Energy Economics 34 (2012) 489–499

Contents lists available at SciVerse ScienceDirect

Energy Economics

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

Explaining the (non-) causality between energy and economic growth in the U.S.—A multivariate sectoral analysis ☆

Christian Gross

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

ARTICLE INFO

Article history:
Received 9 May 2011
Received in revised form 30 November 2011
Accepted 3 December 2011
Available online 22 December 2011

JEL classification:
C3
Q4

Keywords:
Energy
Growth
Multivariate ARDL
Granger causality

ABSTRACT

The rapidly growing literature on the relationship between energy consumption and economic growth has not univocally identified the causal relationship yet. We argue that bivariate models, which analyze the causality only at the macro level, are eventually misleading, especially in cases where both variables do not cover the same scope of economic activity. After discussing appropriate pairs of variables, we investigate Granger causality between energy and growth in the U.S. for the period from 1970 to 2007 for three sectors, industry, commercial sector, transport, as well as on the macro level. Using the recently developed ARDL bounds testing approach by Pesaran and Shin (1999) and Pesaran et al. (2001), we find evidence for unidirectional long-run Granger causality in the commercial sector from growth to energy, as well as evidence for bi-directional long-run Granger causality in the transport sector. The dependence of causality on the level of aggregation is interpreted as evidence for 'Simpsons' Paradox'. The choice of control variables is based on findings from the Environmental Kuznets Curve literature: we find that controlling for the increasing energy productivity of production as well as trade significantly improves the fit of the bivariate model.
© 2011 Elsevier B.V. All rights reserved.

1. Introduction

What is the causality between energy consumption and economic growth? It is the key question of the empirical energy growth literature initiated by Kraft and Kraft (1978), which has been left unanswered univocally—after more than three decades of empirical research. It has been discussed that conflicting results may arise due to different time periods of the studies, countries' characteristics, variables used, and different econometric methodologies see Ozturk (2010) and Payne (2010) for an overview.

In this paper we will argue that another, even more important, reason for the weak evidence is the level of aggregation. Recent studies (e.g. Bowden and Payne, 2009; Zachariadis, 2007) investigate the causality between energy consumption and economic growth both on the macro as well as on the sector level. While the relationship between energy and growth seems to be neutral on the macro level, both studies find evidence for Granger causality for a lower level of aggregation in some cases. In statistical analyses it is not uncommon that evidence can be found for a lower level aggregation, although the results for the total population suggests the opposite. This phenomenon has been named 'Simpson's Paradox' after E. Simpson (1951)[1]. However, if the results for Granger causality tests are found to be dependent on the level of aggregation and not on the variables, it is necessary to analyze the causal relationship at the correct level of aggregation. Otherwise, the results are spurious and policy advice should be given with caution. The paradox becomes even more severe if the pairs of variables for Granger causality analyses are not matching. For this reason, we will extend Zachariadis' notion of appropriate pairs for causality analyses.

The fact that sectors differ with respect to their relationship between energy and growth, is well known in the Environmental Kuznets Curve (EKC) literature: changes of the industry composition have a changing impact on the energy demands of the economy over time. In the early phases of modern economic growth, when a country industrializes, structural change is believed to increase these demands. Later on when the country enters the post-industrial phase, or the service economy, the energy demands are believed to decline (e.g. Kahn, 1979; Panayotou, 1993; Panayotou et al., 2000; Schäfer, 2005; Smil, 2000)[2]. The resulting divergence between energy and economic growth is also a challenge for Granger causality analyses. In order to account for the decreasing energy intensity in a Granger causality framework, we suggest to include major findings from the EKC literature: one major finding is the role of the increasing energy productivity of production, which leads to the divergence between energy and growth. Another main

☆ I thank Stephan B. Bruns, Alessio Moneta, David I. Stern, Ulrich Witt and two anonymous referees for their useful comments that have greatly improved the paper.
E-mail address: gross@econ.mpg.de.

[1] "[…] situations in which statistical dependencies that are consistent in subpopulations disappear or are reversed in whole populations […]" (see Hoover, 2008, p. 19).

[2] Henriques and Kander (2010) emphasize the need to account for sector specific price deflators. Otherwise, the impact of the energy efficient commercial sector on overall energy intensity would be overestimated according to 'Baumol's cost disease' (Baumol, 1967).

0140-9883/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.eneco.2011.12.002

finding is the role of trade, especially for goods producing industries, where energy intensive production is being offshored according to the Pollution Haven Hypothesis (PHH).

For our analysis we use the recently developed autoregressive distributed lag (ARDL) bounds testing approach as proposed by Pesaran and Shin (1999) and Pesaran et al. (2001). We analyze the evidence for long-run as well as short-run Granger causality between final energy consumption and GDP for the U.S. from 1970 to 2007 at the macro level as well as for the industry sector, the commercial sector, and the transport sector. After identifying appropriate pairs of variables for the Granger causality test, we test bivariate as well as multivariate specifications of the model in order to avoid omitted variable bias. The choice of additional control variables is based on major findings of the EKC literature as well as its limitations discussed in the literature.

