ECONOMIC GROWTH TOWARDS A DEMATERIALIZATION REGIME? A REASSESSMENT OF GLOBAL MATERIAL INTENSITY

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ABSTRACT

Contemporary research concerning the decoupling of economic growth from material consumption asserts empirical evidence for a transition to an era of dematerialized economic production. Evidently, empirical studies indicate a relative de-link between material consumption and economic production, the so-called Decoupling Effect. Material intensity MI measured in relevant literature by estimating Material flows/GDP indicators. Indeed, such indicators estimate the material quantity required for producing one unit of GDP (kg/monetary units). Nevertheless, the Material flows/GDP ratios fail to take into account an essential attribute of economic production; the physical dimensionality of production process. Main assumption of the present study is that the satisfaction of human needs and preferences requires “real-world” goods that inevitably have certain physical dimensions; these result in the physical dimensionality of economic production. If GDP is perceived as an abstraction of aggregate monetary units, then its production may require an infinitesimal material input. On the contrary, if we accept the verity that economic goods are shaped on certain physical dimensions and, hence, the material base required for their production, may convey empirical results into different estimations and prospects of decoupling effect. In this context, present study re-estimates the decoupling of global non-fuel material consumption from economic growth for 1900-2009, under the assumption that the saturation of human needs requires goods with certain physical dimensions. To our knowledge this is the first time that non-fuel materials decoupling is being estimated at the global aggregate level. As a result, we propose the non-fuel Material flows/GDP per Capita indicator as an improvement of Material flows/GDP ratio which currently dominates the contemporary literature on decoupling. The empirical results of the proposed indicator may be less “optimistic” for potential decoupling of mass use from economic growth at the global aggregate level.

Keywords: Decoupling effect, material intensity, economic growth, dematerialization, non-fuel materials, production dimensionality, human scale, non-fuel Material Flows/GDP per Capita ratio.

1. INTRODUCTION

From the early attempt of Ayres and Kneese (1969) to measure material flows, until recent utilization of the Economy-Wide Material Flow Accounting1 (MFA) methodology (Eurostat, 2001), various indicators have been developed in order to monitor and assess the metabolic performance of the global economy. Contemporary studies estimate decoupling of economic growth from material use for a country (Krausmann et al., 2011), for group of countries (Bringezu et al., 2003), while, only few ones assess the global

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1 Or Material Flow Analysis, broadly cited as MFA
aggregate level (Krausmann et al., 2009; UNEP, 2011). Evidently, MFA has approached a high level of maturity, bringing out a wide range of publicly accessible material flow databases available for scientific empirical analysis and comparisons among methods and results (Fisher-Kowalski, 2011).

In MFA methodological framework, material intensity (MI) is mainly measured by estimating Material flows/GDP indicators. In this context, countries performance, concerning their progress in decoupling material inputs from their economic growth, can be evaluated by firstly, estimating aggregate Domestic Material Consumption (DMC)\(^2\) and secondly, by estimating DMC/GDP indicators (Bringezu et al., 2003). In this context, the Gross Domestic Product (GDP) index currently dominates in relevant literature of measuring (de-)coupling mass inputs from economic growth (in terms of GDP growth).

In present paper, we argue that the Material flows/GDP MI indicators, prevailing in relevant literature on decoupling effect, fail to depict certain physical attributes of economic production. The use of GDP index, as an abstraction of monetary units, fails to account for the real material requirements of the physical economy. In this context, no matter how accurately the material flows are traced and accounted - whenever compared to GDP - substantial information of the properties of the real-world economic process vanishes from the estimations. The present paper should be perceived as the methodological continuity of a recent study (Bithas and Kalimeris, 2012) that mainly concerned the decoupling of energy inputs from economic growth. Present research aims at (re-)estimating the decoupling effect between material consumption and economic growth under the assumption that the saturation of human needs requires goods that carry certain physical dimensions. Due to this purpose, we propose the use of the non-fuel Material flows/GDP per Capita indicator as a better approximation, to some extend, of the dimensionality that economic production incorporates. We (re-)estimate global aggregate and disaggregated non-fuel material intensity for period 1900-2009. To our knowledge, this is the first time that decoupling non-fuel materials from economic growth are being estimated at the global aggregate level. We aggregate as non-fuel materials: non-fuel biomass; ores and industrial minerals; construction minerals.

The paper is organized as follows: Section 2 briefly reviews the relevant literature on decoupling effect, dematerialization concept and material intensity dialogue; Section 3 analyzes the proposed methodological framework based on the production dimensionality concept and further presents the databases utilized in our estimates; Section 4 presents the analysis and the results of the re-estimated decoupling effect in both global aggregate and disaggregated level; finally, Section 5 summarizes the concluding remarks.

