Science of the Total Environment 619–620 (2018) 338–351

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Unmasking decoupling: Redefining the Resource Intensity of the Economy

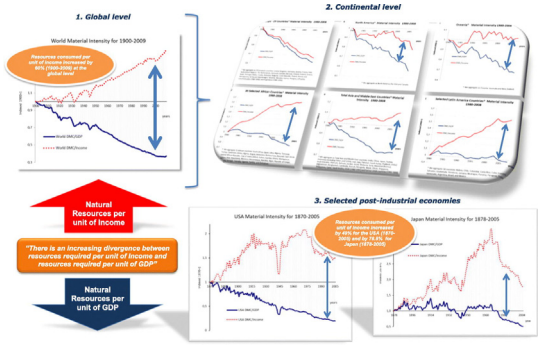
Kostas Bithas [a,b], Panos Kalimeris [a,c,*]

[a] Institute of Urban Environment & Human Resources, Department of Economic & Regional Development, Panteion University of Social and Political Sciences, 29 Aristotelous Street, GR-17671, Kallithea, Athens, Greece
[b] Center for Systems Integration & Sustainability, Michigan State University, Manly Miles Building, 1405 South Harrison Road, East Lansing, MI 48823-5243, USA
[c] Public Power Corporation S.A. (PPC SA), Support Operations Division, Department of Material and Purchasing, 55 Stournari Street, GR-10432 Athens, Greece

HIGHLIGHTS

- Resources consumed per unit of income increased by 60% (1900–2009) at the global level.
- Corresponding increases were 49% for the USA (1870–2005) and 76.8% for Japan (1878–2005).
- An increasing income required disproportionately increasing use of resources.
- After the 1970s, decoupling emerged in knowledge-based economies.
- This must be seen alongside strong coupling in the developing world.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 3 July 2017
Received in revised form 6 November 2017
Accepted 6 November 2017
Available online xxxx

Editor: D. Barcelo

Keywords:
Decoupling
Dematerialization
Material intensity (MI)
Natural resource scarcity
Sustainable development
Economic welfare

ABSTRACT

Interest in investigating the complex link between resources and developments has revived recently following studies which support striking "dematerialized" growth over the last hundred years or so. This so-called decoupling effect is defined as the declining quantity of resources required for producing one unit of GDP. Decoupling studies adopt aggregate GDP as the measure of the outcome of the economy. However, this outcome is contributed by the total population which differs over time and between countries. A valid comparison should use a comparable, standardized indicator that adjusts for population size. GDP per capita, the income index, defines in monetary terms the ultimate outcome of the economy and is adopted by international organizations as the standard index for comparing economies. The income index approximates, in monetary terms, the welfare produced by the economic system and enjoyed by individuals. Recently developed alternative indexes of welfare lack broad data coverage and have limited empirical application as yet. For this reason and for ensuring direct comparison with the standard decoupling estimates, our study remains within the monetary context. The present paper re-evaluates the resources-economy link from the perspective of "the resources required for the production of one unit of GDP per capita (Income)" and hence evaluates the efficiency of turning resources into the actual outcome of the economic system. Our estimates suggest that the dependence of global economic growth on natural resources has increased by over 60% in the last 110 years (1900–2009), contrasting with the prevailing decoupling estimates which suggest a reduction by 63%. We find that the actual decoupling, which began in the mid-1970s in post-industrial economies, is counterbalanced by the intensified resource intensity of several developing economies. Accordingly, in the pursuit of sustainability, the dematerialization target

* Corresponding author at: Institute of Urban Environment & Human Resources, Department of Economic & Regional Development, Panteion University of Social and Political Sciences, 29 Aristotelous Street, GR-17671, Kallithea, Athens, Greece.
E-mail address: pkalimeris@eesd.gr (P. Kalimeris).

https://doi.org/10.1016/j.scitotenv.2017.11.061
0048-9697/

needs to be more clearly incorporated into environmental policies and pervade contemporary economic thinking.

1. Introduction

How an economy depends on resources, and the consequent constraints this places on its prospects of growth, attracted the interest of scholars at an early date (Solow, 1974, 1978; Georgescu-Roegen, 1971; Daly, 1973). Dematerialization potentials - the independence of growth from resources - define the actual limits to growth induced by the scarcity of natural resources (Meadows et al., 1972; Daly, 1997; Ayres, 2007; Turner, 2008; Ayres et al., 2013; Ayres and Voudouris, 2014). In this context, it is of paramount importance to account for the energy and mass requirements of the economic process. From the early attempt of Ayres and Kneese (1969) to measure material flows by the mass balance principle, to the recent Material Flow Accounting (MFA) method (Fischer-Kowalski, 1998; Fischer-Kowalski and Hüttler, 1999; Eurostat, 2001; Fischer-Kowalski, 2011; EEA, 2012), various techniques have been developed for monitoring and assessing resource use in global (Krausmann et al., 2009; UNEP, 2011; Dittrich et al., 2012) and national economies (Bringezu et al., 2003; OECD, 2004; Krausmann et al., 2011; Wang et al., 2016; Efthimiou et al., 2017). Today, MFA has developed into a framework of substantial maturity and methodological accuracy, offering a wide range of publicly accessible databases for empirical analysis that facilitate comparisons between methods and results (Fischer-Kowalski et al., 2011).

