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Determinants of CO_2 emissions in Brazil and Russia between 1992 and 2011: A decomposition analysis

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ABSTRACT

This paper deals with the decomposition analysis of energy-related CO_2 emissions in Brazil and Russia from 1992 to 2011. The refined Laspeyres index (RLI) method applied and both aggregated and sectoral changes in CO_2 emissions decomposed. Brazil's and Russia's economies divided into three economic sectors including agriculture, industry and services. Impact of four main factors, such as economic activity, employment, energy intensity, and carbon intensity in CO_2 emissions changes were analyzed. The aggregated decomposition analysis revealed that Brazil is still far from a decoupling between economic growth and carbon dioxide emissions where Russia achieved a substantial decline in carbon emissions mainly due to the improved energy intensity. The empirical findings of sectoral decomposition analysis emphasized that the economic activity was the major CO_2 increasing factor in Brazil's economic sectors. On the other hand the economic activity effect followed a reducing impact in Russia's sectoral emissions until 2000. The structural changes between sectors and their impacts on CO_2 emissions were captured by employment effect. Energy intensity and carbon intensity effects underlined that environmental sustainability widely neglected in Brazil and Russia during the study period. The results yield important hints for energy planning and sustainable environment.

1. Introduction

An environmental problem, especially the climate change and global warming is one of the most important issues in modern world's agenda. During the last quarter of 20th century, the greenhouse gases showed a substantial increase in atmosphere and this increase already created some unavoidable consequences on our planet regarding the climate change and global warming. Carbon dioxide has the greatest share among six main greenhouse gases and it is the main accelerating factor of greenhouse effect in atmosphere. Carbon dioxide (CO_2) emissions have increased rapidly because of the fossil fuel combustion and the human based activities such as, industrialization, agriculture, urbanization, lifestyle, international trade are the main drivers of fossil fuel combustion (Hatzigeorgiou et al., 2008). Together with the accelerating CO_2 emissions, there exists also an increasing awareness about the environmental issues. Therefore, it is possible to state that CO_2 emissions reduction is a foremost objective of an environmentally sustainable world.

Regarding developing countries, BRIC is an acronym which is firstly used in Goldman Sach's report (in 2003) to define the rapidly growing economies of Brazil, Russia, India, and China (Yuan, 2011). The analysts predict that these four economies will be wealthier than the G6 economies (including United States, United Kingdom, Germany, Japan, France and Italy) by 2050 (Yuan, 2011). As a result of their spectacular economic growth (which is especially observed in China and India), BRICs has became important players of the world's economic arena. During the 2009 financial crises, G6 economies contracted by 4.5% on average, however, Chinese and Indian economies grew by 9.2% and 8.5%, respectively (World Bank, 2015). On the other hand, Brazil's and Russia's economies contracted by 0.3% and 7.8%, respectively in the same year. Furthermore, in the following year, G6 economies grew by 2.8% where BRIC economies grew by 8.2% on average (World Bank, 2015). In 2011, the BRIC economies constituted 27.1% of the size of G6, however, as Yuan (2011) states they could account for over 50% of the size by 2025.

Regarding BRICs, Russia is the only high income country where Brazil and China are the upper middle income countries, and India

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is the lower middle income country according to World Bank's country classification. Correspondingly, the air pollution is highest in India and India is followed by China and Brazil in BRICs in this respect. Russia's air quality is better than the other three countries (Greenstone and Jack, 2015). Similar to the air quality, Russia has the best water quality amongst BRICs.

In BRICs, China's CO_2 emissions showed the fastest increase and it has followed by India and Brazil, in this respect. Russia's CO_2 emissions showed a considerable decline during the past two decades, however, its per capita emissions are still quite higher than the other BRIC countries. In 2011, per capita CO_2 emissions were equivalent to 12.6 tons, where this value was 2.2 tons in Brazil, 1.7 tons in India, and 6.7 tons in China as the World Bank's data indicates. Despite its per capita CO_2 emissions are quite lower than Russia's, Brazil's CO_2 emissions showed a substantial increase (99.1%) from 1992 to 2011.

Researchers generally follow three different methods to identify the factors that lead to changes in CO_2 emissions. These methods are economic regression models, computable general equilibrium models, and decomposition analysis techniques. Decomposition analysis techniques have became popular in 1990s. Earlier decomposition methods were inadequate to decompose the CO_2 emissions with high accuracy and an unexplained residual term was observed at the end of the analysis. (Kumbaroglu, 2011). However, starting from late 1990s, researchers suggested perfect decomposition analysis methods and these methods decompose the changes in CO_2 emissions without leaving any residual term, which is a very desirable property (Tunc et al., 2009).