2. **A BRIEF LITERATURE REVIEW**

According to the most recent publication of UNEP (2011), decoupling effect is distinguished into relative and absolute. Relative decoupling means that resources use growth rate is lower than the rate of economic growth (GDP), while, absolute decoupling defined as the resources use decline irrespective to the economic growth rate. Furthermore, decoupling could be separated in two distinct categories (Bringezu et al., 2003):

- decoupling between resources use and,
- decoupling between environmental impacts and economic growth.

\[^2\] DMC= Domestic Extraction + material imports – material exports
In present article, we firmly examine the first category; nevertheless our empirical results may also provide indirect implications concerning the second decoupling category as well.

It is empirically asserted by the most recent studies (UNEP, 2011; Dittrich et al., 2012) that global material use increased at a slower pace than global economy (GDP growth). Evidently, estimated Material flows/GDP indicators provide empirical evidence for a gradual decline of global MI from at least early 1950s (Krausmann et al., 2009). While conclusions in relevant literature mainly trace relative decoupling trends (UNEP, 2011) there are also a few recent studies providing empirical evidence for absolute material decoupling for some high industrialized countries (Goodall, 2011; Krausmann et al., 2011). In this sense, there is a growing literature asserting that a transition from the industrialization to a post-industrial dematerialization era of the economy may be feasible (Hawken et al., 1999; Behrens et al., 2007).

On the contrary, there are studies which do not empirically support the fact that economy is becoming significantly less material intensive (Rogich, 1996), while others claim that consumption trends observed in developing countries, such as China and India, may further trigger demand for material flows (Scandl and Eisenmerger, 2006). In this sense, others claim that intensity slowdown might be a fallacy in terms of real production (Lawn, 2001; Herring, 2006).

Moreover, several studies suggest that the western lifestyle, being adopted by most of the developing countries, may further trigger substantial material requirements (Røpke, 2001). In this context, some case studies (Weisz et al., 2006) imply that the quest of today’s developing countries for a higher standard of living, would undoubtedly cause an increase in tomorrow’s resources demand. Finally, recent studies (Ayres and Warr, 2004) more radically assume that absolute dematerialization cannot be achieved except by an end to economic growth.

3. METHODOLOGY AND DATA

3.1. The dimensionality of production process and the human scale impacts
Within MFA analysis, MI is mainly estimated by Material flows/GDP indicators. Different types and categories of aggregate and disaggregated material flows are compared to GDP growth in order to provide a sound basis for measuring and comparing dematerialization level among economies and group of countries. Evidently, the empirical assessments show a relative decoupling of mass inputs from growth for at least mid 20th century. This trend is principally explained due to technological progress in material extraction and usage, substitutions among different material types and structural changes in the composition of GDP. The MI indicators sufficiently reflect these trends; yet, this dematerialization era may feed with optimism the prospect of future MI declining potentials (Goodall, 2011).

However, MI indicators fail to account for an essential attribute of production process; the physical dimensionality that economic production incorporates. The first explicit reference to the concept of economic production’s dimensionality in decoupling dialogue has been made in a recent study (Bithas and Kalimeris, 2012). The dimensionality of production is the resultant of the very fact that the “real-world” goods incorporate physical dimensions and, hence, certain material requirements in order to serve the actual human needs and preferences. Our questioning is based on the criticism that GDP is an abstraction of aggregate monetary values. As a result, aggregate monetary values cannot accurately reflect the physical dimensions, and hence, the material base required for the production of a “real-world” good. In this context, GDP, being though a homogenization of
heterogeneous goods in monetary units, fails to depict the physical dimensionality that economic goods incorporate. Consequently, when MI estimation is based on abstract GDP misleads the real material requirements – hence the dimensionality - of economic production.

An accurate quantification of the physical economy’s metabolism calls for a more accurate definition of economic process and economic production. “Real-world” economic goods need substantial material inputs in order to serve the human needs. The physical dimensions of the “real-world” goods determine the physical dimensionality of economic production. In this sense, human needs and preferences (human scale impacts) are, hence, the essential factors which bequeath economic production with its physical properties (dimensionality). As “human scale impacts” we define two interdependent factors: human needs (and preferences) and demographic trends. Taking into account the physical dimensions that economic production incorporates – due to the human scale impacts – empirical estimates of decoupling effect may be less promising for future potential material decoupling, than the ones prevailing in relevant literature.

