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Does renewable and/or non-renewable energy consumption matter for total factor productivity (TFP) growth? Evidence from the BRICS

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ABSTRACT

Studies proved that output growth is mainly associated with the Total Factor Productivity (TFP) growth and variables that affect the TFP have an important explanatory power on output. In this regards, the aim of this study is to examine the causal relationship between different types of energy consumption and TFP growth in the BRICS from 1992 to 2012. A panel bootstrap Granger causality test by Kónya (2006) [68] was employed to investigate the direction of possible connection between energy consumption and TFP growth. Results show that no remarkable causal link exists between renewable energy consumption and TFP growth in the BRICS. However, in the case of non-renewables, energy consumption creates a positive externality that contributes economic development in Brazil and South Africa by the growth of TFP as well as energy use itself. In this respect, policies that promote coal and non-renewable electricity consumption in South Africa and natural gas consumption in Brazil may be beneficial for their economic development.

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1. Introduction

International agreements on environmental policy such as the Kyoto Protocol counseled that one of the ways of reducing environmental damage is to substitute use of non-renewable energy sources with renewables. This may create an opportunity for reducing emissions caused by the usage of non-renewable energy sources in the production process that in turn have negative externalities on economic growth through deterioration of the health of productive agents and the quality of natural resources [1–4]. Besides, using renewable energy sources may improve an economy's technical efficiency [5–8], whereas others decrease [9–11]. Domac et al. [12] also states that, as a combination of *social* (i.e. increased standard of living, social cohesion and stability), *macroeconomic* (i.e. security of supply/risk diversification, regional growth, reduced regional trade balance and export potential), *supply side* (i.e. increased productivity, enhanced competitiveness, labor mobility and improved infrastructure) and *demand side* aspects (i.e. employment, income and wealth creation,

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induced investment and support of related industries), renewable energy use increases the level of economic efficiency.

Renewable energy use is considered beneficial due to emissions reduction and improvement in technical and economic efficiency. However, the share of renewable energy consumption in the world's total energy consumption is still too low. According to International Energy Agency (IEA) statistics, the ratio of the world's renewable energy consumption to total energy consumption is 12.7% in 2011. From the Kyoto Protocol became effective in 2005–2011, the world's renewable energy consumption has risen by only 3.2%, whereas non-renewable energy consumption of the world has risen by 13.3%.

In parallel with the consumption levels, it can be statistically expected that the contribution of non-renewable energy sources to production (i.e. economic growth) is relatively higher than the renewables'. And also empirical findings are expected to be consistent with the theoretical background. However, recent studies related to renewable and/or non-renewable energy consumption and production nexus show conflicting results [13–15]. According to these studies, while renewable energy consumption has positive and relatively higher slope or elasticity parameters, non-renewable energy consumption has negative and lower ones. There can be several reasons for this contradiction such as the energy indicator or methodology used. But the present study assumes that one of the most important reasons for this result is the impact of energy consumption on *total factor productivity*.

Total factor productivity is the central concept arising from growth accounting framework introduced by Solow [16,17]. The growth of management skills and the combination of developments in production technology and efficiency are represented by TFP. Studies proved that output growth is mainly associated with the total factor productivity growth and any dynamic affecting total factor productivity has an important explanatory power on output, as well [18–24]. In this context, Schurr [25] and Jorgenson [26] left no doubt about the link between energy consumption and total factor productivity. Accordingly, energy consumption has a positive impact on TFP, and the impact is sensitive to which type of source is being consumed [27,7,3]. This may be a possible explanation for the results of Bowden and Payne [13], Tiwari [14] and Tugcu et al. [15]. In this regard, the aim of this study is to investigate the causal relationship between renewable and non-renewable energy consumption and total factor productivity growth in the BRICS.

The balance of the paper appears as follows: Literature is being reviewed by Section 2. Methodology is being described by Section 3. Findings are being presented in Section 4. Finally, the study is being concluded by Section 5.

2. Literature review

Ever since the pioneering study of Kraft and Kraft [28], energy consumption and economic growth nexus has become a vast field of interest. Around the *growth*, *conservation*, *feedback* and *neutrality* hypotheses [29,30], the considered literature has classified under three strands.[1]

Studies in the first strand (See in Table 1) investigate the causal relationship between (dis)aggregate energy consumption and economic growth [31–46].

Second strand of the literature (See in Table 2) is composed of the studies that deal with the causality between renewable energy consumption and economic growth ([7,47–54]).

Finally, studies which analyze the causal relationship between renewable and non-renewable energy consumption and economic growth establish the third strand of the literature (See in Table 3) [55–57,13–15,58,59].

Although it is accepted that the total factor productivity growth is one of the most important dynamics in explaining economic growth [23], energy consumption and TPF nexus has a relatively shallow literature. Nevertheless, it is possible to divide this literature into two possible lines. The first one is composed of two studies that investigate the direct relationship between energy consumption and total factor productivity. For the period 1958–1985, Hisnanick and Kymn [27] investigated the effects of energy consumption on TFP growth in the US. Findings revealed that consuming different types of energy sources has significant impact on the productivity fluctuation. Ladu and Meleddu [60] examined the link between total factor productivity and aggregate energy consumption in Italy from 1996 to 2008 at a regional level and indicated that the link between energy consumption and the TFP is sensitive to the time horizon. In the short-run TFP has a negative impact on energy consumption, whereas higher TFP implies higher energy consumption in the long-run.

Studies that consider the link between efficiency in energy consumption and TFP constitute the second part of the literature. Energy efficiency and productivity nexus was tested by [61] in the US for the period 1963–1985. Accordingly, there exists a positive link between variables in interest. It is proved by [62] that, in Nigeria, TFP growth is positively affected by energy consumption for the case of manufacturing industry for the period 1988–1990. According to [5], TFP growth is one of the main factors behind the energy efficiency improvements in the US for the period 1987–1995. After reviewing so many case studies, Worrell et al. [6] concluded that TFP is positively affected by the advances in energy-use.

As a complement to the studies which test the causal relationship between energy consumption and economic growth, and as a contribution to the first line of the literature which is about the direct impact of energy consumption on total factor productivity growth, this study differs from the previous studies in several aspects. The first and foremost, this study considers six energy consumption indicators including renewable and non-renewable energy sources and tries to find out whether any causal relationships exist between them and total factor productivity growth. Second, the study employs a recent panel causality procedure that takes the cross-sectional dependence into account which is an important issue in panel data econometrics. Third, to the best of knowledge, there is no study which investigates the causal link between the energy sources in consideration and total factor productivity growth in the BRICS. Thus, this paper aims to fulfill this gap and contribute to the empirical literature.

3. Methodology investigating and the data

Testing Granger causality within panel data framework is much more complicated issue as one needs to be very careful about several issues associated with the nature of the panel data to be used. First issue in that respect is to control for possible cross-sectional dependence across countries. This problem may arise when a shock originated in a country affects other countries may be because of a high degree of globalization as well as of international trade and financial integration or may be due to fact that two countries are neighbors. The Pesaran [63] documented the importance of testing for the cross-sectional dependence and through the Monte Carlo experiments verified that estimates suffer from the substantial bias and size distortions when cross-

[1] Empirical studies were selected for the analysis. It is mostly benefited from the ScienceDirect database for the literature review. Energy consumption, renewable energy, non-renewable energy and economic growth are among the keywords used for the search.