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A Note on the Power of Panel Cointegration Tests - An Application to Health Care Expenditure and GDP

Giorgia Marini*

Sapienza University of Rome, Italy

Abstract

This paper enlarges on Gutierrez's results on the power of panel cointegration tests. By a comparison of power of panel cointegration tests, we show how the choice of most powerful test depends on the values of the sample statistics. Country-by-country and panel stationarity and cointegration tests are performed on a panel of 20 OECD countries over the period 1971-2004. Residual-based tests and a cointegration rank test in the system of health care expenditure and GDP are used to test cointegration. Asymptotic normal distribution of these tests allows a straightforward comparison for some values of the sample statistics, residual-based and rank tests are not directly comparable as the power of the residual-based tests oscillates; for other values of the sample statistics, the rank test is more powerful than the residual-based tests. This suggests that a clear-cut conclusion on the most powerful test cannot be reached a priori.

Keywords: Panel data; Panel stationarity tests; Panel cointegration tests; Power of tests

Introduction

Since Newhouse [1] seminal paper, research interest has shifted from identifying the proper determinants of health care expenditure [2-5], to checking whether health care is a luxury good [5-11], and more recently to solving the issue of cointegration between health care expenditure and GDP [5,12-21].

The main reason for this change of interests is the extended use of panel data starting from the 1990s [2,3,13]. Advantages and concerns relative to the use of panel data are discussed in various papers [15,22]. One of the main issues raised by the use of panel data is the problem of cointegration of non-stationary variables. Various papers have tried to solve such issue but have reached inconclusive evidence on the matter both on country-by-country and panel tests [6,12,14,23].

The main goal of this paper is to show how the choice of most powerful test actually depends on the empirical values of the statistics. In order to that, we proceed as follows. We first verify the existence of a cointegrating vector of non-stationary health care expenditure and GDP and then we compare the power of three panel cointegration tests to assess which is the most powerful.

Country-by-country and panel stationarity tests and country-by-country and panel cointegration tests are performed on a panel of 20 OECD countries over the period 1971-2004. Residual-based tests and a cointegration rank test in the system of health care expenditure and GDP are used to test cointegration. Asymptotic normal distribution of these tests allows a straightforward comparison. For some values of the sample statistics, residual-based tests and the cointegration rank test are not directly comparable as the power of the residual-based tests oscillates; for other values of the sample statistics, the residual-based tests and the cointegration rank test are directly comparable and the rank test is more powerful than the residual-based tests.

Data Description

Health care expenditure (HE) and GDP are measured in national currencies and expressed in 2000 prices (deflated by GDP deflator). Both variables are taken from the OECD Health Dataset [24]. The starting dataset contains a list of 30 OECD countries with annual data covering the period 1960-2005. Due to missing data, Czech Republic, France, Greece, Hungary, Italy, Korea, Mexico, Poland, Slovak Republic and Turkey have been excluded and the remaining unbalanced panel dataset has a total of N=20 countries. The total number of observations is T=34 years. Both variables are expressed in logarithm and per capita. As graphical analysis for HE and GDP shows that both series contain a linear trend, [1]this characteristic is incorporated both into the model specification and into the tests. Description of the model specification and tests is provided in various papers [15,22,25-31]. Therefore, only results for unit root, stationary and cointegration tests are presented.

Results on Stationarity and Cointegration Tests

Results for country-by-country unit root test (labelled ADF test) and panel unit root test [30] are presented in Table 1.

For HE the unit root hypothesis is only rejected for Germany and Portugal on the 1%, 5% and 10% level, for Australia and Switzerland on the 5% and 10% level, and for Belgium on the 10% level. For GDP the unit root hypothesis can be rejected for three countries (Austria, Belgium and USA) on the 5% and 10% level, and for three countries (Denmark, Finland and Switzerland) on the 10% level. The panel results fail to reject the *I(1)* hypothesis for both HE and GDP. In order to check for possible multicollinearity, a country-by-country stationarity test [32] and a panel stationarity test [27], are also performed and reported in Table 2.

