Journal of Econometrics 185 (2015) 378–391

Contents lists available at ScienceDirect

Journal of Econometrics

journal homepage: www.elsevier.com/locate/jeconom

# Nonparametric rank tests for non-stationary panels

Peter L. Pedroni[a], Timothy J. Vogelsang[b], Martin Wagner[c,d], Joakim Westerlund[e,f,*]

[a] Williams College, Williamstown, United States
[b] Michigan State University, East Lansing, United States
[c] Faculty of Statistics, Technical University Dortmund, Germany
[d] Institute for Advanced Studies, Vienna, Austria
[e] Lund University, Lund, Sweden
[f] Financial Econometrics Group, Centre for Research in Economics and Financial Econometrics, Deakin University, Melbourne, Australia

ARTICLE INFO

*Article history:*
Received 27 March 2012
Received in revised form
21 July 2014
Accepted 29 August 2014
Available online 19 December 2014

*JEL classification:*
C12
C22
C23

*Keywords:*
Cointegration
Cross-sectional dependence
Nonparametric rank tests
Time series panel
Unit roots

ABSTRACT

We develop a set of nonparametric rank tests for non-stationary panels based on multivariate variance ratios which use untruncated kernels. As such, the tests do not require the choice of tuning parameters associated with bandwidth or lag length and also do not require choices with respect to numbers of common factors. The tests allow for unrestricted cross-sectional dependence and dynamic heterogeneity among the units of the panel, provided simply that a joint functional central limit theorem holds for the panel of differenced series. We provide a discussion of the relationships between our setting and the settings for which first- and second generation panel unit root tests are designed. In Monte Carlo simulations we illustrate the small-sample performance of our tests when they are used as panel unit root tests under the more restrictive DGPs for which panel unit root tests are typically designed, and for more general DGPs we also compare the small-sample performance of our nonparametric tests to parametric rank tests. Finally, we provide an empirical illustration by testing for income convergence among countries.

© 2014 Elsevier B.V. All rights reserved.

## 1. Introduction

This paper develops rank tests for the number of common stochastic trends present in a time series panel. The tests are designed to perform well in situations where the cross-sectional dimension of the panel is too large for traditional multivariate cointegration methods to be used successfully. The paper also investigates the relationships between these rank tests and other key tests in the non-stationary panel literature, such as panel unit root tests and tests for the fraction of individual series which are $I(1)$ versus $I(0)$ processes.

Much of the recent non-stationary panel literature has focused on permitting increasingly general forms of cross-sectional dependencies among members of the panel (see, for example, Breitung and Pesaran, 2008; Banerjee and Wagner, 2009, for recent overviews). However, as we discuss in Section 2 of this paper, the extent of the cross-sectional dependency that one permits under the data generating process (DGP) is inherently tied to the types of hypotheses that one can successfully test with asymptotic size control. In particular, as we will see, the absence or presence of (cross unit) cointegration among the series is often a key feature in this regard.[1] This is particularly important in relation to the ability to determine the overall number of individual series that are $I(1)$ versus $I(0)$, as well as the ability to determine which particular series are $I(1)$ versus $I(0)$. Granted, in situations where the time series dimension is large enough, one might consider using time series methods alone rather than panel methods to determine the number of individual series which follow $I(1)$ versus $I(0)$ processes. However, often one is interested not only in the individual

* Correspondence to: Deakin University, Faculty of Business and Law, School of Accounting, Economics and Finance, Melbourne Burwood Campus, 221 Burwood Highway, VIC 3125, Australia. Tel.: +61 3 924 46973; fax: +61 3 924 46283.
*E-mail address:* j.westerlund@deakin.edu.au (J. Westerlund).

[1] In the case of panels of univariate time series, cointegration and cross-unit cointegration are essentially synonyms (see the discussion in Section 2). We use the term cross-unit cointegration to conform with the conventions of the panel unit root literature. For multivariate time series panels there are, however, conceptual differences (see Wagner and Hlouskova, 2010).

http://dx.doi.org/10.1016/j.jeconom.2014.08.013
0304-4076/© 2014 Elsevier B.V. All rights reserved.

series properties, but also the implications of the linkages among the individual series, and most importantly the cross-sectional dependencies that are driven by the common stochastic trends.

An important component of the non-stationary panel literature has been the literature on testing for unit roots in panels. A popular approach to accommodating what have been considered fairly general forms of cross-sectional dependence within this literature has been the factor model approach. An underlying assumption of this approach is the decomposition of the series of the panel into what are assumed to be independent common and idiosyncratic components. The idiosyncratic components are then tested for unit roots and the common components are tested either for unit roots in the single factor case, or cointegration in the multiple factor case. However, in many applications, such as the income convergence illustration we provide in Section 5, one is not interested to know the unit root versus stationarity properties of these separate components, but rather one is interested to know these properties about the individual raw series. For such cases we argue that our rank test approach is the best suited and most general approach available for panels with moderate to large cross-sectional dimensions.

In this regard, our tests do not impose any restrictions on the cross-sectional dependencies of the series. The only restriction on the series' behavior is that a joint functional central limit theorem must hold for the first differences of the $N$-vector of series. In such a general setup, except for the extreme cases when the rank is either full (so that all series are $I(1)$ and not cointegrated), or zero (so that all series are $I(0)$), all series will in general be $I(1)$ and cointegrated. In particular, our computationally simple tests are based on multivariate variance ratios computed from tuning parameter free estimates of the respective components that do not require, and are thus not affected by, choices with respect to kernel and bandwidth, lag augmentation or the number of factors to be extracted. These estimators are based on advances in long-run variance estimation pioneered by Kiefer and Vogelsang (2002a,b).

