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SMALL SAMPLE PROPERTIES OF PANEL COINTEGRATION TESTS IN THE PRESENCE OF STRUCTURAL CHANGE *

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Abstract

Panel tests for non-stationarity are increasingly popular in recent years, also for macroeconomic data. Given that panels used in practice are rather small, there is a need of exploring the small sample properties of the tests in various cases. For annual data the N dimension of the panels is limited to no more than 25, and spatial dimension is also limited, because of the nature of studied entities. So, the main concern of researchers remains the relatively small panels – theoretical critical values should be applied with caution, given that they are taken in limits. An additional feature of macroeconomic panels are cycles – with business cycles one can expect even more than one structural break in the series, because up to 3 major cycles can fit in a series with T=25. In the paper small sample properties for the three "group" statistics of Pedroni (1999) under presence of structural breaks are explored. A set of Monte Carlo experiments is applied to processes with a structural break for three possible break dates at 0.3T, 0.5T and 0.7T. Tested for power against the general alternative.

Keywords: panel cointegration, Pedroni tests, Monte Carlo studies, data with structural break, macroeconomic econometrics.

JEL Classification: C90, C49, C87, E01, F47, O11.

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1. Introduction

Tests for non-stationarity of panel data are of increasing popularity in the last two decades, and their application spreads also towards studies of macroeconomic data. The most popular tests for panel cointegration are Pedroni (1999), a generalization of the classical Engle-Granger approach for the panel case, designed for use with bivariate and multivariate data. Critical values for these tests are normal in limits and can even be standardized to N(0, 1). But given that panels used in practice are rather small, there is a need of further exploring their small sample properties in various cases. In macroeconomic studies, data panels are small, data available to researchers is often limited to 20 or 25 years back, spatial dimension is also limited, due to the nature of studied entities. In cross-country studies, a group including more than 20 or 25 members rarely can be successfully explored; almost the same is the situation with regional (single country) studies. In fact, the relatively small panels remain a main concern for researchers – in these cases theoretical critical values have to be applied with caution, given that they are calculated for the limiting case. An additional feature of macroeconomic panels are cycles – with business cycles one can expect even more than one structural break in the series, because up to 3 major cycles can fit in a series with T=25.

In the paper small sample properties for the three "group" statistics of Pedroni (1999) are explored. A set of Monte Carlo experiments is applied to processes with a structural break for three possible break dates at 0.3T, 0.5T and 0.7T. Tested is for size and power against the general alternative.

The aim of this paper is to appeal for caution in the use of Pedroni (1999) tests.

The paper is organized as follows: Section 2 is a literature review, in Section 3 an example of application of Pedroni (1999) tests with empirical data for South-Eastern Europe countries is made, Section 4 presents the design of the experiment, Section 5 presents the results, Section 6 concludes.

2. Literature Review

Pedroni (1999, 1997) proposes a set of 7 test statistics for the null of no-cointegration – "group" and "panel" versions; all of the test statistics are normal in limit. The Pedroni (1999) tests have quickly become the "de facto" standard in empirical studies of cointegration in panel data, and they continue to be extremely popular also nowadays – among the top 50 panel cointegration papers in the last decade, the Pedroni methodology is used in more than the half. This is a rather surprising outcome, given the known issues with the power of these

tests if cross-section dependencies exist. As panel cointegration methods are still a work in progress, further investigation of the small sample properties seems useful for the macroeconomic researcher.

For practical purposes, in macroeconomic research, most interesting are panels with N-dimension of 10-20, and T-dimension of 10-30. Reasoning for N is found in the fact that useful analyses can be made mainly within groups of countries with similar characteristics (i.e. even EU – 28 countries – should be split in smaller groups in many cases) or other entities (it is an exception if the number of regions in one country exceeds 20). The T dimension is limited by the possible structural change of the economy – periods of more than 20 years rarely make sense, hence there is a 20 (or max. 30) observations limit. Taking quarterly or monthly data brings additional problems caused by the insufficiently of the explored influence of seasonality.

In practical applications N and T are often both small, sometimes even below 10. I.e. if one wants to explore some properties of macroeconomic data in Southeastern Europe, N will be between 10 and 20 (depending on the interpretation of the term "SEE countries"). T also will be between 10 and 20 (annual data) – given the fact of the significant structural changes in SEE economies during the 1990s, analyzing data prior to 1999 makes no sense.

Small N and T panels are rather mainstream than an exclusion in macroeconomic panel studies, especially in SEE and other emerging countries studies.

In macroeconomic data, structural change is likely to be present, and very often is coinciding with business cycles. With a 6-9 years length of a "typical" business cycle, most probable break days in the series are likely to occur at 0.3T, 0.5T and 0.7T. These dates are of strongest interest for further investigation.

3. The interest rates in South-Eastern Europe (an example of application of the panel cointegration test)

As an example for the application of Pedroni (1999) tests, let's take the deposit and lending interest rates for several countries in South-Eastern Europe (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Kosovo, Macedonia, Montenegro, Romania, Serbia and Slovenia).

Using data from the Worldbank (World Development Indicators) and from several central banks we compile panels of 10 countries and 14 years (2001-2014) for deposit and lending rates, respectively.

We take into consideration the nominal interest rates, and in general they are found to be non-stationary – see i.e. Newbold et al. (2001), Campbell and Clarida (1987), Campbell et al.

(1997), Moon and Perron (2007). Matros and Weber (2011) discover non-stationarity even in the interest rates differential, continuing the ongoing discussion about the possible I(2) nature of interest rates.

