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Analysis

Global patterns of metal extractivism, 1950–2010: Providing the bones for the industrial society's skeleton

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ABSTRACT

During the second half of the 20th century, mining expanded globally and must be considered one of the dominant forms of human intervention into the environment. Metals are strategically important resources for industrialized and industrializing societies. In 2010, the five BRICS countries (Brazil, the Russian Federation, India, China, and South Africa) consumed 54% of the metals mined globally. The analysis of material flow data offers a biophysical perspective on mining as a resource frontier and allows for the identification of patterns in global metals extraction and trade. Since 1950, metal extraction has shifted from the early industrializing countries into the emerging economies. In 2010, only 6% of metals mined stemmed from Europe or North America while 76% were extracted in four countries (Australia, China, India, and Brazil). In the countries hosting large-scale mining operations, socio-ecological pressure ensues the so-called extractivist development path is common. High rates of metal deposit depletion mean that today's metal extractors and exporters may depend on imports of metal from anthropogenic deposits (stocks in buildings, infrastructure, and durable products) in the future. The extractivist path and the shifting of metals from natural to anthropogenic deposits are both associated with potential for conflict.

1. A Material Take on Metals Extractivism

The "great acceleration" of global resource use since the 1950s (Steffen et al., 2015) and the unprecedented growth rates during the first decade of the 21st century (Krausmann et al., 2009; Schaffartzik et al., 2014) are related to increased pressure on and damages to the environment, to manifest or looming resource scarcities, and to distributional conflicts. As high levels of consumption in industrialized countries prevail and material requirements in emerging economies grow, the geographical patterns of material extraction, trade, and consumption provide evidence on the role which countries and regions play in the global economy. Understanding these patterns and their dynamics is decisive in identifying the possibilities of and the limits to a future sustainability transition.

Compared to the acceleration that was to follow, the first half of the 20th century showed moderate growth of global material use. Biomass accounted for the largest share of extracted materials while the significance of metal ores increased slowly, their share in extraction rising from 3% in 1900 to 5% in 1950. In terms of the mass of metal mined, iron ores were dominant, accounting for approximately 90% of all extracted metals (Krausmann et al., 2009). After World War II, global material use changed rapidly and, by the 1970s, was composed mainly of abiotic materials, i.e., non-metallic minerals for construction and industrial use, metals, and fossil energy carriers, while renewable, biotic materials contributed a decreasing share (Giljum et al., 2014; Krausmann et al., 2008; Schaffartzik et al., 2014).

Metals, in particular, have been identified as strategically important resources within industrialized and industrializing societies (Graedel et al., 2013; Graedel and Cao, 2010). Iron and aluminum and an increasing range of other metals used in smaller amounts form the 'skeleton' of the industrialized economy. In contrast to, for example, biomass or many non-metallic minerals (sand, gravel), metals are point resources, with a very heterogeneous distribution across the globe. Some metals are mined in only a handful of countries (e.g., in 2010, 77% of chromium was extracted in South Africa, India, and Kazakhstan). Where metals are mined depends first and foremost on where deposits of sufficient quality occur and is also strongly subject to political processes (Auty, 2004; European Commission, 2010; Haglund, 1986): if the possibilities to establish and maintain a mining operation, including access to energy, water, and transport infrastructure, are not given where deposits occur (e.g., in areas experiencing violent conflict or where investments are not made), metals cannot be mined. Trade plays a critical role in securing the metal supply of those countries in which metals are not extracted, providing them with materials crucial for the functioning of industrial society (Graedel and Cao, 2010). Unlike fossil energy carriers and many industrial minerals (e.g., phosphate), metals are not throughflow materials that are transformed into waste and emissions within a year or less. Instead, the major share of extracted metals is accumulated in stocks of buildings, infrastructure, and durable products,

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providing opportunities for future “urban mining” (extraction of metals from anthropogenic sources) and recycling (Reck and Graedel, 2012; Bigum et al., 2012). While natural deposits are depleted, anthropogenic stocks of metals have reached a considerable size and continue to grow (Gordon et al. 2006). In Australia, one of the largest global providers of metals, deposits are exploited at high rates. As a consequence, the metal content of mined ores has declined considerably during the 20th century and for some important metals, extraction is assumed to have “peaked” or to peak in the foreseeable future (Mudd, 2010a; Prior et al., 2012): the rate of extraction of these metals has reached its maximum level and is expected to decline in the future. Mining of lower grade ores, e.g., copper from low-grade sulfides instead of high-grade oxides, may delay but not indefinitely avoid these peaks, at the expense of increasing energy inputs and emissions associated with extraction (ICMM, 2012; Mudd, 2010a, 2007a, 2007b; Norgate et al., 2007, Norgate and Haque, 2010). ‘Mining’ of metal from anthropogenic deposits (buildings, infrastructure, and durable products) at the end of their lifetime is already gaining strategic importance (Gordon et al., 2006).

