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Applied econometrics and implications for energy economics research

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ABSTRACT

Developments in applied econometrics, particularly with regard to unit root tests and cointegration tests, have motivated a rich empirical literature on energy economics over the last decade. This study reviews recent developments in time series econometrics applications in the energy economics literature. We first consider the literature on the integration properties of energy variables. We begin with a discussion of the implications of whether energy variables contain a unit root and proceed to examine how results differ according to the specific unit root or stationarity test employed. We then proceed to examine recent developments in the literature on cointegration, Granger causality and long-run estimates between (disaggregated) energy consumption and economic growth. We review both single country and panel studies and pay particular attention to studies which have expanded the literature through adding variables such as financial development and trade, in addition to energy consumption to the augmented production function, as well as studies which have extended the literature through examining disaggregated energy consumption by type. In each case we highlight best practice in the literature, point to limitations in the literature, including econometric modeling challenges, and suggest recommendations for future research. A key message of our survey is that the profession needs to guard against 'overload' of research in these areas as most applied studies are no longer adding anything more to what is already known.

1. Introduction

Developments in applied econometric estimation methods have been the catalyst for a rich body of applied energy economics research. Judging by papers accepted, and published, in leading energy economics journals, this trend is gaining momentum. There is a need to take stock of this literature. There is a need to review whether, at least in the most popular strands of the energy economics literature, greater volume of applied work is adding anything new. If it is making new contributions—this is welcomed, but if it is not, then future directions of research need to be reconsidered. This paper is a response to the growing energy economics literature motivated by new developments in applied econometrics. This paper not only addresses whether additional applied research is adding new insights to what is already known in two of the most popular fields in the energy economics literature, but also offers several directions for future research, allowing the profession to develop, and expand, upon the rich body of literature that it has so successfully developed.

We focus on two specific strands of the energy economics literature that have their origins in applied econometric methods. Specifically, our focus is on (a) integration properties of energy variables and (b) cointegration and Granger causality analysis. So much growth in energy economics research has documented that a need to undertake a stock take of this literature is not only timely but, hopefully, will also guide future research in energy economics. In certain strands of the energy economics literature, it seems as if applied work is no longer making any new contributions and throwing any new light to what is already known (see also Karanfil, 2009). It is this 'overload' of research in certain fields against which the literature needs to guard.

Our review of the literature suggests two messages, which have important implications for existing and future research in energy economics based on new developments in applied econometrics. First, there is largely a consensus in the unit root literature that most energy type variables are stationary if tests utilize sufficiently large time-series data. This is confirmed by panel data models that examine the same unit root null hypothesis. Because panel data models have the advantage of having more power to reject the null hypothesis—a power gain that results from pooling of time-series components of a panel with its cross-section—almost all panel data unit root models with structural breaks reveal clear evidence that energy variables are stationary. It is imperative to assign greater weight to panel data models of unit root tests, as opposed to time-series models, because unit root models function parsimoniously when they are imposed on large sample sizes. Typically most energy type variables will have 30–40 years of annual data, which, particularly when the literature uses the relatively more popular structural break unit root models, is insufficient for unit root models to function precisely. Panel data models are a perfect response to this

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concern with time-series models. Our main message here is that the energy unit root literature has reached a point of consensus and unless of course there are new developments in unit root tests that suit the application of energy variables, there is perhaps not much to gain from additional applications of unit root tests.

Second, when we ask whether cointegration between energy variables and non-energy variables exists, the answer is overwhelmingly affirmative. Therefore, existence of a long-run relationship between energy variables and non-energy variables has become somewhat of a stylized fact. By comparison, there is no consensus when it comes to interpreting evidence on Granger causality, for which the evidence is mixed.

The mixed findings for Granger causality reflect several factors, including institutional differences between countries, model specification and econometric approach. With respect to model specification and econometric testing, there are at least two important considerations. One is that Granger causality is almost always tested in a multivariate framework, and since the sample size to begin with is already small, a multivariate treatment leads to loss of degrees of freedom. The second concerns the choice of lag length in a Granger causality model. Despite being chosen based on a lag length selection criteria, if the selected lag length is high, the model will be problematic since the sample period of estimation is already small and this results in an over-parameterized model. Ideally, a multivariate model should be used (see Payne, 2010). However, such an empirical specification assumes a large sample size. Typically, in applied energy economics literature, this is hardly the case.

In the absence of large historical time-series data, an alternative framework in which to consider Granger causality is bivariate models, as, for example, in Narayan and Popp (2012) and Narayan and Popp (2010a,b,c,d). There is obviously a trade-off. Within a bivariate framework, concern relates to problems associated with omitted variable bias, while, with a multivariate model the concern is with over-parameterization and loss of degrees of freedom, which contributes to estimation error.

