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Analysis

Bigger cakes with fewer ingredients? A comparison of material use of the world economy ☆

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ABSTRACT

The amount of materials used worldwide in production and consumption increased by 56% from 1995 to 2008. Using an index decomposition analysis based on the logarithmic mean Divisia index, we investigate the drivers of material use, both on a global and a country scale. We exploit a panel dataset of 40 countries, accounting for 75% of worldwide material extraction and 88% of GDP, from 1995 to 2008. The results show that economic growth and structural change towards material-intensive countries explain most of the growth in global material use. Slight gains in material efficiency and falling importance of material-intensive sectors have decelerating effects. The country-level analysis reveals substantial heterogeneity. Some nations exhibit stable or falling material use, while it increases notably in most countries. Improving material efficiency is able to dampen growth of material use in important industrializing nations like China or India.

1. Introduction

In 1995, industries worldwide extracted 48 billion (metric) tons of raw materials from nature to use them in production processes or to consume them. This number rose to 68.7 billion tons by 2008. If unused extraction like overburden from mining is considered, humanity additionally withdrew approximately 41.3 billion tons in 2008 alone. Raw material extraction grew unequally in this time period. China's boosting importance is particularly striking. Its domestic material extraction more than doubled from 7.9 billion tons in 1995 to 18.1 billion tons in 2008. China also expanded its raw material supply in relative terms. While the People's Republic accounted for 16.4% of worldwide material extraction in 1995, it supplied 26.4% of total extraction in 2008 (see Fig. 1, calculations based on Dietzenbacher et al., 2013).[1]

Material use is closely connected to global and local environmental phenomena, from climate change over deforestation to losses in biodiversity. The European Union made resource efficiency a major topic in its policies and it is now a key priority for policymakers across Europe. The European Union emphasized resource efficiency as one of seven flagship initiatives in its Europe 2020 strategy for smart, sustainable and inclusive growth (European Environment Agency, 2011).

Our aim is to disentangle the drivers of material use worldwide. We separate the influence that technical change, structural change and overall economic growth exert on material use. We define material use as the amount of materials that are employed directly by sectors and final consumers, both domestic and imported. Thus, the material use of a country equals the domestically extracted plus imported minus exported materials. It comprises the use of biomass, fossil fuels, and minerals including metals. In accordance with the literature, we do not consider the use of air and water. This definition is similar to the Domestic Material Consumption (DMC, sometimes also termed apparent national consumption as in Steinberger et al., 2010), in the material flow analysis literature (Fischer-Kowalski et al., 2011).[2] We

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[1] All figures on resource extraction exploit the whole environmental satellite accounts of the World Input–output Database including information on countries not included in the main database, aggregated in a "Rest of World" block. Further analysis relies on data for the 40 countries with detailed information. Those 40 countries account for 75% of resource extraction and 88% of economic output.

[2] We denote our measure material use to emphasize that a large share of materials is used in the production process and not consumed directly as final demand. Thus, material use is a production-based indicator. See Weinzettel and Kovanda (2011) and Wiedmann et al. (2013) for analyses of consumption-based indicators of material use.

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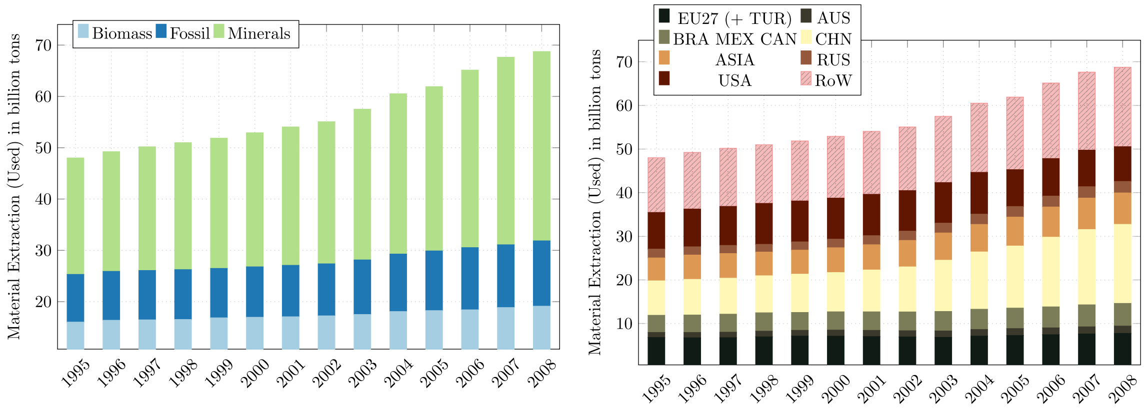

(a) Global Extraction **(b)** Regional Distribution

Fig. 1. Resource extraction and its regional distribution.
Data: Dietzenbacher et al. (2013).

investigate material use rather than extraction for two reasons. Firstly, demand for raw materials is derived from production and consumption decisions. Secondly, regional extraction patterns reflect costs largely determined by geological or climatic conditions.

