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Review

A meta-analysis investigation of the direction of the energy-GDP causal relationship: implications for the growth-degrowth dialogue

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ABSTRACT

The complex relation between energy use and the economic process has long attracted attention. Issues such as the scarcity of energy resources, energy theory of value, degrowth and a-growth approaches are closely related to the relationship between energy and development. The present study traces the implications of the Energy-GDP causality dialogue for the context of the growth-degrowth debate, where the energy-development link plays a decisive role. In that context, the present research investigates the possible existence of a fundamental "macro" direction of causality between energy use and economic growth that is not influenced by study-specific characteristics and events. Towards this objective, we perform a meta-analysis that takes into account 158 studies on causality between energy and GDP, covering the period 1978–2011. This is the first time, to our knowledge, that meta-analysis has been applied to investigate the direction of the energy and GDP causal relationship. The meta-analysis results neither support the existence of a fundamental "macro" direction, nor the so-called "neutrality hypothesis (E ≠ GDP)" in the causal relationship between energy consumption and economic growth.

1. Introduction

The contemporary debate on growth, a-growth and degrowth (van Griethuysen, 2010; van den Bergh, 2011; Kallis, 2011; Kallis et al., 2012; Victor, 2012) represents, in fact, an update of the long-standing dialogue over the scarcity of natural resources at the aggregate level, and constraints on economic process and growth (D'Alessandro et al., 2010). The inevitable limits on growth imposed by the scarcity of natural resources – as delineated in the early works of Georgescu-Roegen (1971, 1977) and Meadows et al. (1972) – are reiterated in modern degrowth approaches (Borowy, 2013; Infante Amate and de Molina, 2013; Lietaert, 2010; Research and Degrowth, 2010). The steady state economy (Daly, 1974, 1996), as a "remedy" for scarcity and environmental degradation, inspired a-growth (van den Bergh, 2011) and degrowth approaches (Kerschner, 2010; O'Neill, 2012; Schneider et al., 2010). On the other hand, optimistic approaches which are based on the expectation of continual technological advance and the possibility of substitution of natural inputs with man-made capital (Solow, 1956, 1957) support the continuation of current growth trends (Baumol, 1986; Solow, 1974, 1978, 1993, 1997). Results from this debate may have direct implications for sustainability science, as the availability of natural resources is regarded as one of the conditions for sustainable development (Bithas, 2008; Bithas and Nijkamp, 2008; Howarth, 2007; Hueting, 2010; Spangenberg, 2010). Nowadays, it should be possible for the various theoretical approaches to be placed on a sounder basis as empirical evidence becomes available. Two aspects of contemporary empirical analysis stand out as crucial for the growth-degrowth dialogue: decoupling natural resources use from GDP growth (Bithas and Kalimeris, 2013; Cleveland et al., 1984; Krausmann et al., 2009; Fiorito, 2013) and the direction of the causal relationship between energy use and economic growth.

The present study attempts to trace the existence of a "macro"[1] direction in the findings on energy-GDP causality and attempts to identify the factors that determine this "macro" direction. In addition, the implications of a macro direction of the E-GDP causality nexus on the energy scarcity and growth-degrowth debate will be investigated. The present research carries out meta-analyses

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[1] As "macro" direction, on the Energy-GDP causality nexus, we define the existence of a prevailing direction that holds in the vast majority of cases and is not influenced by the case-specific characteristics of each case study.

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for the first time in the history of the causality dialogue, employing two different methodologies: Rough Set Data Analysis (RSDA) and multinomial logistic regression.

Clearly, energy (exergy), as the only source of "useful work", is indispensable for the economic process (Warr et al., 2010). Natural resource economists and practitioners place the energy issue at the core of contemporary economic analysis and policy (Bentley, 2002; D'Alessandro et al., 2010). The literature on causality results in four different estimates of the direction of causality: from energy (E) to GDP, from GDP to E, bi-directional causality, and no causality in either direction (Ozturk, 2010; Payne, 2010). If the causality tends to run from GDP to E, or if there is no causal relation between the two, then there might be substantial potential for further growth. In this context, energy scarcity does not impose a severe constraint on prospects for economic growth (Ang, 2007; Ghosh, 2002; Soytas et al., 2007). The energy use which is induced by growth can be adjusted within the limits of energy availability. The aggregate output of the economic process could be oriented towards less energy-intensive goods and technological advance could decouple economic process from energy constraints. Causality running from GDP to E implies further potential for the effective use of energy and restructuring of the economy towards less energy-intensive sectors. On the contrary, if the direction of causality from E to GDP prevails, then limited energy resources will impose serious constraints on growth potentials (Magazzino, 2011; Wolde-Rufael, 2010a). Involuntary degrowth will be the inevitable result of the exploitation of current energy resources unless new "promethean" technologies emerge and new energy resources become available in an economically viable way (Georgescu-Roegen, 1976, 1984).

The paper is organized as follows: Section 2 reviews the relevant literature on the energy-GDP growth causal relationship, extending previous surveys of the literature to cover the period from 1978 to 2011; Section 3 presents the methodological framework; Section 4 presents the results of meta-analysis by rough set analysis; Section 5 presents the results of meta-analysis by multinomial logistic regression analysis of the same dataset; finally, Sections 6 and 7 consist of further discussion of the results and the overall concluding remarks, respectively.