For HE the stationarity hypothesis is rejected for six countries (Australia, Austria, Luxembourg, Portugal, Spain, and Switzerland) on the 1%, 5% and 10% level, for five countries (Canada, Denmark, the Netherlands, Sweden and UK) on the 1% and 5% level, and for the

[1]The graphical analysis for HE and GDP has not been included in the paper due to brevity.

***Corresponding author:** Giorgia Marini, Department of Law, Philosophy and Economic Studies, Sapienza University of Rome, Piazzale Aldo Moro 5, I-00185 Rome, Italy, Tel: +39 06 49910600; Fax: +39 06 49910648; E-mail: giorgia.marini@uniroma1.it

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	HE		GDP	
	Lags	ADF	Lags	ADF
Australia	1	-3.772	0	-1.908
Austria	0	-2.079	0	-3.913
Belgium	0	-3.564	0	-4.109
Canada	1	-2.343	1	-2.966
Denmark	0	-2.246	0	-2.624
Finland	1	-1.957	1	-3.259
Germany	0	-4.327	0	-3.534
Iceland	1	-2.127	1	-2.562
Ireland	1	-1.231	2	-1.589
Japan	1	-2.016	1	-1.031
Luxembourg	2	-2.171	1	-2.278
Netherlands	1	-2.21	1	-2.514
New Zealand	1	-2.123	1	-2.115
Norway	1	-3.136	1	-3.078
Portugal	1	-4.558	1	-3.096
Spain	1	-2.395	1	-3.054
Sweden	1	-2.119	1	-2.736
Switzerland	1	-4.093	1	-3.394
UK	1	-2.103	1	-3.174
USA	1	-1.79	1	-4.273
IPS panel test	-0.312		-1.548	

Note: The maximum lag order for the ADF test (8 lags) is by default calculated from the sample size, using a rule provided by Schwert (1989). The 1%, 5% and 10% critical values are -4.316, -3.572 and -3.223 for the country-by-country test and -2.326, -1.645 and -1.282 for the panel test.

Table 1: Country-by-country and panel unit root tests.

rest on the 1% level. For GDP the stationarity hypothesis cannot be rejected for Ireland, while it is rejected for nine countries (Belgium, Canada, Denmark, Finland, Portugal, Sweden, Switzerland, UK and USA) on the 1%, 5% and 10% level, for four countries (Luxembourg, New Zealand, Norway, and Spain) on the 1% and 5% level, and for the rest on the 1% level. The panel results reject the hypothesis of stationary series for both HE and GDP.

Results relative to country-by-country tests of no cointegration and panel tests of no cointegration (labelled Engle-Granger procedure and IPS test for homogeneous panels and LLC test by [29] for heterogeneous panels, respectively) and country-by-country tests of cointegration and panel tests of cointegration [28,33-35], are presented in Tables 3 and 4, respectively[2] .

From Table 3, the hypothesis of no cointegration is rejected for ten countries on the 1%, 5% and 10% level, for USA on the 1% and 5% level, and for nine countries on the 1% level. The panel results fail to reject the no cointegration hypothesis.

From Table 4, the hypothesis of cointegration cannot be rejected for all countries except Denmark, Japan, New Zealand and Sweden. The cointegrating rank is determined by the sequential likelihood ratio trace test procedure. Using tests at the 5% level, a rank $r=1$ is found for 16 countries, indicating that HE and GDP are cointegrated. For the remaining four countries the selected rank is $r=0$, which indicate that HE and GDP are not cointegrated for these countries. For the panel rank test the hypothesis that the largest rank in the panel is $r=0$ is rejected, but the hypothesis of a largest rank $r=1$ cannot be rejected.

According to the results in Tables 3 and 4, HE and GDP are cointegrated around linear trends for the sample of OECD countries.