One could argue that to obviate the small sample and omitted variable biases, one should use a panel Granger causality model. It will be sufficient, to the extent that the objective is to examine a group of countries, for a panel Granger causality model will not reveal anything about the causality relationship for individual countries that make up the panel. In sum, a panel data model will not be appropriate if the research question and resulting policy implications focus on results for individual countries.

The rest of the paper is set out as follows. Section 2 is about integration properties of energy variables. It begins with an analysis of motivation and implications, reviews the literature, discusses what constitutes the 'state-of-the-art' in the field and concludes with an agenda for future research. These steps are repeated in Section 3 on the subject of cointegration, Granger causality, and long-run estimates. The final section concludes by reiterating the main implications and messages in the paper.

2. Integration properties of energy variables

2.1. Motivation and implications

The main motivation for testing for a unit root in energy consumption or production is to ascertain whether shocks have permanent or temporary effects. If energy consumption or production contains a unit root, shocks will have permanent effects. If energy consumption or production is stationary, a shock will result in only a temporary deviation from the energy variable's long run growth path (Smyth, 2013).

There are several implications stemming from whether shocks to energy variables are permanent or temporary (Narayan and Smyth, 2007; Smyth, 2013). The major implication is whether the relevant shock represents a policy change designed to reduce consumption of fossil fuels or promote consumption of renewable energy. If fossil fuels contain a unit root, policies designed to reduce energy consumption will be effective because the negative shock induced by the policy change will be persistent. If renewable energy contains a unit root, policies designed to induce permanent changes, such as renewable portfolio standards, will be more effective than policies designed to induce temporary changes, such as tax incentives (Barros et al., 2012).

There are several other implications as well. First, if energy is integrated into the real economy, one can expect that following a shock to energy consumption or production, non-stationarities will be transmitted to other macroeconomic variables, such as employment and output. Second, if shocks to energy variables result in persistent spreading to other macroeconomic variables, this raises serious questions about economic theories, such as real business cycle models, premised on output being stationary and has implications for the efficacy of Keynesian demand management policies. Third, whether energy variables contain a unit root has implications for forecasting energy demand and the correct modeling of energy and other variables, such as economic growth (for more details see Smyth, 2013).

2.2. Overview of existing studies

The early studies applied the Augmented Dickey–Fuller (ADF) unit root test to energy consumption for a large number of countries (Hasanov and Telatar, 2011; Narayan and Smyth, 2007). The main conclusion from these studies was that the unit root could be rejected for about one third of countries. While these findings serve as a benchmark, traditional unit root tests, such as the ADF test, have several limitations, meaning they have low power to reject the unit root null hypothesis. These limitations include low power to reject the unit root null hypothesis in the presence of one or more structural breaks, non-linearities in the data, if the alternatives are of a fractional form or if there is an insufficient number of observations. Each of these limitations has served as a catalyst for subsequent studies to re-examine whether there is a unit root using more recent tests which address one or more of these shortcomings associated with traditional tests.

A limited number of studies have addressed the issue of the low power of traditional tests in the presence of non-linearities in energy variables (Aslan, 2011; Aslan and Kum, 2011; Hasanov and Telatar, 2011; Maslyuk and Smyth, 2009). Overall, the evidence from these studies is that energy variables contain a unit root (Aslan and Kum, 2011) or that the evidence is ambiguous (Aslan, 2011; Hasanov and Telatar, 2011). In general, the evidence from studies which have applied non-linear unit root tests is more consistent with energy consumption and production being non-stationary. Related studies that have applied a non-linear version of an observed components model have found evidence of persistence in consumption of specific types of energy such as coal and natural gas (Congregado et al., 2012; Golpe et al., 2012).

A number of studies have addressed the issue of the low power of traditional tests to reject the unit root null hypothesis in the presence of one or more structural breaks. Most studies which have employed a univariate unit root test with one or two structural breaks have used the Lee and Strazicich (2003) Lagrange multiplier (LM) unit root test with one or two breaks (Agnolucci and Venn, 2011; Apergis et al., 2010a,b; Aslan, 2011; Aslan and Kum, 2011; Lean and Smyth, 2013, 2014a,b; Maslyuk and Dharmaratna, 2013; Mishra and Smyth, 2014a, b; Narayan et al., 2010a,b,c,d). Some studies have employed the Narayan and Popp (2010) unit root test with one and two breaks (Apergis and Payne, 2010a,b,c,d; Mishra and Smyth, 2014a,b). The main finding from these studies is that energy consumption is stationary around a broken trend, although some studies have reached inconclusive results or found that energy variables contain a unit root, even after accommodating structural breaks (see e.g. Aslan, 2011; Lean and Smyth, 2013; Maslyuk and Dharmaratna, 2013; Mishra and Smyth, 2014a,b).

Most studies that have tested for a unit root in energy consumption have employed annual data; however, some studies have