Main aim of present research is to (re-)estimate the decoupling of non-fuel materials use from GDP growth within a more realistic approach that takes into account the physical dimensions of economic production. For this purpose, we solely utilize non-fuel material flows as the essential material basis required for the production of “real-world” goods and per capita GDP index as an indirect reflection of the “human scale impacts” on economic production. Undoubtedly, the ideal would have been to obtain an economic indicator that is systematically being able to take into account the physical dimensions of economic goods and, consequently, of economic production. As the accurate representation of such an indicator remains rather a hard and ambitious task, we propose the non-fuel Material flows/GDP per Capita indicator as an indirect approximation of the dimensionality that economic production incorporates. The population growth, in tandem with the human needs and preferences remain a profound basis, in order to comprehend the actual physical dimensionality that economic production incorporates.

3.2. Data

Present study aspires to trace the essential mass inputs forming the material base of economic goods. Due to this purpose, we take into account only the non-fuel material flows. The study examines the period 1900-2009. We aggregate as global non-fuel materials: non-fuel Biomass; Ores and Industrial minerals; Construction Minerals. In order to measure only the non-fuel component of Biomass, we have excluded wood fuel biomass from total aggregate Biomass time series. Data on wood fuel Biomass estimations kindly provided by Prof. Fridolin Krausmann after personal communication. We assume that data on non-fuel Biomass is the only fuel part of total biomass. Annual data of non-fuel materials are drawn from Krausmann et al. (2009), one of the most significant recent studies on global decoupling estimation (Data available at: http://www.uni-klu.ac.at/socec/inhalt/1088.htm). Non-fuel material flows are expressed in 1000 metric tons per year (1000 t/yr).


3 However, due to lack of specified data, our estimates fail to trace the use of timber extraction and other agricultural by-products as fuel materials; consequently there is a probability of underestimating the real fuel biomass quantity. For more details, see Krausmann et al. (2009)

4 The International Geary-Khamis dollar is a hypothetical unit of currency that has the same purchasing power the United States dollar had in the USA in 1990.
4. ANALYSIS AND RESULTS


In this section we estimate the global non-fuel MI for 1900-2009. Figure 1 shows the evolutionary path of non-fuel materials in comparison with GDP growth. Non-fuel MI decreases constantly during 1900-1920, while three main brake-periods of relative stabilization are observed: during the early economic recession period (1921-1930); during pre-WWII period (1931-1941); and, finally, in early post-WWII (1945-1950). In fact, the latter period is the last time that a slight increase in non-fuel MI is traced. 1950 is a milestone year as it marks a constant and long period of reduction in non-fuel MI, until 2000. Finally, a relative stabilization is observed during 2001-2009. Obviously, long-term dematerialization trends can be identified for two main periods (1900-1921 and 1950-2000) in Fig. 1.

Figure 1. The “Total non-fuel materials/GDP” indicator for 1900-2009 (data source: Krausmann et al., 2009 and personal communication).

Figure 2 shows the evolutionary path of non-fuel materials in comparison with per capita GDP growth. Evidently, this indicator (Fig. 2) evolves in stark contrast compared to that presented in Figure 1. The Total non-fuel materials/GDP per Capita ratio remains relatively invariable during 1900-1920, while depicts generally three fluctuation periods traced in 1921-1930; 1931-1941; and during 1945-1950. Similarly with Fig. 1, 1950 is a turning point for MI estimated in Fig. 2. Yet, in contrast with Fig. 1, the Total non-fuel materials/GDP per Capita ratio traces a long period of slowly increasing non-fuel MI which endures until 2000. Special focus should be given in the 2001-2009 period which is being characterized by a sheer augmentation in MI. In conclusion, Fig. 2 depicts rather a coupling pattern, after 1950, compared to Fig. 1.
Figure 2. The “Total non-fuel materials/GDP per Capita” indicator for 1900-2009 (data source: Krausmann et al., 2009 and personal communication).

4.2. Global disaggregated level

Figure 3 estimates MI for each component of Total non-fuel materials supply. The left-hand side of Fig. 3 estimates the “standard” MI by using GDP, hence: Global ores and industrial minerals/GDP (3a); Global construction minerals/GDP (3c); and Global non-fuel biomass/GDP (3e) ratios. The right-hand side of Fig. 3 presents estimates MI by using GDP per capita, hence: Global ores and industrial minerals/GDP per Capita (3b); Global construction minerals/GDP per Capita (3d); and Global non-fuel biomass/GDP per Capita (3f) ratios, respectively.