[2]We chose the IPS test by [30] and the LLC test by [29] instead of more recent test by [18] because both IPS and LLC tests are constructed as the panel ECM test statistics by pooling across the cross-sectional dimension.

Power of the Panel Tests of Cointegration

We assume that the estimated values of the three panel tests of co-integration reported that at the bottom of Tables 3 and 4 (IPS, LLC and LLL tests) are the true values of the statistics associated to the data generating process (DGP). The fact that all tests are normally distributed allows comparisons.

We use the sampsi STATA command to draw the power function of the three tests. This command estimates the required power of a test comparing the characteristics of the DGP and the sample. Therefore, for each panel test of cointegration sampsi command tests whether the value of the sample statistics is equal to the value of the statistics associated to the DGP, given the level of significance of the test ($\alpha=0.05$), the size of the population and sample, and the standard deviation.

When the value of the sample statistics is equal to the value of the statistics associated to the DGP, the test has the minimum power of 0.05. For values of the sample statistics different from the value of the statistics associated to the DGP, power of the test increases up to maximum power of 1.

Power of the three tests is represented in Figure 1. The sample statistics takes values between -8.1 and 2.5. Panel tests are directly comparable only for certain values of the statistics. For values between -7.3 and -5.1 the residual-based tests and the rank test are not directly comparable as the power of residual-based tests oscillates. For values between -7.3 and -6.1, the IPS test is more powerful than the LLC test, and *vice versa* for values between -6.1 and -5.1. Over the interval -5.0 and -3.75, power is not defined, while between -3.75 and -3 only the residual-based IPS test and the rank LLL test are directly comparable: the latter is more powerful than the former.

	HCE	GDP
	KPSS	KPSS
Australia	0.101	0.188
Austria	0.079	0.147
Belgium	0.157	0.092
Canada	0.144	0.090
Denmark	0.125	0.112
Finland	0.195	0.103
Germany	0.164	0.173
Iceland	0.178	0.161
Ireland	0.160	0.225
Japan	0.194	0.195
Luxembourg	0.085	0.146
Netherlands	0.132	0.148
New	0.161	0.135
New Zealand	0.157	0.132
Portugal	0.097	0.091
Spain	0.065	0.142
Sweden	0.129	0.072
Switzerland	0.114	0.083
UK	0.127	0.113
USA	0.173	0.041
Hadri panel test	11.442	13.621

Note: Since the KPSS test has approximately correct size except when T is small and l is large [32], we exclude the case $l=9$. Following [14], we set lag length l equal to integer $[4(T/100)^{1/4}]$. The 1%, 5% and 10% critical values are 0.216, 0.146 and 0.119 for the country-by-country test and -2.326, -1.645 and -1.282 for the [27] test. Serial dependence in the disturbances is taken into account in the [27] test using a Newey-West estimator of the long run variance.

Table 2: Country-by-country and panel stationary tests.

