Energy Economics 40 (2013) 753–759

Contents lists available at ScienceDirect

Energy Economics

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

What if energy time series are not independent? Implications for energy-GDP causality analysis

Stephan B. Bruns *, Christian Gross

Max Planck Institute of Economics, Kahlaische Str. 10, 07745 Jena, Germany

ARTICLE INFO

Article history:
Received 29 April 2013
Received in revised form 21 August 2013
Accepted 31 August 2013
Available online 12 September 2013

JEL classification:
Q43
C32
C52

Keywords:
Energy
GDP
Granger causality
Correlation
Electricity
Petroleum products
Renewables
Toda–Yamamoto
Johansen–Juselius

ABSTRACT

Time series of electricity, petroleum products, and renewables are found to be highly correlated with total energy consumption. Applying this insight to the huge literature on energy-GDP causality explains that the results of total energy-GDP causality tests frequently coincide with the results of energy type-GDP tests. Using the test by Toda–Yamamoto in combination with a cointegration-based testing approach, we detect such cases of concordance for 92% of the countries in our sample of 65 countries. We infer that drawing specific economic conclusions with regard to single types of energy from bivariate causality analysis is difficult.

1. Introduction

The seminal paper by Kraft and Kraft (1978) on energy-GDP Granger causality initiated an ongoing and highly contentious debate on the direction of causality.[1] Most recently, however, there is growing evidence that the debate can be resolved. In a meta-regression analysis of a large sample of the literature on energy-GDP causality, Bruns et al. (forthcoming) find that (total) energy consumption has some genuine causal connection with GDP. This finding corresponds also to other recent contributions to the debate (e.g., Gross, 2012; Stern and Enflo, 2013).

Apart from total energy consumption, special attention is often given to the role of single types of energy (see Ozturk, 2010 and Payne, 2010 for an overview). "Electrification", "Oil Economy", and "Green Economy" are only a few keywords attributing economic relevance to the energy types electricity, petroleum products, and renewables.[2]

Our aim is to contribute to the politically relevant debate on energy type-GDP causality by putting more emphasis on statistical aspects of energy time series. We raise the question to what extent time series for different types of energy are independent of total energy. Our argument rests upon the simple fact that total energy is the aggregate of all different types of energy, which might entail statistical dependence between total energy and the different types of energy. It applies even more so if total energy and all types of energy fluctuate with GDP in a similar way, e.g., due to business cycles. As our principal contribution, we investigate whether this plausible statistical dependence is strong enough to interfere with tests of energy-GDP causality. If energy types are not sufficiently independent of total energy, energy type-GDP causality tests might match with total energy-GDP causality tests. If this was the case, it would be difficult to draw specific economic conclusions from causality analysis with regard to single types of energy.

* Corresponding author.
E-mail addresses: s.b.bruns@googlemail.com (S.B. Bruns), gross@econ.mpg.de (C. Gross).

[1] This includes Granger causality from energy to GDP (or vice versa), bi-directional Granger causality, or no Granger causality. In the remainder of the paper, when talking about "causality", we always refer to the concept of Granger causality (Granger, 1969).

[2] Of course, specific economic relevance can also be attributed to coal, natural gas, nuclear, and other types of energy. As will be discussed in Section 3, we cannot consider these types of energy here for reasons of data availability.

http://dx.doi.org/10.1016/j.eneco.2013.08.020

In a sample of 65 countries we find that different types of energy are highly correlated with total energy consumption. Using the test by Toda and Yamamoto (1995) as well as a Vector Error Correction Model/ Vector Autoregression (VECM/VAR) testing approach based on Engle and Granger (1987) for analyzing total energy-GDP and energy type-GDP causality, we find that, for at least one energy type, results match for 92% of the countries. Using a probit model we find that the probability of a match increases with the degree of correlation between an energy type and total energy.

The paper is organized as follows. In Section 2, we outline the theoretical background. The description of the dataset and the estimation strategy follows in Sections 3 and 4, respectively. In Section 5, we briefly discuss our findings. Section 6 concludes.

2. Theoretical considerations

In the energy-GDP literature it is common to analyze economic relevance of energy by means of causality tests of the energy-GDP relationship (Ozturk, 2010; Payne, 2010). Usually, the tests by Granger (1969), Sims (1972), Hsiao (1979), Engle and Granger (1987), Johansen (1988, 1991), Toda and Yamamoto (1995), Pesaran and Shin (1999) and Pesaran et al. (2001) are applied to time series for different countries, by using different control variables, and so on. If one finds evidence for causality, energy has particular relevance for the growth of the economy (or vice versa).

