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A panel stationarity test with gradual structural shifts: Re-investigate the international commodity price shocks[☆]

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ABSTRACT

This paper proposes a simple panel stationarity test which takes into account structural shifts and cross-section dependency. Structural shifts are modelled as gradual/smooth process with a Fourier approximation. The so-called Fourier panel stationarity test has a standard normal distribution. The Monte Carlo simulations indicate that (i) if the error terms are *i.i.d,* the test shows good size and power properties even in small samples; and (ii) if the error terms are serially correlated, the test has reasonable size and high power. We re-examine the behavior of the international commodity prices and find out an evidence on the persistence of shocks.

1. Introduction

The panel unit root tests during the last two decades have triggered interest because incorporating time dimension with cross-sectional dimension leads to increase in power of the tests. The early attempts go back to Levin et al. (2002), Im et al. (2003), Maddala and Wu (1999), and Choi (2001) in which cross-sections in a panel data are assumed to be independent. Since the independency assumption is not likely to hold in practice, the literature is extended by the second generation unit root tests which account for cross-section dependency (among others, Breuer et al., 2002; Smith et al., 2004; Bai and Ng, 2004, Pesaran, 2007).

Given the importance of structural breaks in the behavior of macroeconomic series, a special attention in the unit root analysis has been paid to allow the existence of structural shifts. One important question in the literature is how to account for breaks. The traditional approach is to use dummy variables in which structural shifts are assumed to occur instantaneously (for example, Perron, 1989; Zivot and Andrews, 1992; Lee and Strazicich, 2003; Im et al., 2005). In addition to the dummy variable approach, the smooth transition approach is also used since structural changes in macroeconomic time series are likely to be gradual (*inter alia* Leybourne at al., 1998; Kapetanios et al., 2003). Both the dummy variables and the smooth transition modelling assume *a priori* one or two structural shifts and require to know dates, number, and functional form of breaks. Even though the recent studies have focused on multiple structural breaks (*inter alia* Carrion-i-Silvestre et al., 2009; Westerlund, 2012), the unit root tests with many endogenous breaks are subject to determining maximum number of breaks, estimating location of breaks, over parametrization, and loss of power (Enders and Lee, 2012a; Rodrigues and Taylor, 2012). To deal with these problems, Becker et al. (2006), Enders and Lee (2012a, 2012b) and Rodrigues and Taylor (2012) propose the testing procedures with a Fourier approximation based on the variant of Flexible Fourier Form by Gallant (1981). The Fourier approximation does not require to know *a priori* dates, number, and/or form of breaks. This approach captures structural break(s) by using frequency components. The specification problem of selecting dates, number, and form of breaks is thereby transformed into incorporating the appropriate Fourier frequency (Enders and Lee, 2012b). Since the developments in time-series analysis can easily be extended to the panel framework, the unit root tests based on the Fourier approximation in time series context have led to a new direction in the panel unit root literature. Lee et al. (2015) in that respect develop the panel version on the Fourier DF-type test by

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Enders and Lee (2012b) in order to allow for smoothing structural changes in deterministic terms.

Developing testing procedures with the null hypothesis of stationarity[1] has witnessed ongoing research in both the time series and the panel data literature. The stationarity test developed by Kwiatkowski et al. (1992) (the KPSS test) has attracted interest by practitioners and widely used in the empirical studies. Lee et al. (1997) analyze the effect a structural break on the KPSS test and show that it diverges from the distribution under the null hypothesis if a structural break is ignored. Their Monte Carlo analysis indicates that the KPSS test rejects the null hypothesis too often in the case of a structural shift. In the panel data literature, Hadri (2000) develops the panel stationarity test based on the univariate KPSS statistics. Hadri and Kurozumi (2011, 2012) propose the panel stationarity tests that allow for cross-section dependency based on a factor structure. Since the presence of structural breaks affects the limiting distribution of the individual statistics under the null hypothesis, it is crucial to control for structural breaks in the stationarity tests to deal with the size distortion problem. The more recent panel data studies have focused on accounting for structural breaks (*inter alia*, Carrion-i-Silvestre et al., 2005; Hadri and Rao, 2008; Hadri et al., 2012). It is worthwhile emphasizing that all these studies benefit from the dummy variable approach for modelling structural shifts.

This paper proposes a simple panel stationarity test with gradual structural shifts and cross-section dependency. The test also permits the heterogeneity across cross-sections in a panel. The testing procedure is a combination of the time series stationarity test developed by Becker et al. (2006) in which structural shifts are modeled with a Fourier approximation and the panel stationarity test proposed by Hadri and Kurozumi (2011, 2012) in which cross-section dependency is accounted with a common factor structure[2]. The distribution of the individual statistic only depends on the Fourier frequency and the panel statistic has a standard normal distribution. The small sample properties of the panel stationarity test are investigated by Monte Carlo simulations for the different data generating processes. We find that for the independent and identically distributed errors the empirical size of the test is close to the 5 percent nominal size irrespective of time (T) and cross-section (N) dimensions. Besides there is a substantial increase in the power as T or N or both increase[3]. The size and power analysis for the serially correlated errors shows that the test has good power as T increases and reasonable size properties.