Thus accepting the non-stationarity of interest rates seems plausible and we can proceed further with the cointegration tests.

We apply the bivariate Pedroni (1999) test for the "none" case (no intercept or trend), using lending rates as a dependent variable (deposit rates as independent variable), and obtain ambiguous results. The corrected values of the statistics (test statistics are normally distributed in their limits under the null) are:

rho = 1.39,
t (non-parametric) = -1.45,
t (parametric) = -1.27.

so the null of no cointegration cannot be rejected at 5%.

One possible explanation of this result are the very high values of the interest rates in Romania and Serbia in the beginning of the period (later both countries shift to low-inflationary monetary policy, so high interest rates are not typical for the region).

In our case, it is possible that there is a structural break at around 0.3T (data is for 2001-2014), at least for some countries. Entrance in NATO and EU is a major change practically for all countries in the region. The effects of it show up as early as around 2004. Since then low inflation and growing financial deepening is a fact, especially for EU countries like Bulgaria, Croatia, Romania and Slovenia.

Anyway the critical values of the tests are calculated for the limiting case, and need further investigation for small samples.

4. The Experiment

To explore the small sample properties of the tests, a Monte Carlo experiment of 10000 iterations is made. Of the seven Pedroni (1999) statistics, explored are the three based on pooling along the "between-dimension", the so-called "group" statistics – the "group rho-statistic", the "group t-statistic (non-parametric)" and the "group t-statistic (parametric)".

Between-dimension statistics are constructed by simply averaging the individually estimated coefficients for each member series, and as they are estimated under an alternative hypothesis allowing different values for the autoregressive coefficient, they allow for an additional source of heterogeneity in data.

Studied are 3 possible break dates – at 0.3T, 0.5T and 0.7T, for N={5, 10, 20}, and T={10, 20, 30, 50} respectively.

Data is constructed following the commonly used type of data generating process (DGP) with normal errors and for the bivariate case.

In particular, for the purposes of the study we use a modification of the Breitung and Candelon (2005) DGP. In their study, Breitung and Candelon (2005) use data with structural breaks (value of 3 for the coefficient of the structural break dummy) to explore properties of several panel unit root tests, a similar DGP seems useful also for our study of cointegration tests.

Data is generated as:

$$y_{i,t} = \gamma d_{i,t} + u_{i,t} + v_{i,t}$$

$$u_{i,t} = u_{i,t-1} + \varepsilon_{i,t}$$

where S_i S_i is the break date, γ γ is the magnitude of the break, $d_{i,t} = 0$ $d_{i,t} = 0$ for $t < S_i$ $t < S_i$, $d_{i,t} = 1$ $d_{i,t} = 1$ for $t \geq S_i$ $t \geq S_i$, and $\varepsilon_{i,t}, v_{i,t} \sim N(0,1)$ $\varepsilon_{i,t}, v_{i,t} \sim N(0,1)$.

5. Results

Calculations were made in R (R Core Team, 2015), using the *"pco"* package. To estimate the power of the tests in small samples, experiments with 10000 replications were made, and a nominal significance level of 0.05 was used.

Table 1: Power of "group" Pedroni tests in series with a break at 0.3T

NxT	rho	t (non-parametric)	t (parametric)
5x10	0	0.17	0.15
5x20	0.05	0.39	0.40
5x30	0.41	0.65	0.68
5x50	0.86	0.90	0.94
10x10	0	0.26	0.23
10x20	0.07	0.57	0.59
10x30	0.64	0.87	0.89
10x50	0.98	0.99	0.99
20x10	0	0.35	0.33
20x20	0.13	0.80	0.83
20x30	0.86	0.97	0.98
20x50	1	1	1

Source: own calculations.

With the small power of the Pedroni (1999) tests in small panels, ambiguity of the test statistics in Section 3 can be explained with ease – in the 10x20 case, power of the three statistics is respectively 0.07, 0.57 and 0.59.

Table 2: Power of "group" Pedroni tests in series with a break at 0.5T

NxT	rho	t (non-parametric)	t (parametric)
5x10	0	0.08	0.07
5x20	0.02	0.32	0.33
5x30	0.40	0.66	0.70
5x50	0.90	0.95	0.97
10x10	0	0.09	0.07
10x20	0.03	0.47	0.49
10x30	0.60	0.86	0.90
10x50	0.99	1	1
20x10	0	0.10	0.09
20x20	0.05	0.71	0.74
20x30	0.85	0.98	0.99
20x50	1	1	1

Source: own calculations.

Table 3. Power of "group" Pedroni tests in series with a break at 0.7T

NxT	rho	t (non-parametric)	t (parametric)
5x10	0	0.07	0.06
5x20	0.06	0.39	0.39
5x30	0.56	0.80	0.82
5x50	0.98	0.99	0.98
10x10	0	0.08	0.07
10x20	0.11	0.63	0.63
10x30	0.83	0.97	0.98
10x50	1	1	1
20x10	0	0.09	0.07
20x20	0.23	0.86	0.87
20x30	0.98	1	1
20x50	1	1	1

Source: own calculations.

6. Conclusion

The Pedroni tests should be used with caution, if there is a possible structural break, even with no cross-section dependence in the data. In the case when the break occurs in the middle of the series, there is a substantial loss of power of all test statistics.

In the case of lack of cross-section dependence, series with a length of more than 30 observations in the T dimension can be used with a reasonably good expected power of the tests, even in panels with small N dimension.

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