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Analysis

The metabolic transition of a planned economy: Material flows in the USSR and the Russian Federation 1900 to 2010

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ABSTRACT

The study of long-term historical trends in material flows has gained some prominence in Ecological Economics since the first studies for Austria and the United Kingdom were published as part of a special section in 2002. This research expands the existing knowledgebase by presenting material flows for the Russian Federation and its predecessor states employing a standard accounting framework. The study of material flows for the Russian Federation provides an interesting and unique case of a planned economy and its transition to a market based form of economic organization. We show that in spite of considerable differences in the physical economy, the USSR developed material use patterns similar to that of Western industrialized economies. Lower levels of consumption were more than outweighed by inefficient production. The transition towards a market economy drove rapid improvements in resource productivity but also growth in metabolic rates. The results indicate that the transition to an industrial metabolic profile proceeds largely irrespective of economic and political conditions. An improved understanding of the evolution of socio-economic systems and the material flows that fuel them is increasingly relevant for designing new systems of production and consumption and facilitating a transition towards a more sustainable industrial metabolism.

1. Introduction

Over the last century global natural resource use has grown at a fast pace and there is no sign of slowing down. Between 1900 and 2010 freshwater extraction multiplied from 580 to 4400 km^3/yr (Shiklomanov, 2000) and primary energy consumption from 40 to 550 EJ/yr (Krausmann et al., 2009). Crop harvest has grown from 1 to 7.5 Gt/yr, iron ore extraction from 0.09 to 2 Gt/yr (Krausmann et al., 2009). As everything that goes in must ultimately also leave the economy, the amount of wastes and emissions has also surged: global CO_2 emissions from burning fossil fuels and cement production have risen from 0.5 Gt to 10 Gt/yr (Boden et al., 2009) and municipal solid waste from 0.1 Gt to 1.2 Gt/yr (Hoornweg et al., 2013). Human use of resources and the corresponding wastes and emissions, denoted as socio-economic metabolism, is the direct or underlying cause of a wide array of humanity's most challenging sustainability problems. It has been argued that the scale of socio-economic metabolism cannot continue to grow as in the past, and humanity must find ways to return to a safe operating space for material use within planetary boundaries (Bringezu, 2015; Haberl et al., 2011).

Understanding the historic trajectories that led to the current industrial metabolism is an important precondition for developing strategies for a transition towards more sustainable metabolic patterns (Gonzales de Molina and Victor Toledo, 2014). In this paper we apply material and energy flow accounting, a method of capturing the biophysical basis of the economy and physical exchange processes between the socio-economic system and its environment (Fischer-Kowalski et al., 2011), to investigate the evolution of resource use in the Russian Federation and its predecessor states in the 20th century. While in recent years material flow accounts have been made available for most countries of the world and the evolution of material flows has been thoroughly studied at a decadal scale, quantitative assessments which shed light on long-term historical trends in material use are still rare. Only a handful of studies have investigated the development of material flows over a whole century, covering key periods of the emergence of modern industrial economies. The existing studies include several economies of global importance: the United Kingdom as the forerunner of the industrial revolution (Schandl and Schulz, 2002), the USA as the country that dominated the global economy through much of the 20th century (Gierlinger and Krausmann, 2012), and Japan, a late comer which very rapidly caught up with Western industrial countries after World War II (WWII) (Krausmann et al., 2011). Most recently Spain has been added to the list (Infante-Amate et al., 2015). The only planned economy for which a long-term MFA has been compiled is Czechoslovakia (Kovanda and Hak, 2011). These studies show how material flows

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evolve, how material use relates to economic development in different phases of industrialization and under which conditions dematerialization occurs. The observed pattern of the transition from an agricultural economy with biomass as the main resource, towards an economy with a fossil fuel based energy system, has been termed the metabolic transition (Haberl et al., 2011; Krausmann et al., 2008). It can also be observed in current industrialization processes in emerging economies like China (Schaffartzik et al., 2014).

This study adds an important element to the existing series of historical case studies of long-term material flow and resource productivity analysis. It presents a century-long MFA series for the USSR and the Russian Federation, its legal successor. The USSR is an interesting case of high global relevance as industrialization proceeded under fundamentally different economic and political conditions than in the West until the USSR finally collapsed in 1991 and turned into a capitalist market economy. The evidence we provide for the USSR complements a recently published study on material flows in the countries of the former Soviet Union (FSU) which focused on the period 1992 to 2008 (West et al., 2014). It also adds a biophysical reading of economic development to the considerable body of literature on the economic history of the region focusing on Soviet industrialization and transformation and to the few studies on its environmental history, mostly addressing issues of conservation and pollution (e.g. Gregory and Stuart, 1994; Allen, 2003; Josephson et al., 2013).

