gan et al., 2013; Hashimoto et al., 2008; Bleischwitz et al., 2009; Steger and Bleischwitz, 2011; Van der Voet et al., 2005; Giljum et al., 2010). In addition to economic structure, Gilijum et al. (Giljum et al., 2010) have also proposed that international trade and resource endowments play a major role in material productivity on the national level. In summarizing all of the available literature on examining the factors influencing material productivity (Steinberger and Krausmann, 2011; Gan et al., 2013; Hashimoto et al., 2008; Bleischwitz et al., 2009; Steger and Bleischwitz, 2011; Van der Voet et al., 2005; Giljum et al., 2010; Steinberger et al., 2010; Wiedmann et al., 2015), previous studies have fallen into two categories. On the one hand, simple regression analysis has been used to elaborate on factors influencing material productivity based on cross-sectional data with a single time point mainly in developed countries (Steinberger and Krausmann, 2011; Gan et al., 2013; Bleischwitz et al., 2009; Steger and Bleischwitz, 2011; Van der Voet et al., 2005; Giljum et al., 2010; Steinberger et al., 2010; Wiedmann et al., 2015). On the other hand, index decomposition analysis (IDA) has been used to explain the influencing dynamics of Japanese material productivity (Hashimoto et al., 2008). IDA is a technique that emphasizes the decomposition of the indicator (for example, material productivity) into the different factors described in a series multiplication equation. No previous studies have focused on estimating the dynamic impacts among selected influencing factors on material productivity in China.

China, as the biggest emerging economy, has made remarkable achievements in social and economic development with its unprecedented consumption of natural resources since the initiated economic reforms in 1978 and, consequently, with a series of environmental issues. In 2008, China's total material consumption of 22.6 billion tons accounted for 32% of the world's total and made it by far the world's greatest consumer of primary materials, nearly fourfold the consumption of the USA, which was the second ranked consumer (West et al., 2013). Therefore, it is urgent to change the economic growth pattern from high growth of high consumption to a more sustainable growth path. To accelerate the transformation, the Chinese government has already proposed improving material productivity by 15% over the period of 2011–2015 (The State Council of the People's Republic of China (2011)). The improvement of material productivity in China also greatly promotes the world's efforts in resource conservation and environmental protection.

The main objective of this article is to investigate the long- and short-run impacts between material productivity and selected socioeconomic factors, such as energy intensity, economic structure, international trade and resource endowment in the case of China by using the auto-regressive distributed lag (ARDL) model over the period of 1980–2010. Compared to IDA, ARDL is preferable for examining dynamics of material productivity due to its following two advantages. First, ARDL, as an econometric tool, is relatively flexible in choosing explanatory variable. Second, it can quantify the long- and short-run impacts on material productivity. In the case of China, the selected time range reflects the rapid process of industrialization with a large consumption of natural resources and reveals typical emerging economies' developmental trajectories. There is no doubt that ARDL will be of vital importance during the transition of China's future development patterns through studying what drives material productivity during this period of time. Section 2 is the literature review. Section 3 describes the methodology and data; this section introduces the definition of material productivity, choice of explanatory variables, description of model and data sources. The empirical results are presented in section 4, and following are our conclusions and discussions.

2. Review of literature

Previous studies have focused on methodological foundations and accounting methods of Material Flow Analysis (MFA) (Fischer-Kowalski et al., 2011; Schütz and Steurer, 2001; OECD, 2008). Studies examining the factors influencing material productivity are few, and this topic is relatively under-researched. For the methodology, regression analysis is the main tool that has been used to elaborate on factors influencing material productivity. Van der Voet et al. (Van der Voet et al., 2005) presented the first regression analysis to estimate the influences of socioeconomic variables on material productivity by using panel data from the EU. They stated that the differences in material productivity can be attributed in large part to income level (GDP per capita) and the structure of the economy. More recently, several authors (Steinberger and Krausmann, 2011; Gan et al., 2013; Steinberger et al., 2010; Wiedmann et al., 2015) also have suggested income level as a critical factor for a nation's material productivity due to associated technology improvements driven by economic development (Larson et al., 1986). However, there is also an objection regarding income level as a factor for material productivity. They believe that income level can mask the effects of others (OECD (Organisation for Economic Co-operation and Development), 2013). Bleischwitz et al. (Bleischwitz et al., 2009; Steger and Bleischwitz, 2011) have