Convergence in Health Care Expenditure of 14 EU Countries: New Evidence from Non-linear Panel Unit Root Test

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Convergence in Health Care Expenditure of 14 EU Countries: New Evidence from Non-linear Panel Unit Root Test

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Abstract

This paper attempts to examine the convergence hypothesis of health care expenditure per capita of 14 European Union (EU) countries during the 1975–2008 period by applying the Cerrato et al., (2009) nonlinear panel unit root test. Although the conventional linear panel unit root tests reject the null uniformly, the Cerrato et al., (2009) test shows evidence that one cannot reject the null hypothesis of unit root for health care expenditures of each country relative to the EU average, after taking nonlinearity into account. Our results are robust using different reference countries. The empirical findings imply that the exisitng " EU health policy reforms" and " European law on health care provision" may not able to encourage greater health care convergence in EU.

Keywords: Health care expenditures, Nonlinear Panel Unit Root Tests, EU Health Reform
JEL Classification Codes: I10, I18.

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Introduction

Without doubt, health care expenditure has been rising drastically in the European Union (EU). There also exists large gap within EU; for instance, the health care expenditure per capita of Norway ($5352) is almost double of Greece's figure ($2724) in 2009. According to the OECD health statistics, the average annual health expenditure per capita growth rate from 2000-2009 is 6.9 per cent for Greece but only 0.7 per cent for Luxembourg[1]. Is this evidence of catch-up effect that relatively poorer countries' per capita health expenditure will converge to the EU average?

The concept of convergence is defined as 'the result of a process in which the structures of different industrial societies come increasingly to resemble each other' (Jary and Jary, 1991, p.121). The theoretical basis of economic convergence comes from the neoclassical growth model, that in the long-run, all countries will converge to a common (conditional) equilibrium level of income per head - the steady state - provided that trade is free, technologies are common across states, and countries share similar preferences. One of the implications is that the growth rates of income per head across countries are inversely related to initial conditions. This Solow (1956) model predicts that countries will converge to their steady states in a conditional sense.

In fact, there is evidence of economic convergence within EU. Katlia (2004), for example, finds that the accession countries catch up with the EU during two periods, namely, 1960-1973 oil crisis (due to increased trading activity and high investment rate from the neighbor countries), and mid-1980's to mid-1990's. Abai et al. (2007) find an accelerating income convergence in the EU, because with increasing financial integration, capital is flowing from the rich to the poor countries. Dogan and Saracoglu (2007) use five panel unit root tests to investigate income convergence in the EU. Relative to the EU average, they find some evidence that the candidate countries catch up with the existing members. As a matter of fact, when Ben-David (1996) examines the relation between income convergence and international trade; he finds that the mere prospect of joining the EU has already positively influenced the economic development of the accession candidates. Since disposable ncome is the most important determining factor of health expenditure; can the income convergence be translated into health expenditure convergence? The findings of existing literature are rather mixed with regard to health care expenditure convergence in the EU.

Some prior studies show evidence that health care expenditures converge among EU member states (Nixon, 1999). Hitiris and Nixon (2000) examine the σ and β convergence in health care per capita spending of the EU members before the latest expansion (EU-15). By using the life expectancy and Infant mortality rate as explanatory variables, Hitiris and Nixon (2000) identify 1960-1995 and 1980-1995 as periods for σ and β convergence, respectively. Hofmarcher, Rohrling and Riedel (2004) recognize that there is a wide gap in the average health expenditure levels before the full EU integration. Evidence tends not to support health care per capita expenditure convergence until mid-1990s. But the EU membership was extended to more countries in 1995; and in May 2004 ten of the then EU accession countries became full members of the EU. The income gap is supposed to be narrower in the enlarged EU as the new members' GDP per capita converge to the EU average. Narayan (2007) examines whether or not per capita health expenditures of OECD countries converge to the per capita health expenditures of the USA over the period 1960–2000; he finds evidence of convergence using linear univariate and panel tests. Schmitt and Starke (2011) examine 'conditional' convergence of various types of social expenditures in 21 OECD countries by error correction model. She finds strong evidence of conditional convergence of various states of welfare including health expenditure per capita.

Using linear panel unit root test, Maddala and Wu (1999), however, conclude that the time series of health expenditure on average contains a unit root for the OECD countries. Wang (2009) examines the extent of health care expenditure (and its nine components) convergence among the 52 states in the U.S. The convergence extent and speed is moderate; and the performances of individual components are diverse. He ascribes hospital care to the bulk of cross-state convergence in total expenditure, while prescription drugs spending is the most important diverging factor. Aslan (2008) investigates the OECD per capita health care spending using the Lima and Resende (2007) persistence method. Regional inequality is evaluated in terms of panel data unit root tests advanced by Im, Pesaran and Shin (2003). The evidence illustrates that one cannot

[1] The Slovak Republic figure was 10.9 per cent.

reject the null hypothesis of unit root for the (log) of the ratio of health care expenditures of each country relative to a reference unit except average of per capita health expenditures. Recent studies on intra-provincial evidence also suggest substantial disparities in health service in China using linear LM panel unit root test (Chou , 2007). Kerem et al. (2008) use the average health expeniture -GDP ratio and health expenditure per capita of EU-12 countries to test for β-, σ- and γ-convergence. They find that economic integration does not lead to an automatic homogenization of health care expenditure and health policy in the region. Based on the social citizenship development theory, Montanari and Nelson (2013) examine convergence in various health care dimension (health expenditure is one of them) of different EU countries. For countries not particularly affected by the recession and budgetory restrictions, they find no convergence of any health dimension except the increasing share of private financing. Panopoulou and Pantelidis (2011) provide a synthesis of the current literature. They do not find evidence of convergence among 17 OECD countries. The full panel can diverge but groups of countries can converge to different equilibria.