In line with the majority of studies for the U.S., we find neutrality between energy and growth at the macro level. In addition, we find evidence for unidirectional long-run Granger causality in the commercial sector from growth to energy. We also find evidence for bi-directional Granger causality in the transport sector. Adding or removing additional control variables is found to create or break long-run causality. This finding is important especially in the transport sector, where controlling for the increasing energy productivity of production neutralizes the long-run relationship when growth is the dependent variable. For the industry sector we find that controlling for trade is important for identifying short-run Granger causality when growth is the dependent variable. We conclude that some of the divergence across sectors can be explained by the fundamental differences between goods and service producing industries. In various specifications energy productivity is found to Granger cause growth as well as energy. The latter is interpreted as evidence for 'Jevon's Paradox'[3]. We find only weak evidence for the impact of energy prices on energy consumption for the transport sector. Given the evidence of long-run Granger causality on the sector level, compared to a neutral relationship on the macro level, we conclude that the Granger causality between energy and growth should only be analyzed on the sector level. Otherwise, results for the total economy are spurious.

The paper is organized as follows: first, we discuss reasons for the inconclusive evidence for Granger causality in the existing empirical literature. We further elaborate Zachariadis' identification of appropriate pairs for causality analyses and use those pairs we consider appropriate for our analysis. We also discuss our extensions of the basic bivariate models mostly used in the empirical literature. Section 3 describes the econometric methodology. We investigate the causal relationship between energy consumption and economic growth in the U.S. for the period 1970–2007 and three economic sectors as well as for the macro level. Cointegration tests are based on the ARDL bounds testing procedure as proposed by Pesaran and Shin (1999) and Pesaran et al. (2001). Afterward, we analyze the existence of long-run and short-run Granger causality. In Section 4 we discuss our findings and the final section concludes.

2. Reasons for the inconclusive evidence for causality between energy and growth

2.1. Simpsons' Paradox: the 'correct' level of aggregation

Theoretical approaches to the relationship between energy and growth are manifold (see Stern, 2004 for a summary). Ecological economists, in particular, emphasize the dependence of economic production on natural resource flows (e.g. Ayres and Warr, 2009; Cleveland et al., 1984; Schurr et al., 1960; Stern, 2011). Nevertheless, the empirical evidence from the energy-growth literature is rather mixed and weak.

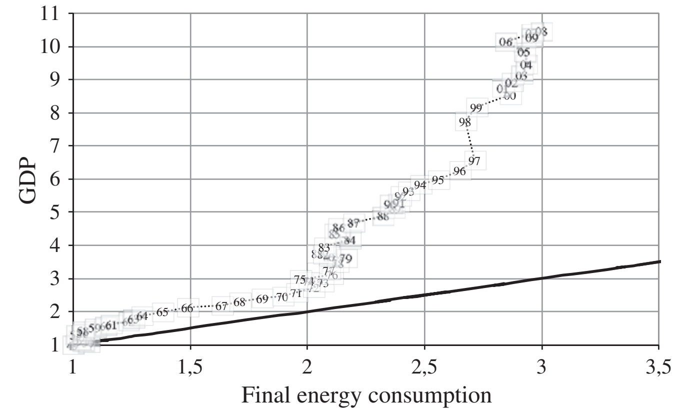

Fig. 1. Development of GDP and energy consumption in the U.S., 1949–2009 (1949 = 1); solid line represents constant energy intensity.

Fig. 1 shows the development of GDP in constant prices as a function of final energy consumption in British thermal units (Btu) in the U.S. from 1949 to 2009[4]. Until the late 1970s the relationship is almost linear. After the oil crisis in the late 1970s energy consumption drops back, while GDP remains almost constant. At the beginning of the 1980s, the slope is continuously increasing with another dropback in the late 1990s. The figure indicates that studies covering the years until the oil crisis should be more likely to find evidence for a relationship between energy consumption and growth, while later studies have to deal with the decreasing energy intensity. In the EKC literature, the decreasing energy intensity at the macro level is also known as the de-coupling between energy and growth. As the theory of the EKC assumes that the development of energy-related parameters is invertedly U-shaped with respect to increasing growth per capita, it describes a non-linear relationship between growth and energy-related parameters.

A shortcoming of the empirical energy growth literature is the underlying assumption of the same relationship between energy and growth over time. Causality is either running from energy to growth ('growth'), from growth to energy ('conservation'), is bi-directional ('feedback') or absent ('neutrality'). An obvious solution to account for the, in fact, nonmonotonic development of the relationship between energy and growth is to control for structural breaks. However, recent studies, which investigate the causality between energy consumption and economic growth both at the macro as well as at the sector level, show that the reason for the divergence is more fundamental and should be elaborated in more detail.

While Zachariadis (2007) and Bowden and Payne (2009) do not find evidence for Granger causality between energy and growth for the macro level, both studies find evidence for Granger causality for a lower level of aggregation in some cases. Without explicitly referring to Simpsons' Paradox, both studies show that the causality between energy and growth is hidden when only the macro level is taken into consideration. Figs. A.1–A.3 indicate why the results differ across the three sectors industry, commercial, and transport and why the results for the macro level are poorly related to the evidence at the sectoral level. The figures show the same plot as in Fig. 1, but with the development of sectoral value added relative to the development of sectoral final energy consumption. We find a decreasing energy intensity in all sectors. However, the scales differ so that the

[3] Jevons (1864) maintained that technological efficiency gains – specifically the more "economical" use of coal in engines doing mechanical work – actually increased the overall consumption of coal, iron, and other resources, rather than "saving" them, as many claimed. Twentieth-century economic growth theory also sees technological change as the main cause of increased production and consumption ('rebound effect'; see also Alcott, 2005).

[4] The majority of studies have been published for the U.S. For reasons of compatibility, we limit our analysis to the U.S.

دریافت فوری ← متن کامل مقاله

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات