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1 Introduction

The works of Engle and Granger (1987) [6] and Johansen (1991) [12] laid the ground for cointegration analysis. In their framework, the number and shape of linear long-run relationships can be estimated, as well as the linear adjustment of the system towards these equilibria. Readily the possibility of nonlinear behavior was advanced, c.f. Granger and Terasvirta (1993) [8].[1] However, not until Hansen and Seo (2002) [10] did the matter received a fully formal treatment, latter expanded by Bec and Rahbek (2004) [3], Saikkonen (2005) [19], Seo (2006) [23], Seo (2007) [22], Saikkonen (2008) [20], Kristensen and Rahbek (2010) [14] and others. Virtually all the tests and estimators developed involve complex calculations or non-standard asymptotic distributions or both. In this paper, we propose very simple linearity test and estimation procedure for a nonlinear Error Correction Model (ECM).[2]

All possible advantages of taking nonlinear relations into account in a stationary environment are present in this framework. See, for instance, van Dijk, Terasvirta and Franses (2002) [26]. But more important here, in addition to that, is the possibility to model persistent behavior in a globally stationary setting, as noted in Gonzalo and Pitarakis (2006) [7]. A linear function equals zero only in one point, while a nonlinear may have a whole interval of the domain with image equal zero. As a result, a linear adjustment function implies that every deviation from cointegration relation starts to be corrected away immediately. Diversely, a nonlinear adjustment function may accommodate a deviation for a long period, until another shock takes the deviation to a value where the adjustment function does not equal zero anymore.

The first step in this approach is to test whether the ECM adjustment is linear or not. There are two available tests under this framework. One in Hansen and Seo (2002) [10] and another in Seo (2007) [22]. Each of this tests

[1] Nonlinearities in the cointegration relation itself, as in [21] may not have an Error Correction representation, as noted in Gonzalo and Pitarakis (2006) [7]. This makes the two approaches rather separate from each other.

[2] We assume cointegration rank is known. For cointegration tests, see Kapetanios, Shin and Snell (2006) [13] and Seo (2006) [23].

has one specific form of nonlinearity as alternative. In the former, it is a two-regime threshold regression. In the later, it is a smooth transition setting.

As in many cases of linearity testing, under the null hypothesis there are unidentified parameters, turning the usual maximum likelihood approach impossible. The solution used in both papers, proposed in Davies (1987) [5], is to perform a supLM-type test. The result are two difficult tests to implement. First, the likelihood functions are discontinuous or too flat, requiring grid searches over some parameters. Second, cumbersome bootstrap simulations are needed in order to assess the asymptotic distributions, which are nonstandard and not free from nuisance parameters. Moreover, although the tests are derived against a very specific alternative hypothesis, it is sensible to expect a high power against many classes of nonlinearities, nevertheless lacking consistency.

The linearity test proposed herein is based on the Taylor expansion of the adjustment function of the ECM, in the spirit of Luukkonen, Saikkonen and Terasvirta (1988) [16]. The test is calculable as a standard F test. We show that, for a broad class of nonlinear adjustment functions, the test is consistent and χ^2 asymptotically distributed. Monte Carlo experiments show that in finite samples the test has nice size and power properties, often better than the preexisting ones.

We also provide a condition on the derivatives of the nonlinear function, which is attended by any smooth transition model, under which a two step estimator for the parameters in the model has normal asymptotic distribution. The first stage is a Ordinary Least Squares regression, while the second stage is a Nonlinear Least Squares one. Using a maximum likelihood approach, Kristensen and Rahbek (2010) [14] show it is possible to have asymptotic normal estimators, although a nonstandard distribution is the general case. Whereas they point that the linear model is in the subset of models with normal estimators, they do not provide any general condition to determine which models pertain to each case. While there is no formal way to determine which function to estimate, we provide a heuristic approach based on a semi-parametric investigation of the data to help the choice process.

Finally, we apply the test and estimation to international agricultural commodities prices. We find evidence of nonlinear behavior in the wheat prices. Our results point to a behavior consistent with the presence of transaction costs. The estimates of the cost are 17.4% for the pair Argentina and United States and 12.1% for the pair Argentina and Brazil. These figures make sense, putting higher costs between more distant markets.

The rest of the paper is organized as follows. Section 2 presents the

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model and discusses its properties and applications. Section 3 describes the test procedure and establishes its asymptotic distribution. Section 4 describes the estimation procedures and establishes asymptotic distribution of the estimated parameters. Section 5 compares the small sample properties of the proposed test with the preexisting ones. Section 6 applies the methodology developed throughout the paper to international agricultural commodities prices. Section 7 concludes.

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