In this paper we present material flow data for the period 1900 to 2010, covering the full period of industrial development and important economic and political transformations. In line with most MFA studies we focus on extraction, trade and consumption of materials but do not quantify outputs of wastes and emissions for which the database is insufficient. We use a methodology consistent with that of existing long-term MFA studies. This allows for comparison of the trends observed for the USSR with those of Western industrial economies (UK, Japan, USA) and of planned economies of the former European Eastern Bloc (Romania, Bulgaria, Poland and Czechoslovakia), although most of the latter studies cover a much shorter time period. We explore differences and similarities in the transformation of the physical economy between planned and market oriented economies, and the impact of collapse and the restructuring of the economy on material use.

The main goal of the paper is to analyze the development of material extraction, trade and consumption of the USSR and the Russian Federation in the context of its economic and political development and in international comparison. This contributes to a better understanding of the global metabolic transition. All data are made available publicly for further use.[1] The next section provides a concise overview of data sources and methods. Based on the results of the material flow analysis we then discuss the evolution of the physical economy of the USSR and its successors during different periods of economic and political development. In Section 4 we investigate differences and similarities in the pattern of the metabolic transition with other Western and centrally planned economies. Finally we explore the coupling of material use and economic growth, the factors underlying the low level of material productivity (Section 5) and how the USSR missed chances to develop a less material intensive metabolic profile (Section 6). We end with some conclusions on how the USSR fits into the general pattern of the metabolic transition.

2. Methods and Data

2.1. Territorial System Boundaries

We compiled data for the extraction and trade of materials for the period 1900 to 2008/2010. This entailed several changes in territorial system boundaries. The USSR as such existed between 1922 and 1991. For the period 1900 to 1921 data refer to the Russian Empire[2]; for 1922 to 1991 they refer to the USSR. The USSR expanded its territory in several steps[3] between 1922 and the end of World War II. It reached its largest expansion in 1946 and remained constant until its dissolution in 1991. For the time period after the disintegration of the USSR we show data for both the Russian Federation, the largest successor state, and an aggregate of all other successor states. Data for the other successor states are based on West et al. (2014). For years around the two world wars data are too fragmented to compile reasonable aggregates; thus no results are shown for the periods 1914 to 1919 and 1941 to 1945. While territorial changes may appear in absolute numbers as minor statistical breaks, this is of less significance for values expressed per capita or per unit of GDP.

2.2. Reliability of Soviet Statistics

We used national and international statistical sources to compile data on extraction, imports and exports. The reliability of statistical data published by the USSR has been an issue of debate among economic historians (Davies et al., 1994; Jasny, 1959; Allen, 2003). Despite the fact that the USSR developed a very extensive statistical reporting system and invested significant resources into recording and reporting statistical data as a basis for centralized planning (Grossman, 1960), concerns have been raised that statistics have been manipulated to produce the impression of achievements greater than those actually attained. There is little doubt that some of the official figures published by Soviet authorities are flawed. However, it has been shown that this mostly concerns important general aggregate indices like national income, industrial output or labor productivity. In contrast, the detailed, more technical underlying statistical information from, for example, industry statistics on the output of individual commodities has indeed been judged as reliable by economic historians (with some exceptions, see Allen, 2003). This involved archival research which compared unpublished records with published data and tested for internal consistency in the statistics (Allen, 2003). Data quality also varies over time but the quality of Soviet statistical records generally improved over time. Overestimations in individual materials don't seriously distort the overall picture presented for the four main material groups in this paper.

2.3. Data Sources and Estimation Procedures

We apply the methodology of economy wide material flow accounting (MFA, see Fischer-Kowalski et al., 2011) and follow the system boundaries and accounting guidelines proposed by the European Statistical Office (Eurostat, 2009) and the adaptations of estimation procedures for global and long-term historical application suggested by Krausmann et al. (2015). This methodology is largely consistent with the methods applied in other long-term MFA studies and produces comparable results. We quantify three types of direct material flows: Domestic Extraction (DE), Imports, and Exports, and calculate the material flow indicators Domestic Material Consumption (DMC; DE plus Imports minus Exports), Physical Trade Balance (PTB; Imports minus Exports), Material Productivity (MP; GDP/DMC) and Material Intensity of fossil and mineral materials ($MI_{min\&foss}$; $DMC_{min\&foss}$/GDP). The MFA database comprises 60 to 70 different material groups. We present material flow data in aggregation by four main material groups: biomass, fossil energy carriers, ores and metals and non-metallic minerals.

The material flow account is based on data available from international and national statistical sources and data compilations and for

[1] Data will be made available at: http://www.uni-klu.ac.at/socec/inhalt/1088.htm.

[2] The territory of the Russian Empire was not stable in the observed period. During and after WWI the territory of the Russian Empire contracted as parts of today's Finland and Poland and the Baltic States were lost.

[3] The Turkmen and Uzbek S.S.R.s were established in 1924, the Tadzhik S.S.R. was established in 1929, and the Kazakh and Kirgiz S.S.R.s were established in 1936. In 1940 the Karelo-Finnish, Moldavian, Estonian, Latvian, and Lithuanian S.S.R.s were established. These additions increased the population of the original USSR by approximately 10 to 13%.