Global growth in metal demand and long-term increase of world market prices for many metals provide incentives for countries to seek revenue through the exploitation of their natural resource base and the export of primary commodities. The expansion of extraction frontiers drives the potential for conflict between nature conservation, the provision of important ecosystem functions such as carbon sequestration, and different forms of societal resource use. Competition also arises between the proponents of different forms of resource use (e.g., of mining or agriculture, surface mining or rural settlement, corporate or artisanal mining) (Muradian et al., 2012). The expansion of the resource frontier associated with mining operations is often very pronounced and far-reaching environmental and social changes are made in relatively short periods of time. The implications of the extraction of resources for export have been analyzed within political ecology as *extractivism* (and more recently also as neo-extractivism, see Burchardt and Dietz, 2014; Gudynas, 2010; Lambert, 2012; Ruiz Marrero, 2011). While the exact definitions of extractivism vary between researchers (Acosta, 2013), most agree on the basic characteristics: the extractive sectors contribute a large share of total value added, the export of primary commodities is among the most important sources of revenue, and labor and natural resources are exploited beyond their ability to reproduce themselves (Bunker, 1985). Mining operations expand into new territories (Haglund, 2011). The high demand for land, energy, and water associated with metal mining may additionally cause competition for these resources among different local and regional stakeholders (Bebbington et al., 2008). Resource-rich countries that pursue an extractivist development model are particularly prone to conflict in which the role of mining operations has been emphasized by researchers (Bridge, 2004; Hilson, 2002; Jenkins, 2004; Martinez-Alier, 2001; Özkaynak et al., 2012). The “discovery, extraction and processing of mineral resources is widely regarded as one of the most environmentally and socially disruptive activities undertaken by business” (Jenkins and Yakovleva, 2006, p. 272). Evidence has been gathered for Latin America in general (Urkidi and Walter, 2011), for Peru (Bebbington and Williams, 2008; Urkidi, 2010), the Philippines (Holden, 2005), India (Temper and Martinez-Alier, 2013; Martinez-Alier et al., 2014), Ghana (Hilson and Yakovleva, 2007), Namibia (Conde and Kallis, 2012), South Africa (Adler et al., 2007), and New Caledonia (Horowitz, 2009). In several countries, revenues from mining have not significantly improved with increasing rates of extraction, even when primary commodity prices were high. For Sub-Saharan Africa, corruption and nepotism in the administration of mining operations and lack of adequate taxation have been identified as the main obstacles to overcoming the ‘resource curse’ (Bebbington et al., 2008; Campbell, 2006; Rosser, 2006; Stürmer, 2010). Conflict with regard to mining also occurs in the industrialized economies in which metal extraction plays an important role such as Australia (Trigger, 2005), with recent conflicts erupting over water extraction in the Murray–Darling basin between farmers and miners (Berry, 2010). Environmental contradictions have also been identified in the mining of copper in the US American Southwest (Bridge, 2000). Political and social factors are crucial in determining whether resource-rich countries benefit from the extraction and export of metals or the negative impacts for people and the environment prevail (Rosser, 2006). The strong specialization on individual natural resources, such as metals, for export leaves economies vulnerable to the potentially high price volatility (Dwyer et al., 2011) of these resources (Acosta, 2013; Gudynas, 2010; Svampa, 2013). The focus on mining in extractivist economies can – as long as the exploitation of reserves remains viable – lead into such a ‘specialization trap’, possibly accompanied by deteriorating terms of trade (Harvey et al., 2010), depending on the development of international prices and of the role of other sectors within the economy (Muradian and Martinez-Alier, 2001). While during the early 21st century, a growing global demand for metals curbed the problems associated with this specialization, stagnating or even declining demand will reinforce these problems for extractivist economies. Simultaneously, the loss of metal reserves through extractive activities must be taken into account when evaluating the economic benefits associated with extractivism (World Bank, 2006).

This article provides a material perspective on metals extractivism in order to complement the existing, qualitative analyses from within political ecology with a quantitative perspective. Drawing on material flow accounting data to trace the global patterns of metal extraction and trade between 1950 and 2010, a spatial disconnect is observed between 1) the exporters of primary metal commodities, 2) countries which transform primary materials into commodities, and 3) the consumers of the latter. By considering not only the pure metal but also taking the large amounts of waste rock into account which are extracted during mining operations, a proxy for the socio-ecological pressures associated with metal mining is provided (Mudd, 2010a).

2. Material Flow Accounting for Metals: Methods and Data

Global patterns and dynamics of metal extraction and trade are shaped by biophysical as well as socio-economic factors. In this article, material flow data on metal extraction and trade is analyzed. The data were compiled according to a material flow accounting (MFA) approach (Fischer-Kowalski et al., 2011) in a global database covering extraction and trade by a total of 65 material groups (including 17 different metals or metal groups) in 177 individual countries between 1950 and 2010 (Schaffartzik et al., 2014). An overview of the relevant MFA methods and data sources is provided in the following, a detailed description can be found in the online supplementary material. Two additional levels of detail are introduced for the purposes of this analysis which allow for a better understanding of the patterns and dynamics of global metals extraction and trade: 1) the separate reporting of metal content and waste rock extraction and 2) the distinction of trade in primary and secondary commodities.

Data on metal extraction at the country level was obtained from the United States Geological Survey (USGS, 2013); this data was digitalized by Rogich et al. (2009) for the decades from 1970 to 2000. Data from the British Geological Survey (BGS, 2013) was consulted for cross-checks. Data on imports and exports of ores, metal concentrates, and metal products were extracted from the UN Comtrade database (UNSD, 2013) which provides trade data for individual countries in physical and monetary units from 1962 onwards. Prior to 1980, coverage of trade flows in the UN Comtrade database is sparse for a number of countries. It is possible that these countries were not deeply integrated into global markets in the earlier decades so that the global trade aggregates present only a slight underrepresentation (Loy, 2013).

The development of metal extraction is specifically examined for 14 individual countries, four country groupings, and six different metals (iron, aluminum (bauxite), chromium, lead, manganese, and copper)