More recently, researchers tend to use disaggregate data to analyze energy-GDP causality in more detail. When doing so, however, statistical problems might arise when the variables under investigation do not share the same level of aggregation (see Gross, 2012 and Zachariadis, 2007 for a discussion of "appropriate pairs of variables" for energy-GDP causality analysis). With regard to the most frequently studied relationship between national energy and national GDP, only national *total* energy consumption, i.e., the aggregate of all types of energy, corresponds to all energy inputs needed for nation-wide production.[3]

Nevertheless, knowledge about the relationship between different types of energy, i.e., subaggregates of total energy, and GDP is desirable and particularly important for giving detailed energy policy advice. Petroleum products, for example, are essential for production and transportation of many goods, as well as consumer uses such as automobile fuel and heating. Electricity is generally assumed to be the highest quality type of energy with regard to economic usefulness per heat equivalent (Stern, 2011). Renewable types of energy are often considered as labor intensive and, hence, of particular economic importance (e.g., Lehr et al., 2008). So far, empirical analyses have been carried out for the energy types electricity (e.g., Altinay and Karagol, 2005; Tang and Tan, 2012), petrol (e.g., Lotfalipour et al., 2010; Zou and Chau, 2006), and renewable energy types (e.g., Payne, 2009; Vaona, 2012).[4]

In the remainder of this paper we discuss energy type-GDP relationships in the light of some statistical peculiarities inherent to (dis-) aggregate energy time series. The basic question we raise is, to what degree time series for different types of energy are independent of total energy. To a certain degree dependence may stem from the simple fact that total energy is the sum of all energy types. Moreover, assume that fluctuations of economic activity affect the consumption of all energy types in a similar way. The growth rates of the energy types are then likely to be correlated with total energy. Suppose further that annual growth rates of all energy types coincide over a longer period of time. The amount of statistical information provided by the different energy time series therefore might not be sufficient to statistically distinguish different types of energy from total energy. In such a case, it cannot be excluded that results of causality tests between different types of energy and GDP only reproduce the findings of causality tests between total energy and GDP.

When giving advice for energy policy, however, it is necessary to have full knowledge about interdependencies among all energy time series. Suppose, for example, that petroleum products are found to cause GDP. In a bivariate causality test recommendations to further invest in petroleum infrastructure are justified only if the time series for petroleum products is sufficiently independent from the time series for total energy. Omitting the remaining energy sources from the test might, however, result in omitted-variable bias and falsely attribute the effect of total energy to petroleum products.

We derive the following empirically testable hypotheses from our theoretical considerations.

H1a. Time series for the energy types electricity, petroleum products, and renewables are not independent of total energy.

H1b. Total energy-GDP and energy type-GDP causality tests do not match randomly.

H2. The degree of non-independence between time series for single energy types and total energy explains the probability of a match between causality tests.

3. Data

We evaluate the validity of our hypotheses by using time series data on GDP (measured in constant local currency) for 65 countries from the World Development Indicators (World Bank, 2012). Data on energy consumption (measured in tons of oil equivalent) are taken from the International Energy Agency (2008). We include only those countries where all required energy times series are available, at least for 30 years. This is done both to increase consistency of the data and to avoid spurious results due to a lack of observations. Hence, we can account for total energy consumption, and electricity, petroleum products, and renewables (i.e., combustible renewables and waste, geothermal, hydro, solar, and wind). Apart from the full sample of countries, we extend our analysis to different income groups as well: high income, upper middle income, lower middle income, and low income. Income groups are selected according to the World Bank List of Economies (World Bank, 2011).

4. Estimation strategy

4.1. Correlation between total energy and different types of energy

In order to address H1a, we analyze the statistical dependence between total energy and the different types of energy. It allows us to find out to what extent single types of energy contain more statistical information than total energy. When evidence for strong dependence is found, single energy types can be regarded as a proxy for total energy. In such a case the relationship between a single type of energy with GDP cannot be adequately quantified.

A common measure of statistical dependence is Pearson's correlation (e.g., Lee Rodgers and Nicewander, 1988). According to Granger and Newbold (1974) correlation may be spurious if time series are non-stationary. Since GDP and energy time series are very systematically found to be integrated of order one in prior studies on energy-GDP causality, we take the first difference of the logged variables for analyzing correlation between total energy and the different types of energy.

4.2. Matching of causality tests

In order to address H1b, we analyze whether a test for causality between a single type of energy and GDP yields the same results as a

[3] Another appropriate pair of variables would be sectoral total energy and sectoral GDP. However, we limit our analysis to national total energy and national GDP as the benchmark case in order to restrict the number of results.

[4] Not forgetting the studies of energy type-GDP causality for coal e.g., Wolde-Rufael (2010) and natural gas e.g., Zamani (2007).