



On energy consumption and GDP studies; A meta-analysis of the last two decades



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ABSTRACT

The relationship between energy consumption and GDP growth has been intensely examined in multiple frameworks set by various methods and countries. This paper is a meta-analysis of 51 studies published in the last two decades, with worldwide data since 1949, on the relationship between energy consumption and GDP growth. The aim is to systemize some of the factors that cause the variation of results in these studies. Our results yield evidence that the long run elasticity of GDP growth with respect to energy consumption is not independent of the method employed for cointegration, the data type and the inclusion of variables such as the price level or capital in the cointegration equation. Also 1% increase in capital, increases the elasticity of GDP with respect to energy consumption by 0.85%.

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1. Introduction

A plethora of studies has dealt with the relationship between energy consumption and GDP growth with conflicting results both on the existence and the direction of causality. These are shown in Table 1 of the current paper. Some of the studies already include literature reviews up to the date of their publication. For an example see [1–3] or [4] for a complete literature survey. So far however, no meta-analysis of these studies has been performed. The existent studies are mere narrative reviews with no methodological rigor capable to allow inference, which makes it hard to synthesize this large literature.

A meta-analysis is the statistical analysis of a large collection of disparate research results for the purpose of integrating the findings [5] into a regression equation, or as in [6] the term is

described: a “study of studies”. Therefore, its aim in the energy consumption-growth nexus is not to make policy recommendations on how energy consumption can be used in an efficient and sustainable way enabling growth at the same time. This is done in the individual studies. A meta-analysis provides a synthesis of the trends in a sample of studies and allows a more detailed overview of them by examining various hypotheses [7].

In [8] it is claimed that one of the greatest strengths of meta-analysis is the ability to combine and summarize large amounts of information from previous studies. Therefore, the meta-analytic sample is a collection of data stemming from the individual studies of the topic of interest. According to [9], meta-analyses rely on shared subjectivity, rather than objectivity, since the authors decide what variables and which studies to include. An extenuation to this comment is the transparency of data collection and the admittance of criticism to other analysts.

The majority of meta-analyses have taken place in psychology, education, medicine, transport and labor economics [10]. Many meta-analytic studies have also taken place in various fields of

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Table 1
Author, publication year and number of observations.

Authors	Year of publication	Observations
Acaravci and Öztürk [25]	2010	12
Akinlo [30]	2008	7
Al-Iriani [31]	2006	6
Altinay and Karagol [32]	2004	1
Altinay and Karagol [33]	2005	1
Ang [34]	2007	1
Ang [35]	2008	1
Apergis and Payne [19]	2009a	4
Apergis and Payne [20]	2009b	6
Apergis and Payne [18]	2010	9
Asafu-Adjaye [36]	2000	4
Balcilar et al. [37]	2010	7
Bartleet and Gounder [38]	2010	2
Belloumi [39]	2009	1
Bowden and Payne [40]	2009	5
Chiou-Wei et al. [14]	2008	9
Eggoh, Bangake and Rault [41]	2011	10
Erdal et al. [3]	2008	1
Esso [21]	2010	7
Friedl and Getzner [42]	2003	1
Fuinhas and Marques [43]	2012	5
Ghali and El-Sakka [44]	2004	1
Glasure and Lee [45]	1998	2
Gosh [46]	2002	1
Halicioğlu [47]	2009	1
Hamit-Hagar [48]	2012	1
Ho and Siu [49]	2007	1
Hondroyannis et al. [15]	2002	2
Jalil and Mahmud [50]	2009	1
Lean and Smyth [51]	2010	5
Lee [52]	2005	17
Lee and Chang [53]	2008	16
Lee and Chien [54]	2010	7
Lise and Montford [55]	2007	1
Mahadevan and Asafu-Adjaye [56]	2007	20
Masih and Masih [57]	1996	6
Mozumder and Marathe [58]	2007	1
Narayan and Prasad [27]	2008	30
Odhambo [59]	2010	3
Odhambo [60]	2009	1
Oh and Lee [61]	2004	2
Öztürk and Acaravci [1]	2010	1
Öztürk et al. [2]	2010	3
Paul and Bhattacharya [62]	2004	1
Shiu and Lam [63]	2004	1
Squalli [64]	2007	11
Tsani [65]	2010	4
Wang et al. [66]	2011	1
Yuan et al. [16]	2008	4
Zhang and Cheng [23]	2009	1
Zhixin and Xin [67]	2011	1