In MFA, the link between growth and natural resources is defined as the Material Intensity (MI) of the economy, and is estimated as the amount of resources required for the production of one unit of GDP. This key indicator, the ratio of Resources to GDP, is usually referred to as the "*Domestic Material Consumption/Gross Domestic Product*" [(DMC[1])/GDP] ratio. Supplementary indicators, such as DMC per capita, may provide some additional information which, however, does not characterize the core of the resources-economy link. The observation of declining trends in the DMC/GDP ratio is interpreted as signaling the so-called "decoupling effect", suggesting a gradual delinking of the economy from resources throughout the economic history of the last 100 years (Eurostat, 2001, 2002, 2009; Bringezu et al., 2004; Krausmann et al., 2009; UNEP, 2011; Krausmann et al., 2011; Gierlinger and Krausmann, 2011). This has important practical implications as contemporary studies of decoupling support the view that the independence of economic growth from natural resources is feasible under appropriate policies and institutions (Hatfield-Dodds et al., 2015; Schandl et al., 2016; Szigeti et al., 2017) - an optimism which, however, induces skepticism in other researchers (Lenzen et al., 2016; Ward et al., 2016; Bithas and Kalimeris, 2016; Bithas and Kalimeris, 2017; Alexander et al., 2018).

Declining trends in the DMC/GDP ratio contrast with the dramatically increasing trends in the per capita use of resources (DMC/population). This increase implies a fundamental dependence of the human system on resource use. Indicatively, per capita use of resources increased globally by 119.5% from 1900 to 2009, whereas the resources consumed in producing one unit of GDP (DMC/GDP) declined by 62.7% over the same period (Krausmann et al., 2009). In the USA, the former increased by 142.3% from 1870 to 2005 while the latter declined by 80% (Gierlinger and Krausmann, 2011). Despite this discrepancy, the recent literature shows a remarkable reliance on the trends in the resources required for one unit of GDP and supports a strong decoupling relationship in recent economic history.

In the present paper, we argue that the main reason for the contradictory evidence concerning the relationship between the human (socio-economic) and the natural systems supplied by the increasingly divergent trends in resources per capita and resources per unit of GDP is the defective evaluation of the Resources–Economy (R-E) link by the DMC/GDP ratio. Aggregate GDP reflects the scale of an economy - how big it is in monetary terms - but it says nothing about its actual outcome, that is, the satisfaction arising from the consumption of marketed goods. Yet the reason why the economic system produces goods and services is in order to satisfy human needs. Therefore, the number of human beings who share the aggregate outcome of the economy matters. The same aggregate GDP, distributed among different populations of individuals, may correspond to widely different economies with contrasting structures. India and France, for example, present very similar aggregate GDP (India 2,263,523 million US$, France 2,465,454 million US$[2]), yet no one would argue that India and France are similar economies, producing similar ultimate outcomes. The tremendous difference in population size (India 1,342,500,000 persons, France 64,942,000) makes comparison in terms of aggregate GDP meaningless as far as indicating the ultimate outcome of these economies goes. We are driven to consider instead the GDP per capita index, which is 1686 US$ for India and 37,964 US$ for France, in order to express the difference between the two economies. Population size is among the decisive driving forces of both production and consumption and determines the relative shares of the economic sectors (Brooks and Andrews, 1974; Samuelson, 1985). Remaining within the monetary context, the widely used indicator that approximates the outcome of the economy, while incorporating total population and its implications for the structure of the economic system, is GDP per capita, the income index (Kaldor, 1939; Hicks, 1939; Pigou, 1951; Samuelson, 1950; Sen, 1979). This has promoted the use of GDP per capita (Income) as the operational index for classifying economies into developed and developing ones by international organizations (Eurostat and OECD, 2012; OECD, 2013), reflecting the different level of economic welfare enjoyed by individuals in the two groups of countries. Notably, GDP and hence GDP per capita, have certain shortcomings in their ability to reflect economic welfare and even more in relation to depicting human well-being. Criticism of the use of GDP-based indexes has recently increased (van den Bergh, 2010; Daly, 2013; Costanza et al., 2014) and pioneering scientific attempts to develop alternative indexes in place of the flawed GDP have appeared in the literature. Green National Product (GNP), the Human Development Index (HDI), the Index of Sustainable Economic Welfare (ISEW) and the Genuine Progress Indicator (GPI) promise to overcome the limits of GDP-based indexes and provide a better measure of the actual outcome of the socio-economic system (Cobb and Daly, 1989; Cobb and Cobb, 1994; Stiglitz et al., 2009). However, these indexes are still in the development phase and the requisite empirical data are available for only a limited number of economies and for shorter periods than GDP-based indexes. (Lawn, 2003; Coyle, 2016) Taking into account the lack of data as well as our desire to focus on direct comparison with the standard dematerialization estimates, we confine our study to the monetary realm with due acknowledgment of its limitations, with ignorance of environmental externalities a particularly pertinent one.

The present study proposes the *materials required for the creation of one unit of income* (DMC/Income) ratio as an alternative indicator for

[1] Domestic Material Consumption (DMC) equals domestic extraction (DE) plus material imports, minus material exports: DMC = DE + Imports − Exports.

[2] GDP, Income and Population data source: http://data.worldbank.org/data-catalog/world-development-indicators. Retrieved in September 2017.