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Are fluctuations in energy variables permanent or transitory? A survey of the literature on the integration properties of energy consumption and production

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ABSTRACT

This study reviews the empirical literature on the integration properties of energy consumption and production. The survey begins with a discussion of the implications of whether energy variables contain a unit root and proceeds to examine how results differ according to the specific unit root or stationarity test employed. Various issues in the literature such as country coverage, use of aggregate versus disaggregate energy data and national versus sub-national data are discussed. Results are found to be sensitive to methodology and type of energy considered. Suggestions for future research are discussed.

Contents

1. Introduction

Over the last 5 years a literature has emerged on the integration properties of energy consumption and production [1–24]. A feature of this literature is that it uses a range of tests to examine if there is a unit root in energy consumption or production. The focus has been on both aggregate energy consumption and production, as well as disaggregated energy consumption and production; namely, fossil fuels (coal, natural gas, oil and petroleum) and renewable energy, including disaggregated biomass, geothermal and solar energy. In addition, numerous other studies have tested for a unit root in energy consumption as the first stage toward testing whether there is a long-run relationship and Granger causality between energy consumption, economic growth and other variables. Testing for a unit root in energy variables has been variously described as "a new branch of research in energy economics" [10:

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1953] and "a new branch of research in [the] economics literature" [14: 4256].

Recent surveys have reviewed the literature on cointegration and Granger causality between energy consumption and economic growth [25–27]. There are, however, no studies which review the smaller, but growing, literature specifically dedicated to testing the integration properties of energy variables and, in so doing, provide an overview of these studies for the applied researcher. The purpose of this paper is to critically review the existing literature on the integration properties of energy consumption and production and suggest directions for future research. Section 2 will discuss the motivation for this literature and the implications of finding that energy consumption contains a unit root or, alternatively, is stationary. Section 3 addresses the various methodological issues pertaining to the type of unit root or stationarity test employed. Section 4 addresses other issues such as country coverage, type of energy analysed, level of disaggregation and the use of national versus subnational data. The final section concludes with some suggested directions for future research.

2. Motivation and implications of findings

Most studies have employed unit root tests for which the null hypothesis is that there is a unit root in energy consumption or production, although some studies have employed stationarity tests, for which the null hypothesis is stationarity. The main objective of this literature has been to examine whether shocks to energy consumption or production have permanent or temporary effects. If energy consumption or production contains a unit root, shocks will have permanent effects. This would be consistent with hysteresis or path dependency in energy consumption or production [1]. However, if energy consumption or production is stationary, shocks will result in only a temporary deviation from the long-run growth path. In turn, whether shocks are permanent or temporary has several implications for forecasting and modelling energy as well as potentially more broadly for other macroeconomic variables.

First, the existence of a unit root in energy consumption or production suggests that random shocks to energy consumption or production may lead to permanent departures from predetermined target levels. This has important implications for both policies designed to increase use of clean energies, such as renewable energy, and decrease use of fossil fuels. If consumption or production of renewable energy contains a unit root, this implies that positive shocks associated with permanent policy changes, such as the renewable portfolio standard, will be more effective than temporary policy stances, such as investment or tax incentives over a pre-specified and limited time horizon [21]. On the other hand, if shocks to renewable energy generate only temporary deviations from the long-run growth path, this implies that permanent policy changes may have little impact on employment and output [17].

The implications for fossil fuels work in reverse because policies are typically designed to reduce fossil fuel consumption as opposed to promote use of cleaner energies. If fossil fuels are found to contain a unit root or exhibit persistence, policies designed to reduce fossil fuel consumption will have positive environmental outcomes [17,20]. To illustrate why, take policies such as carbon taxes on transport fuels designed to reduce petroleum consumption. If petroleum consumption is stationary such policies will be ineffective in reducing consumption of petroleum, but if petroleum consumption contains a unit root, such policies will have permanent effects in reducing petroleum consumption [8].

Second, to the extent that energy is integrated into the real economy, if shocks to energy consumption or production are persistent, output, employment and, thus, other key macroeconomic variables can be expected to inherent that persistence. As Hendry and Juselius [28] noted, "variables related to the levels of any variables with a stochastic trend will inherent that non-stationarity and transmit it to other variables in turn. ... Links between variables will then spread such non-stationarities throughout the economy". Several studies have demonstrated that the elasticity of output with respect to a given change in energy use can be inferred from the dollar share of energy expenditure in total output [4–6,24]. While Hamilton [29] suggested that in the United States the dollar share of energy expenditure in total output is about 4%, there is a fair bit of evidence to indicate that output has been more responsive to crude oil disruption than this figure implies [30,31]. One explanation for observed disruptions being greater than the elasticity of output would predict is that the effects of disruptions in energy supply on output become larger once one allows for mark-up pricing under perfect competition [4]. Further evidence comes from studies suggesting a high correlation between energy consumption and output [25–27]. Based on the strong statistical co-movement between energy consumption and output, it is reasonable to conclude that sufficient links exist for the transmission of non-stationarities [10].

Third, whether output is stationary has important implications for alternative economic theories. If a unit root in energy consumption or production is transmitted to real output, this has implications for real business cycle theories, which are premised on output being stationary [32,33]. In turn, if real output is non-stationary, this raises questions about a number of macroeconomic models which depend on real output being stationary [34–36]. Whether output is stationary also has implications for the efficacy of government fiscal policy. If a unit root in energy consumption or production is transmitted to real output, following the logic in Hendry and Juselius [28], hysteresis in energy consumption or production is transmitted to hysteresis in unemployment. If labour markets are characterised by hysteresis, it follows Keynesian demand management policies may be needed to stimulate demand [32,37]. Alternatively, if real output is stationary, stabilization policies will not be needed as employment levels will revert to their natural rate or long-run growth path [37].

Finally, whether consumption or production of energy contains a unit root has implications for both forecasting and modelling consumption and production of energy. If consumption and production of energy is stationary, it is possible to forecast future levels. If energy variables contain a unit root, forecasting is not possible (see [1,7,17,20,24]). Whether consumption or production of energy contains a unit root is important in modelling energy, economic growth and other variables within a unit root, cointegration and Granger causality framework. The correct approach to cointegration and Granger causality modelling between such variables depends on whether energy contains a unit root. While most studies using this framework proxy energy using energy consumption (see [25–27]), some studies have proxied energy using energy production (see [38–40]). With a single time series (as opposed to a panel setting) if one or more of the variables, including energy consumption or production, is stationary, the appropriate approach to testing for cointegration is the autoregressive distributed lag or bounds testing approach proposed by Pesaran et al. [41].

3. Overview of existing studies

3.1. Univariate unit root tests without structural breaks

Table 1 summarises studies which examine the integration properties of energy consumption and production. Much of the evidence from univariate unit root tests without structural breaks suggests that energy variables contain a unit root in the majority