Note: One observation means a single country study.

environmental economics but fewer of them have taken place in energy economics; on capital-energy substitution elasticities [11], wind power learning [12] and price elasticity of gasoline [13] are some of the most recent. None to the best of author's knowledge has taken place in the field under study, i.e. the energy consumption and GDP growth nexus.

Studies on the relationship between energy consumption and GDP growth sometimes yield conflicting and ambiguous results due to different methods, sample periods, model specifications being employed [14] or different consumption patterns and presence of omitted variable bias. Besides methodological differences, in [15] more reasons are added for this variety of results: the different institutional, structural frameworks and the policies followed by countries. In [16] the varying impacts from different sources of energy are also reported and the different development stages and processes in each country. [17] also report the cross-section

dependence between countries which is usually overseen and this leads to biased results.

Therefore, motivation for this study was the proliferation of studies in the field with their variety of tools and results. It is an intriguing question to answer whether the methods and tools themselves used in the studies are responsible for the results reached. For example whether the cointegration method, the data range, the geographical region the study uses, do indeed play any role in the results of the study. Even the year of publication might be a proxy for the quality of the study, since more sophisticated methods develop through time. Worthy of reporting is that the multiformity of the studies hinders the homogenization of the variables that were extracted from each study, thereby causing a number of missing observations for some variables or an exclusion of some studies from the meta-data set.

The rest of the paper is organized as follows: Section 2 presents basic theory on the relationship between energy consumption and GDP growth, Section 3 is the data description, Section 4 is the model specification, Section 5 comprises the results and their discussion and Section 6 is the conclusion.

2. The relationship between energy and GDP growth

The relationship between GDP growth and energy consumption is important to design an effective energy and environmental policy that will promote sustainable development. Inefficient usage of energy leads in turn to global warming and climate change therefore affecting GDP growth. [18] provides an enlightening account on the relationship between energy and GDP growth and how policy, depending on its aims and objectives, may respond under four major hypothesis. There are four streams of literature [19,20], about this relationship. First, under the growth hypothesis, energy saving policies which reduce energy consumption may have an adverse impact on real GDP, because the economy is very dependent on energy to grow. Energy leads growth and it affects it directly or indirectly as a complement to other input factors of production. The growth hypothesis situation can be met for instance in energy inefficient economies (e.g. with low pollution control technologies or an underdevelopment in renewable energies) or developing countries.

Second, the conservation hypothesis suggests that growth leads energy. Energy consumption can decrease without necessarily a negative effect on growth, therefore in such situations greenhouse reduction measures can be pursued without detriment to growth because causality does not run from energy to growth. Third, the neutrality hypothesis suggests that energy consumption has little or no impact on GDP, therefore, again, a conservative policy will cause no impediment to growth. Hence, in such situation, there is no reason why a conservation policy should not be adopted if necessary. Fourth, the feedback hypothesis suggests that energy consumption and real GDP are interrelated, because there is bi-directional causality and hence they are complements to each other. The policy implications of the feedback hypothesis are the same with the growth hypothesis in that energy conservation measures will eventually decrease growth.

Policy makers need to know the link between energy consumption and GDP growth and which additional variables lead GDP growth in order to manage tools such as rationing energy consumption and controlling carbon dioxide emissions. It is a timely question how to formulate an energy policy focused on a country's social and economic objectives (e.g. supply security, balance of payments) with respect to Kyoto protocol restrictions. Knowledge of the above relationship together with the knowledge of specific economy characteristics and inefficiencies (political constrains, outdated infrastructure, production shifts from energy

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