This paper aims to decompose the changes in CO_2 emissions in two very different countries, Brazil and Russia for the period between 1992 and 2011. Since the decomposition analysis methods use both national and sectoral data, both aggregated and sectoral CO_2 emissions changes have been analyzed in this study. For sectoral analysis, Brazilian and Russian economies are divided into three aggregated sectors, including agriculture, industry, and services. It is necessary to understand the impact of various sectors in CO_2 emissions, the sources and changes in the sources of emissions from 1992 to 2011 to see what was ignored during that period in terms of environmental sustainability. The sectoral decomposition of CO_2 emissions allows the researchers to see the scale of changes over time and develop some sustainable projects for every economic sector. As a result, this can be considered as a step towards sustainable use of energy sources (Tunc et al., 2009). On the other hand, the aggregated decomposition of CO_2 emissions creates an advantage to compare these two different countries' efficiencies and inefficiencies regarding environmental and economic sustainability. Regarding BRICs, published studies mostly focused to China and India. Although CO_2 emissions showed a huge increase in China, a decoupling between economic growth and emissions have been observed recently. Researchers clearly stated that the decoupling was caused by declining energy intensity (Wu et al., 2005; Wang et al., 2005; Ma and Stern, 2008; Zhang et al., 2009). Similar to China, a decoupling between CO_2 emissions and economic growth was also observed in India due to the improved energy efficiency (Paul and Bhattacharya, 2004). The aggregated decomposition of CO_2 emissions therefore allows the researchers to test whether there is any decoupling between CO_2 emissions and economic growth in Brazil and Russia.

Among different methods of decomposition, refined Laspeyres index (RLI) method developed by Sun (1998) is utilized for this study. Moreover, additive version of this method is used where the change in one variable is decomposed as summation of changes in the components of that variable. Thus, changes in CO_2 emissions can be decomposed into changes in economic activity effect, energy intensity effect, population effect, and carbon intensity effect. Kumbaroglu (2011) utilized this method in his study to decompose the sectoral CO_2 emissions in Turkey over 1990–2007. The RLI method has some features (such as it passes from all tests, time-reversal, factor-reversal and zero value robustness) and possesses some desirable properties. In addition it does not leave any error term after the analysis conducted. Therefore the RLI method is an appropriate technique to decompose the CO_2 emissions.

The remainder of this paper is organized as follows. Next section analyzes the refined Laspeyres index method briefly. Section 3 provides an overview of economic and demographic changes, energy market structures, and CO_2 emission changes in Brazil and Russia. Section 4 includes the empirical findings of the RLI decomposition method from 1992 to 2011. Finally, Section 5 concludes the paper.

2. Methodology

We utilized the refined Laspeyres index (RLI) method in this study because of its ease for both understanding and calculation. Earlier version of the RLI method (that is called the Laspeyres index method) was not able to capture the changes in emissions accurately and an error term was arised after the computation of decomposition analysis. However, a refinement process was proposed by Sun's 1998 work and the error term evenly distributed to the other variables. The RLI method is an extension of the well-known Kaya identity which is used to analyze the impact of four different factors which changes the CO_2 emissions. These four factors are, per capita production (GDP/Population), the energy intensity of production (Energy Use/GDP), the carbon intensity of energy consumption (CO_2/Energy Use), and population, such as:

$$CO_2 = (\text{GDP/Population}) \times (\text{Energy Use/GDP}) \times (CO_2/\text{Energy Use}) \times (\text{Population}) \tag{1}$$

In this study, we both computed the sectoral and aggregated decomposition of CO_2 emissions. In sectoral decomposition analysis we used the sectoral economic output, employment, energy use and carbon dioxide emissions instead of aggregated GDP, population, energy use, and carbon dioxide emissions for agriculture, industry and services sectors. For simplicity, it is possible to denote the carbon intensity effect by C, energy intensity effect by E, income effect I, and employment effect by P. We are estimating the total contributions of the affecting factors, therefore the Kaya identity can be written as:

$$CO_2(k) = \sum I(k) \times E(k) \times C(k) \times P(k) \tag{2}$$

Then the income effect can be calculated as

$$I(k) = \sum \Delta I(k) \times P(k) \times E(k) \times C(k) + 0.5 \times (\Delta P(k) \times E(k) \times C(k) + P(k) \times \Delta E(k) \times C(k) + P(k) \times E(k) \times \Delta C(k)) + \sum \Delta I(k) \times (1/3) \times (\Delta P(k) \times \Delta E(k) \times C(k) + \Delta P(k) \times E(k) \times \Delta C(k) + P(k) \times \Delta E(k) \times \Delta C(k)) + 0.25 \times (\Delta P(k) \times \Delta E(k) \times \Delta C(k)) \tag{3}$$

Employment effect

$$P(k) = \sum \Delta P(k) \times I(k) \times E(k) \times C(k) + 0.5 \times (\Delta I(k) \times E(k) \times C(k) + I(k) \times \Delta E(k) \times C(k) + I(k) \times E(k) \times \Delta C(k)) + \sum \Delta P(k) \times (1/3) \times (\Delta I(k) \times \Delta E(k) \times C(k) + \Delta I(k) \times E(k) \times \Delta C(k) + I(k) \times \Delta E(k) \times \Delta C(k)) + 0.25 \times (\Delta I(k) \times \Delta E(k) \times \Delta C(k)) \tag{4}$$

Energy intensity effect

$$E(k) = \sum \Delta E(k) \times P(k) \times I(k) \times C(k) + 0.5 \times (\Delta P(k) \times I(k) \times C(k) + P(k) \times \Delta I(k) \times C(k) + P(k) \times I(k) \times \Delta C(k)) + \sum \Delta E(k) \times (1/3) \times (\Delta P(k) \times \Delta I(k) \times C(k) + \Delta P(k) \times I(k) \times \Delta C(k) + P(k) \times \Delta I(k) \times \Delta C(k)) + 0.25 \times (\Delta P(k) \times \Delta I(k) \times \Delta C(k)) \tag{5}$$

Carbon intensity effect