Because the tests are cointegration rank tests, they can be used to infer any rank, and not just the null hypothesis of full rank, which is standard in the literature on non-stationary panels. In fact, the forms of hypotheses considered within this literature are very limited. Specifically, while the null hypothesis is almost always taken to be that all $N$ series are $I(1)$, the alternative hypothesis is usually formulated as that at least some series are $I(0)$. This leaves a rejection of the null somewhat uninformative as it does not indicate how many $I(0)$ series there are. This issue is discussed to some extent by Pesaran (2012), who recommends "the (panel unit root) test outcome to be augmented with an estimate of the proportion of the cross-section units for which the individual unit root tests are rejected" (see page 545). Motivated in part by this recommendation, we also propose a sequential rank testing procedures that compare favorably with for example the Johansen (1995) vector autoregression (VAR) based approach for moderate values of $N$, and increasingly so for larger values of $N$. We also show that for the special case of panels without the presence of cross-unit cointegration, our rank tests can be used to test the same null hypothesis usually tested by conventional panel unit root tests,[2] with the additional advantage that any rank can be tested. Accordingly, in this setting our tests allow one to determine the fractions of $I(1)$ versus $I(0)$ series present in the panel.[3]

The new tests have good small-sample properties, which is demonstrated in a series of Monte Carlo simulation experiments. The proposed sequential rank test procedure is also shown to compare well to the Johansen (1995) trace test. In terms of sample size, the comparative advantage of our test occurs when $N$ is moderately sized, in that it is smaller than the $T$ dimension, but larger than one can handle well with parametric based multivariate cointegration methods. Similarly, we also show that when used in place of panel unit root tests the new tests outperform widely-used first-generation as well as state-of-the-art second generation tests under the conditions for which these other tests were designed.[4]

The remainder of the paper is organized as follows. In Section 2 we first discuss the DGPs and assumptions used in our approach and then discuss the relationships of our setup to the assumptions and DGPs used in the existing non-stationary panel literature. Section 3 presents the rank tests, provides critical values and discusses the local asymptotic power (LAP) properties of our tests for the special case of cross-sectionally independent panels. In this way, by comparing the LAP of our tests with the LAP of two widely-used first-generation panel unit roots, we seek to demonstrate that there is no cost to the generality of our approach even when the more restrictive assumption of cross-section independence is true. Next, in Section 4 we study the small-sample performance of our tests and compare our tests with several second-generation tests under the conditions for which these tests were designed. Finally, we also compare the small-sample performance of our sequential rank test procedure with the Johansen trace test in this section. Section 5 in turn contains a brief empirical illustration of the rank tests taken from the growth and convergence literature. Section 6 offers concluding remarks.

## 2. Assumptions and model discussion

### 2.1. Assumptions

The DGP is a stated in terms of the $N$-dimensional vector of time series $\mathbf{y}_t = [y_{1t}, \ldots, y_{Nt}]'$, and is given by

$$\mathbf{y}_t = \boldsymbol{\alpha}_p \mathbf{d}_t^p + \mathbf{u}_t, \tag{1}$$

with observations available for $t = 1, \ldots, T$. Here $\mathbf{d}_t^p = [1, t, \ldots, t^p]'$, for $p \geq 0$, is a polynomial trend function (with $\mathbf{d}_t^0 = 1$) and $\boldsymbol{\alpha}_p$ is the associated matrix of trend coefficients.[5] The typical specifications considered for $\mathbf{d}_t^p$ include a constant ($p = 0$) or a

2 According to one of the referees, "cointegration rank tests are of no use in testing for unit roots in panels" and "any rank test can never be considered as a panel unit test since they do not test the same hypothesis". We take a different view. One can analyze the properties of rank tests when the null and alternative hypotheses align with those that are typically of interest when panel unit root tests are used. As we show in the paper, the asymptotic null distributions of the rank tests are well defined and pivotal when all series are $I(1)$ and there is no cointegration (a typical assumption that is made under the null hypothesis of panel unit root tests). In this case the rank tests have power to reject this null when all or some of the series are $I(0)$ (the typical alternative of panel unit root tests). Suppose that all series are $I(1)$ but there is cointegration among these $I(1)$ series. If one wanted to test the panel unit root null that "all series are $I(1)$", then the rank tests are not informative and we agree with the referee. To test this null hypothesis one would need to use a panel unit root test that tests "all series are $I(1)$" and permits cointegration among $I(1)$ series. Our view is that sometimes ranks tests can be used to test "all series are $I(1)$" and sometimes not depending on what one can, or is willing, to assume about cointegration among $I(1)$ variables. We disagree that ranks tests can *never* be used to test for unit roots in panels.

3 The fact that our asymptotic theory is for $N$ fixed and only $T \to \infty$ is another indication that our tests are closely related to the multivariate time series literature. However, there are also close links to the standard first-generation panel unit root literature for the case of cross-sectionally independent panels. For this case both pooled and group-mean versions of our tests are available, which are asymptotically normally distributed in a $T, N \to \infty$ setting, and which have been explored in previous drafts (see, for example Pedroni and Vogelsang, 2005).

4 Note however that, by construction, since they are based on variance ratios, in contrast to panel unit root tests, our tests require that the cross-sectional dimension $N$ of the sample is not larger, and is preferably smaller, than the number of observations over time, $T$.

5 Clearly, more general deterministic components can be considered to accommodate for example seasonal dummies or breaks in trends.

Download English Version:

https://daneshyari.com/en/article/5096068

Download Persian Version:

https://daneshyari.com/article/5096068

Daneshyari.com