The “ores and industrial minerals/GDP ratio” (Fig. 3a) presents mainly three sharp dematerialization periods: during 1913-1921 (WWI); 1929-1932 (The Great Depression); and 1941-1946 (WWII). Since 1946, the ratio gradually follows an increasing path until 1970, when its material intensity peaks at the highest point of the whole examined period. Eventually, material intensity of ores and industrial minerals gradually decreases for most of 1971-1994. Since 1995, and until the end of examined period, in 2009, the “ores and industrial minerals/GDP ratio” seems to be stabilized, showing a hint for possible increase of material intensity during 2001-2009. On the other hand, the “ores and industrial minerals/GDP per Capita” ratio (Fig. 3b) depicts a rather different evolution pattern. Albeit it presents the same dematerialization periods, not as sharp as they depicted in Figure 4a though, the “ores and industrial minerals/GDP per Capita” ratio shows a sharp increase in material intensity for the period 1946-1974. The smooth fluctuations in material intensity observed during 1975-1994, followed again by a sharp increase in material intensity during 1994-2009.

The “construction minerals/GDP” ratio (Fig. 3c) results in three dematerialization periods: 1913-1919; 1929-1933; and 1939-1945. From 1945 until 1960 material intensity increases sharply, to give a period of relative stability in 1960-1980. Smooth fluctuations with short MI decline periods are observed in 1980-2000. Next, it is followed again by a sharp increase in MI during 2000-2009. On the contrary, the “construction minerals/GDP per Capita” ratio (Fig. 3d) presents only smooth fluctuations during 1900-1945, while after 1945 and until 2009 results in rather a more coupling relationship between construction minerals and GDP per capita.
Finally, in Figure 3e and 3f, we estimate the “non-fuel biomass/GDP” and “non-fuel biomass/GDP per Capita” ratios, respectively. The former ratio results in constant material intensity reduction during 1900-2009, while the latter results in a more moderate biomass relative decoupling, with periods of relative stability (1900-1950; 1985-1995) and periods of relative decoupling (1950-1980; 1995-2006).

5. CONCLUSIONS

The utilization of the Material flows/GDP ratio prevails in relevant literature concerning the empirical estimations of decoupling economic growth from mass inputs. Evidently, the
ratio has followed a historically decreasing path for most of the last century. Consequently, projections based on the observed material intensity decline, may raise optimism for a transition into an era of dematerialization for economic process. This optimism is may further fed upon the shift of post-industrial economies into a service oriented economy (structural changes), technological progress and mutual substitutions among material forms. Nevertheless, the Material flows/GDP ratio neglects an essential attribute of economic production: its physical dimensionality. Human needs and preferences require goods with certain physical dimensions, which cannot be produced without certain material inputs. Hence, real-world's economic production has certain dimensions determined by the human scale impacts (Human needs and demographic trends). In this context, we propose the non-fuel Material flows/GDP per Capita ratio as a better approximation, compared to the “standard” non-fuel Material flows/GDP ratio, of the material requirements of real world production process. The focus in comparison between two ratios should be based on the evolutionary pattern each ratio follows through economic history.

It goes without saying, that technological advance has decisively contributed to the more efficient use of natural resources. This progress allows the satisfaction of certain human needs by producing lighter goods that require less material inputs, while material technology progress enabled mutual substitutions among material types giving access to more lightweight and resistant new materials. Due to these technological achievements, the structure of economic production may shift towards a more service-oriented economy. Evidently, these trends are sufficiently reflected on Material flows/GDP ratio. On the other hand, the non-fuel Material flows/GDP per Capita ratio we propose contributes to an additional feature; accounts for the dimensionality that economic process incorporates.

Empirical estimation of the global aggregate non-fuel Material flows/GDP per Capita ratio indicates increasing material intensity after 1950 and until 2009. Evidently, the different way that the non-fuel Material flow/GDP and non-fuel Material flow/GDP per Capita ratios evolved, results in different expectations for decoupling prospects in the future. If production is perceived as a dimensionless abstraction measured in aggregate monetary units (the use of GDP index), then, there are high expectations of reducing the material requirements for its creation. On the other hand, if economic production is conceived as a physical process that produces useful goods and services in order to serve human needs (human scale) then, albeit there might be some potential for decoupling (due to technological progress, material substitution and transition to a service-economy), yet there are also constraints because of the physical properties (dimensionality) of the real-world products. Present study attempts to set the scientific dialogue within a more realistic framework and highlights the imperative for a sound interdisciplinary basis concerning the estimations of decoupling effect. In any case, dimensionality of GDP may require the development of more accurate and concrete indicators in the future.

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