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Persistence in world energy consumption: Evidence from subsampling confidence intervals

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ABSTRACT

This paper analyzes the persistence properties of energy consumption in 107 countries over the 1971–2011 period. It uses subsampling confidence interval methods that are more informative than simple unit root tests to describe the underlying process of energy consumption. Because subsampling requires fewer assumptions on the nature of the data generating process, inference is less prone to a number of potential misspecification errors. By focusing on the degree of persistence in the process describing a country's energy consumption, the analysis not only provides evidence on the stationarity or nonstationarity of the energy consumption but also gives insight into the likely success of environmentally oriented government intervention. The analysis finds that the 107 countries can be grouped into three persistence classes: those whose energy consumption is explosive (highly populated countries with high growth rates); those with nonstationary energy consumption (developing and highly oil dependent economies); and those whose energy consumption is stationary (developed and energy-rich countries). In nonstationary cases, government intervention can be effective and produce permanent improvements in energy conservation and other environmental concerns. In stationary cases energy conservation and environmentally-oriented demand-management policies can have only temporary effects and thus designed to speed re-adjustment to the longer run underlying trend.

1. Introduction

In this paper, we investigate persistence in energy consumption across 107 countries over the 1971–2011 time period.[2] We argue that constructing confidence sets for the degree of persistence in energy consumption is an informative way of analyzing its persistence property. To do so we use the different subsampling method introduced by Romano and Wolf (2001) to calculate the confidence sets and to separate stationary patterns of energy consumption from non-stationary ones.

The distinction between stationary and integrated energy consumptions is important in several ways. First, if energy consumption follows a stationary process, then shocks arising from changes in environmental protection policies or energy supplies are transitory such that future energy consumption can be forecasted based on past values (Apergis et al., 2010a,b).[3] On the other hand, similar shocks to an integrated or non-stationary energy consumption will cause permanent changes to the process such that the expected or forecasted value will not revert to its previous mean or trend. Second, because energy consumption is correlated with many macroeconomic variables, persistence in the energy consumption will likely be transmitted to other macroeconomic variables (Smyth, 2013). For example, if energy consumption follows a unit root process, then this property will be transmitted to production and unemployment. Hence a negative shock to energy consumption would be expected to raise the unemployment rate permanently and in order to bring the unemployment rate back to its previous trend, stimulatory intervention would be necessary (Smyth, 2013). Third, for econometric modeling

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2 A variable is called persistent if the effect of shocks to the variable continues for a long time in the future.

3 A reliable forecast of future energy consumption is very important for economic and environmental planning and for ensuring energy security. If the process describing energy consumption contains a unit root, then forecasting future energy consumption values based on past values will result in erroneous forecasts. To make an accurate forecast, additional information about key economic variables is required.

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and understanding the correct policy response, it is important to know whether energy consumption follows a stationary process or has a unit root. Particularly when considering causality running between energy consumption and the economic environment, one needs to relate variables and policy instruments with comparable degrees of integration, whether in levels or first-differences.

An energy consumption process that is stationary implies that energy shocks of different kinds will be temporary in their effect and not very long lasting. This in turn means that an adverse shock to energy consumption will not require government intervention for energy consumption to return to normal. On the other hand, an adverse shock in a country whose energy consumption is non-stationary is permanent and hence will require government intervention to restore normalcy. Note also that the degree of persistence in the underlying energy consumption process is an important concern both for countries that are net exporters as well as countries that are net importers. For energy-exporters, energy consumption is important as a revenue generator for the economy (and often the government) while for energy-dependent countries energy consumption becomes important on the supply side of the economy in relation to growth. For example, if energy consumption is non-stationary and energy demand declines, then countries that are energy exporters know that revenues from energy exports will not return to their previous trend/mean and that new sources of revenue must be found to maintain income levels.

Because of its importance the stationarity and persistence of energy consumption have already been examined in a number of recent studies. These typically adopt one of two approaches focusing on unit root analysis. First, many researchers have used univariate unit root tests, without or with structural breaks. Important contributors to this literature include the following: Apergis and Payne (2010), Fallahi (2011), Hasanov and Telatar (2011), Maslyuk and Dharmaratna (2012), Narayan et al. (2010), Narayan and Smyth (2007), and Congregado et al. (2012). Second, researchers such as Chen and Lee (2007), Hsu et al. (2008), Mishra et al. (2009a,b), Narayan et al. (2008), Narayan and Smyth (2007), and Lean and Smyth (2012)have used panel unit root tests.