We exploit the World Input–output Database (WIOD, Dietzenbacher et al., 2013), containing harmonized input–output tables for 40 major economies and 34 sectors as well as data on material extraction. Based on the WIOD, we construct a panel of material use taking into account both domestically extracted and imported materials. Subsequently, we use an index decomposition analysis (IDA, Ang and Zhang, 2000; Ang et al., 2010; Voigt et al., 2014) to investigate trends in material use. The decomposition approach applied in this study allows us to analyze both national and global developments.

A number of studies investigate drivers of material use empirically. They can be divided into three groups according to the employed methodology. The first group is based on index decomposition analysis applied to country-level data. Hoffrén et al. (2000) present an early example of this literature for the case of Finland. Hashimoto et al. (2008) decompose the material intensity of Japan from 1995 to 2002 and find that changes in demand structure and efficiency gains in production are the most important drivers of falling material intensity in this period.

Other studies on material use are based on structural decomposition analysis (SDA). Pablo Muñoz and Hubacek (2008) investigate Chile's material use from 1986 to 1996. They measure material use as domestic material input (DMI), which equals the sum of domestically extracted and imported materials. Thus, their measure also includes materials extracted for exports. Pablo Muñoz and Hubacek (2008) find that overall economic growth and increased exports explain most of Chile's raising DMI. Falling ore grades (the share of metals in a unit of ore) in copper mining contribute as well. Another study of a raw material exporting country is conducted by Wood et al. (2009), decomposing the growth of Australian material use. Similar to Pablo Muñoz and Hubacek (2008), they find economic growth and increasing exports to be particularly important. Contrary to the Chilean case, they identify small growth of material efficiency. Weinzettel and Kovanda (2011) compare the raw material consumption (RMC) in the Czech Republic in 2000 and 2007 using an SDA. RMC is a consumption-based indicator, measuring the raw material extraction implied by final consumption. They find that technology, including both material intensities and economic structure, improved between these years, but did not compensate for the growing demand in the Czech Republic. All previous studies relying on index decomposition analysis or structural decomposition analysis are carried out at the level of single countries. To our best knowledge, we present the first multi-country IDA of material use.

A third group of papers employs econometric techniques to examine the drivers of material use. Steinberger et al. (2010) use cross-sectional data of 175 nations in 2000. They find that income is an important driver for material use, but with notable differences between types of materials. The use of biomass exhibits a small income elasticity, but the use of minerals and fossil fuels grows proportionally to income. Wiedmann et al. (2013) investigate factors explaining the material footprint, a consumption based indicator, of 186 countries in 2008. Their regressions also show that income is important. For each 10% increase in income, the material footprint grows by 6%. Steger and Bleischwitz (2011) use panel data to assess drivers of material use and material intensities in the EU from 1980 to 2000 (EU 15) and between 1992 and 2000 (EU 25). Their study is the only one known to us which employs panel data, rendering their approach highly complementary to ours. While Steger and Bleischwitz (2011) pool their data and consider a large variety of potential explanatory variables, we focus on developments over time while restricting our analysis to a limited number of explanatory factors. Steger and Bleischwitz (2011) find energy consumption, construction activities, and the length of transportation networks (e.g. roads, rail networks) to be important drivers of both endogenous variables.

Our contribution is related to the index decomposition literature and introduces three novel features. Firstly, we are able to exploit a consistent and harmonized dataset containing detailed information on economic activity and material extraction. It combines a global scale with a fairly high sectoral resolution. Secondly, we are able to observe changes in material use over a long and merely current period from 1995 to 2008. And thirdly, we are able to aggregate economic output and material use of 40 major economies into a global aggregate, allowing us to distinguish between within-country and between-country structural change. This adds an additional dimension to the three drivers of material disentangled on the country level: Overall economic growth, structural change in the sectoral composition of an economy, and within-sector intensity changes.

Our findings suggest that economic growth is the main driver for the development of global material use. At an aggregate level, there was no "decoupling" of economic growth and material use. There is, however, large heterogeneity in the development of individual countries as well as sectors. Some nations, for example, exhibited economic growth combined with falling material use.