The recent dynamics of international commodity prices have attracted more interest in investigating the behavior of commodity markets. Understanding the behavior of commodity prices has a long theoretical and empirical debate. The Prebisch-Singer hypothesis on the one side postulates a long term tendency with declining trends (Prebisch, 1950 and Singer, 1950). The classical view on the other hand argues that the real commodity prices show a positive trend in the long term (Sarkar, 1986). The equilibrium price theory suggests that the supply and demand forces will push commodity prices towards stable equilibrium in the long-run. A serious research effort has been exerted and the evidence on whether the shocks to international commodity prices are transitory or permanent is not still clear cut. We re-analyze whether international commodity prices are stationary by using the Fourier panel stationarity test proposed in this paper. The results support the evidence on that the null hypothesis of joint stationarity is rejected and many of the real commodity prices follow the unit root process, implying that the shocks to international commodity prices are permanent. This finding contrasts with the results from the previous panel data studies in which the structural breaks are taken into account as sharp process. The new panel stationarity test hence provides a fresh information regarding the nature of shocks to international commodity prices.

The paper is organized as follows: the next section is devoted to develop the Fourier panel stationarity test and to simply show its asymptotic distribution. In Section 3, we conduct the Monte Carlo analysis for the small sample properties. In Section 4, the nature of shocks to international commodity prices is examined. Finally, Section 5 includes the conclusion.

2. Model, test statistic and asymptotic distribution

We consider the following data generating process (DGP):

$$y_{it} = \alpha_i(t) + r_{it} + \lambda_i F_t + \varepsilon_{it} \tag{1}$$

$$r_{it} = r_{it-1} + u_{it} \tag{2}$$

where $i = 1, \ldots, N$ cross-section dimension, $t = 1, \ldots, T$ time dimension, r_{it} is random walk process with initial values r_{i0}=0 for all *i*, without loss of generality as heterogeneous constant terms are included[4]. ε_{it} and u_{it} are mutually independent and identically distributed (*i.i.d*) across *i* and over *t* with $E(\varepsilon_{it}) = 0,\ E(\varepsilon_{it}^2) = \sigma_{\varepsilon i}^2 > 0,\ E(u_{it}) = 0,\ E(u_{it}^2) = \sigma_{ui}^2 \geq 0$, and a finite fourth-order moment. F_t is unobserved common factor and λ_i are the loading weights. F_t is stationary and serially uncorrelated with $E(F_t)$=0 and $E(F_t^2) = \sigma_F^2$>0. ε_{it}, F_t, and λ_i are independently distributed for all *i*. Finally, F_t is assumed to be known[5].

The Eq. (1) describes the deterministic term as a time-dependent function denoted by $\alpha_i(t)$. Any structural breaks or nonlinearity in the deterministic term can be captured by a Fourier approximation which mimics a variety of shifts regardless of date, number, and form of breaks (Becker et al., 2006). If the intercept terms include any structural shifts with unknown forms, the Fourier expansion with a single frequency component[6] is described as

$$\alpha_i(t) = a_i + \gamma_{1i} sin\left(\frac{2\pi kt}{T}\right) + \gamma_{2i} cos\left(\frac{2\pi kt}{T}\right) \tag{3}$$

where γ_{1i} and γ_{2i} respectively measure the amplitude and displacement of shifts and *k* denotes the Fourier frequency. The Eq. (3) allows one to obtain time-varying intercept term by nonzero values of γ_{1i} and γ_{2i} to capture smooth changes in the intercept. More generally both the intercept and the slope of time trend may fluctuate over time. If the trend function is nonlinear (either with breaks or other types of nonlinearity), it can be approximated by the Fourier expansion (Jones and Enders, 2014)

$$\alpha_i(t) = a_i + b_i t + \gamma_{1i} sin\left(\frac{2\pi kt}{T}\right) + \gamma_{2i} cos\left(\frac{2\pi kt}{T}\right). \tag{4}$$

Introducing a time trend in a Fourier approximation removes the restriction of same starting and ending values of the sinusoidal function. The Eq. (4) thereby can capture any changes in the intercept and the slope of deterministic trend by nonzero values of γ_{1i} and γ_{2i} which bring out smoothly curving trend functions (Lee et al., 2015: 4). It is worthwhile noting that the trend functions with sudden breaks are not nested within a single frequency Fourier approximation. If y_{it} has the linear trend with

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[1] The null hypothesis of stationarity would be more natural than the null of unit root for many macroeconomic series (Carrion-i-Silvestre et al., 2005) and useful to confirm results from the tests with the null hypothesis of unit root (Hadri, 2000; Becker et al., 2006).

[2] The econometric contribution of this paper hence is simple because the proposed test is based on the existing procedures in the time series and panel data literature. However, the testing procedure would be useful to better understand the nature of shocks by comparing results with those from the panel stationarity tests in which structural shifts are modelled as sharp process.

[3] This result is consistent with the generally invoked powerfulness of the panel unit root and stationarity tests (see Hadri, 2000).

[4] For the importance of initial values in autoregressive models, see Abadir (1993) and Abadir and Hadri (2006).

[5] In practice the common factor is replaced by its estimates. We discuss this point in Section 4.

[6] We refer Becker et al. (2006) for a detailed discussion on using a single frequency instead of cumulative frequencies.