2. The causality debate between energy consumption and economic growth

There has been a growing literature over the last three decades concerning the issue of the causal relationship between energy consumption and economic growth measured in terms of GDP. This ongoing debate has produced at least 172 research papers so far. These encompass a wide variety of approaches. They focus on different countries, groups of countries or even parts of a country, and employ various econometric methodologies, time periods and proxy variables. In more detail, the four possible findings regarding the direction of the causal relationship between energy consumption and economic growth, already introduced above, are as follows (Ozturk, 2010; Payne, 2010):

- **Neutrality hypothesis or no causality (E ≠ GDP):** no causal relation exists between GDP growth and energy consumption. This implies that energy consumption is not correlated with GDP growth and it follows that energy scarcity and conservative policies in relation to energy use do not affect economic growth (Ozturk, 2010). The "*neutrality hypothesis*" has been documented by Akarca and Long (1980), Yu and Hwang (1984), Yu and Choi (1985), Erol and Yu (1987), Yu and Jin (1992), Cheng (1996), Glasure and Lee (1997), Fatai et al. (2002), Soytas and Sari (2003), Altinay and Karagol (2004), Soytas and Sari (2006a), Jobert and Karanfil (2007), Lee (2006), Soytas et al. (2007), Halicioglu (2009), Payne (2009), Soytas and Sari (2009), Acaravci and Ozturk (2010), Payne and Taylor (2010) and Payne (2011a).
- **Conservation hypothesis (GDP → E):** unidirectional causality running from GDP growth to energy consumption. This hypothesis implies that GDP growth causes energy consumption. It suggests that an economy that functions in such a causal relationship is less energy dependent; consequently, any conservation policies concerning energy consumption will have little or no adverse effect on economic growth (Ozturk, 2010). The "*conservation hypothesis*" has empirical support in findings of Kraft and Kraft (1978), Abosedra and Baghestani (1989), Cheng and Lai (1997), Cheng (1998, 1999), Soytas et al. (2001), Aqeel and Butt (2001), Soytas and Sari (2003), Narayan and Smyth (2005), Al-Iriani (2006), Lee (2006), Yoo and Kim (2006), Zachariadis (2007), Mozumder and Marathe (2007), Zamani (2007), Mehrara (2007), Lise and Van Montfort (2007), Lee and Chang (2007b), Ang (2008), Karanfil (2008), Hu and Lin (2008), Zhang and Cheng (2009), Ghosh (2009), Narayan and Smyth (2009), Chang (2010), Ozturk et al. (2010), Lean and Smyth (2010) and Kumar (2011).
- **Growth hypothesis (E → GDP)**: unidirectional causality running from energy consumption to GDP. It implies that energy consumption causes GDP growth. The "*growth hypothesis*" suggests that the availability of abundant cheap energy sources promotes economic growth. In that sense, while increases in energy consumption may contribute to further economic growth, reductions in energy consumption may have negative effects on growth (Ozturk, 2010). The "*growth hypothesis*" is supported by empirical findings of Ramcharran (1990), Stern (1993), Masih and Masih (1996, 1998), Glasure and Lee (1997), Stern (2000), Asafu-Adjaye (2000), Soytas and Sari (2003), Morimoto and Hope (2004), Wolde-Rufael (2004), Thoma (2004), Lee (2005), Lee and Chang (2005), Soytas and Sari (2006b), Lee (2006), Ang (2007), Lee and Chang (2007a), Narayan and Singh (2007), Soytas and Sari (2007), Yuan et al. (2007), Lee and Chang, 2008; Narayan and Smyth (2008), Abosedra et al. (2009), Akinlo (2009), Apergis and Payne (2009a, 2009b), Odhiambo (2009b), Chang (2010), Tsani (2010), Warr and Ayres (2010), Wolde-Rufael (2010a), Magazzino (2011), Payne (2011b), Asghar and Rahat (2011), Fotros and Maabudi (2011), Heo et al. (2011), Alam et al. (2011), Tiwari (2011), Yin and Wang (2011) and Arifin and Syahruddin (2011).
- **Feedback hypothesis (E ↔ GDP) or bi-directional causality**: a bi-directional causality flows between GDP and energy consumption. Both energy consumption and GDP growth trigger each other. The "*feedback hypothesis*" is documented by Hwang and Gum (1991), Ebohon (1996), Masih and Masih (1996, 1997), Asafu-Adjaye (2000), Yang (2000), Hondroyiannis et al. (2002), Glasure (2002), Soytas and Sari (2003), Paul and Bhattacharya (2004), Oh and Lee (2004), Ghali and El-Sakka (2004), Han et al. (2004), Lee (2006), Soytas and Sari (2006b), Yoo (2006a, 2006b, 2006c), Zou and Chau (2006), Climent and Pardo (2007), Francis et al. (2007), Ho and Siu (2007), Mahadevan and Asafu-Adjaye (2007), Zachariadis and Pashourtidou (2007), Lee et al. (2008), Yuan et al. (2008), Erdal et al. (2008), Tang (2008), Odhiambo (2009a), Belloumi (2009), Mishra et al. (2009b), Apergis and Payne (2010a, 2010b), Belke et al. (2011), Shuyun and Donghu (2011), Kouakou (2011) and Kahsai et al. (2012).

The empirical findings on the energy consumption-economic growth nexus consist of a variety of often conflicting results; nothing approaching a consensus has emerged in the literature. This raises important questions concerning the appropriateness of the chosen methodology and the selected variables (Beaudreau, 2010).