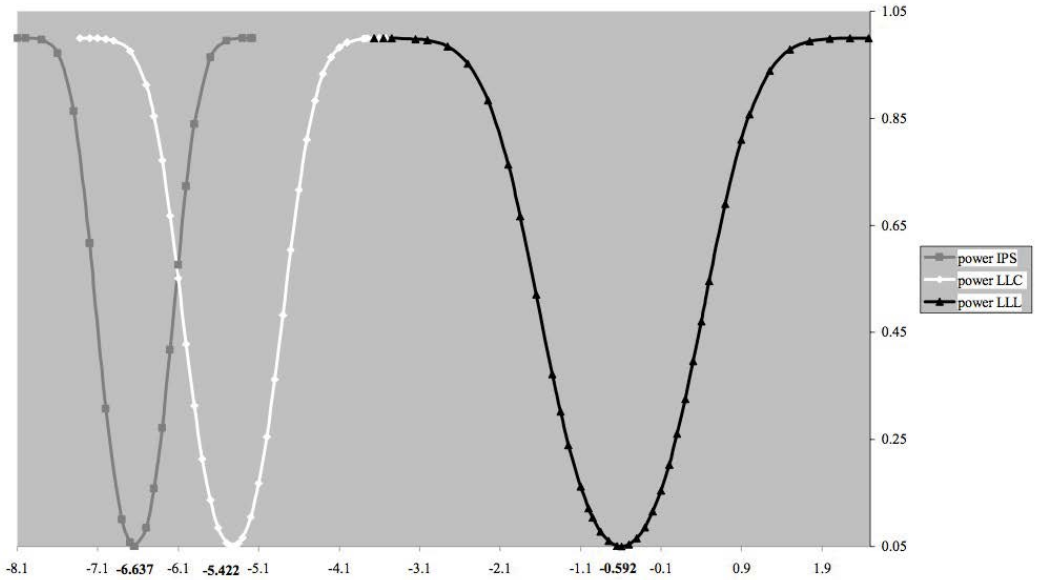

Figure 1: Power of IPS, LLC and LLL tests.

	Lags	Engle-Granger Procedure
Australia	1	-4.137
Austria	0	-2.155
Belgium	0	-2.647
Canada	1	-3.009
Denmark	0	-2.494
Finland	1	-3.012
Germany	0	-4.052
Iceland	0	-3.585
Ireland	1	-2.925
Japan	1	-2.354
Luxembourg	0	-1.829
Netherlands	1	-3.513
New Zealand	1	-2.907
Norway	0	-4.18
Portugal	0	-3.616
Spain	2	-3.888
Sweden	1	-2.321
Switzerland	1	-3.885
UK	1	-3.819
USA	1	-3.372
IPS test for homogeneous panels	-5.422	
LLC test for heterogeneous panels	-6.637	

Note: The 1%, 5% and 10% critical values are -4.150, -3.500 and -3.180 for the country-by-country test and -2.326, -1.645 and -1.282 for the panel tests.

Table 3: Country-by-country and panel tests of no cointegration.

Trace statistics				
	Lags	*h=0*	*h=1*	Rank *r*
Australia	1	25.162	0.27	1
Austria	1	51.729	1.465	1
Belgium	1	91.262	3.84	1
Canada	2	16.164	0.225	1
Denmark	1	10.171	0.068	0
Finland	1	50.055	0.79	1
Germany	1	77.617	0.316	1
Iceland	1	68.978	0.154	1
Ireland	1	52.91	0.006	1
Japan	1	88.056	5.576	0
Luxembourg	1	22.148	1.016	1
Netherlands	1	51.992	0.293	1
New Zealand	1	0.347	0.014	0
Norway	1	113.989	1.367	1
Portugal	1	65.78	0.737	1
Spain	1	28.053	0.024	1
Sweden	1	8.59	0.031	0
Switzerland	1	17.122	0.467	1
UK	3	24.41	3.508	1
USA	1	48.932	0.193	1
LLL panel test	54.604		-0.592	

Note: Critical values for the trace test are tabulated in [33] and are 15.197 and 3.962 for testing *h=0* and *h=1*, respectively. The 1%, 5% and 10% critical values are for the panel tests 2.326, 1.645 and 1.282.

Table 4: Country-by-country and panel tests of cointegration.

Conclusion

This paper offers an alternative way to compare power of panel tests of cointegration based on the comparison between values of the sample statistics and statistics associated to the DGP. The choice of the most powerful test depends on the values of the sample statistics. Both residual-based tests and a cointegration rank test are asymptotically normally distributed, which allows a straightforward comparison. For some values of the statistics, the residual-based LLC test is more powerful than the IPS test, and *vice versa* for other values. For those value of the statistics such that residual-based test and the rank test is comparable, LLL test is more powerful than residual-based LLC test. Therefore, the choice of the most powerful test is not only an empirical matter but also an open issue without a clear-cut choice.

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