Unit root statistics test the null hypothesis that the sum of the coefficients in a sequence equals unity, against the alternative hypothesis that this sum is less than unity. Rejecting the null means only that the process is stationary; it does not provide any information on the degree of persistence in the energy consumption.[4] However as Keating (1991, p. 92) has argued, “[p]ersistence is not an either-or question; it is a matter of degree — how much of the impact remains over time”. Moreover, as Narayan and Smyth (2014) point out, structural breaks are common in time series data and the absence of long historical time series make the use of unit root tests with structural breaks inefficient. Therefore, new approaches are needed to study the persistence of energy consumption. For this reason we take a different approach and construct confidence intervals for the persistency parameter of the energy consumption series. It is worth noting that from the policy maker’s point of view, persistency is as important as the presence of unit root.[5] Therefore the use of unit root tests and knowledge of the stationary/nonstationary nature of the energy consumption process does not provide all the information required for policy use.

The persistence degree of time-series data can be examined by constructing bootstrap confidence intervals either for the largest autoregressive coefficient or for the sum of the autoregressive coefficients.[6] When the confidence interval contains 1 we can conclude that the time series is a difference stationary process and when the upper bound of the confidence interval is less than 1, the process will be trend stationary.

There are different types of bootstrap methods available in the literature to construct the confidence interval. Some authors have used conventional bootstrapping, which takes samples with replacement of size L from the original sample of size L. Most of these approaches rely on the assumption of independent innovations. Other scholars, such as Romano and Wolf (2001), propose constructing confidence intervals based on taking samples without replacement, called subsampling bootstrap or simply subsampling. The novelty of this approach is that unlike the conventional bootstrapping technique, it can handle innovations that exhibit long memory process or have discontinuities.[7] In addition, these procedures require only weak assumptions and can even be applied to dependent innovations. Finally, they have good finite sample properties.[8]

The benefits of using subsampling bootstrap confidence intervals to examine the existence of a unit root and the persistence degree of a time series are multifold. First, the confidence interval is much more informative than the point estimate, such as those produced by the unit root test.[9] Second, the confidence interval can be constructed in such a way that the results are robust to the presence of a root on or near the unit circle.[10] Third, the method does not require the validity of Gaussian assumptions regarding the estimates of the coefficients and provides more accurate results even in finite samples. Fourth, subsampling method outperforms traditional tests even for series that exhibit long memories (Andrews and Lieberman, 2006, Pilar, 2005, among others). Furthermore, it has been shown that subsampling confidence intervals are more reliable than confidence intervals constructed using asymptotic theory. In sum, the results from subsampling confidence intervals provide information that is more reliable to policy makers and will thereby better help them design appropriate policy.

2. Literature review

While the integration property of energy consumption has been studied in many papers, the results have been mixed, seemingly dependent on the time interval chosen and the econometric technique employed.[11] For example in the case of Turkey, Altinay and Karagol (2004) examine energy consumption data over the 1950–2000 time and show that the data appear to be stationary. Lise and van Monfort (2007), on the other hand, examine stationarity between 1970 and 2003 and show that the energy consumption process is non-stationary. Soytas and Sari (2003) arrive at the same conclusion. Most recently, Aslan and Kum (2011) examined the integration properties of energy consumption in disaggregated data over the 1970–2006 time period. Using linear and non-linear unit root tests they conclude that different sectors have different orders of integration.

[4] Long memory unit root tests are an exception. These tests provide some information about the degree of persistence.

[5] For example, a highly persistent stationary process may be indistinguishable from a nonstationary process over short time intervals.

[6] The bootstrap method initiated by Efron (1979) has been employed widely in empirical and theoretical studies. See Efron and Tibshirani (1993) for an introduction to bootstrapping.

[7] The presence of a unit root in time series is considered as one of the cases that causes discontinuity in the limiting distribution of estimators.

[8] It is a very important advantage in research projects such as ours that use annual data where the number of observations is limited.

[9] For example, it shows the variation range of the measured degree of persistence. Furthermore, the lower bound of the confidence interval indicates the minimum degree of persistence of the time series.

[10] It is well known that unit root tests suffer from power loss when the time series has a root close to the unit circle (see Maddala and Kim, 1998) .

[11] For a complete survey of the literature on the integration properties of energy consumption see Smyth (2013).