There is one common feature of these studies – using linear unit root test. Considering the fact that the EU has gone through drastic integration process, structural change can plausibly cause non-linearity in health care expenditure. In our paper, we fill the gap in current literature of health care convergence by using nonlinear panel unit root test (Cerrato et al. (2009)). We find weak evidence of this convergence hypothesis among 14 EU members.

Determinants of Health Care Expenditure

What are the important factors affecting spatial variation of health care expenditure per capita? Numerous studies find evidence that income (GDP as a proxy) is the most significant factor explaining variations in health care expenditure, and therefore the path of health expenditure should mimic that of economic growth path. Can the shrinking income gap translate into more equality in health care expenditure?

One of the most important papers is Newhouse (1977). The author examined the per capita health expenditure of 13 OECD countries. Using cross-section regression, he found that 92% variation of health expenditure can be explained by GDP variation. His finding is consistent with the general belief that healthcare is a luxury good. The 2012 Aging Report by the Directorate-General for Economic and Financial Affairs of the European Commission also finds a strong GDP per capita effect on the growth of per capita public health expenditure among the EU member countries. Along this line of research, economists explored the integration and cointergration properties between disposbale income and health expenditure. In early 1990's, most of the studies were based on country-by-country study. McCoskey and Selden (1998) was one of the early studies using panel unit root test. Jewell et al. (2008) re-examined the income-health expenditure link by utilizing 20 OECD country data. Recognizing the key drawback of unit root test, they utilized the panel LM unit root test to account for heterogeneous structural break. Batalgi and Moscone (2010) examine the long-run correlation of (annual) health care expenditure and income using a panel of 20 OECD countries, adjusting for both cross-section dependence and unobserved heterogeneity. They take advantage of the nonstationarity and cointegration properties of the health care expenditure and income series. Although the income elasticity is less than those of previous studies, Batalgi and Moscone (2010) reconfirm the positive relation.

Obviously, income is not the only health expenditure determinant. While confirming the importance of GDP, Hitiris and Posnett (1992) attempted to examine the non-income linkage. Their choice of variables included demographic structure, epidemiological needs and health financing; although these factors are not significant. Di Matteo and Di Matteo (1998) examined the balance between public and private health expenditure in the Canadian system. The key determinants were per capita income, government transfer variables, the share of individual income held by the top quintile of the income distribution and long-term economic forces. Applying recursive panel estimation procedure, Herwartz and Theilen (2003) found evidence for cross country homogeneity during the period 1961-1979. However, country-specific factors dominated in the last two decades, indicating evidence of divergence in health care systems. Bilgel and Tran (2013) utlized panel data on GDP, the relative price of health care, the share of publicly funded health expenditure, the share of senior population and the life expectancy at birth to investigate the determinants of Canadian provincial health expenditures over a 28 year period. Estimation results from Generalized Instrumental Variables (GIV) and Generalized Method of Moments (GMM) suggested that long-run income elasticity of health care expenditure was significanly lower than one, contrary to the general perception that health care being a luxury good.

Increasing international cooperation is another reason for potential convergence in health care spending. Developments in the last two decades encouraged more joint actions among the EU member states to promote health protection, subsidize medical and health care policy research, establish international information systems and promote health care expenditure equality[2]. The 1991 Maastricht Treaty and the 1997 Treaty of Amsterdam empowered the European Parliament to promote larger scope of international cooperation and provided new direction of community action toward illness and sickness. The treaty of Lisbon, which entered into force on 1, December 2009, encouraged the EU members to go through a process of greater political, social and economic integration. This mechanism generated forces for convergence at the level of public health care among EU member states. The Commission of the European Communities (1994) argued that increasing integration among the EU citizens and professionals may lead member states to seek 'long-term solutions in similar directions' (ibid, p.40). Abel-Smith et al. (1995) and McKee et al. (1996) both argued that EU health policy reforms and European law on health care provision may lead to greater convergence in health care expenditure across EU. Meanwhile, a number of organizations, for example the European Regional Development Fund (ERDF) and the European social fund, have initiated projects to shore up international cooperation.

Research Methodology

This section is devoted to describing various unit root tests. We start with the traditional Dickey-Fuller test, followed by the Im, Pesaran and Shin (2003) linear panel unit root statistic. Finally, the Cerrato et al. (2009) nonlinear panel unit root test will be introduced.

Conventional Unit Root Test

We first employ annual health care expenditure per capita data, to construct health care expenditure series relative to the average of other EU members, such that the series of interest for country i at time t is:

$$y_{i,t} = \ln(\frac{g_{i,t}}{\overline{g}_t})$$

where $g_{i,t}$ is the health care expenditure per capita of country i, and $\overline{g}_t$ [3]is the average health care expenditure per capita in EU other than the country being considered. To check for the existence of a unit root process, one can perform the Dickey Fuller test. However, it is well-documented in the literature that, when a series is stationary but close to unit root, the Dickey Fuller test has relatively low power. One plausible solution is increasing the sample size, which can be a challenge for macroeconomic series. In fact, only annual data are available for the EU health care expenditure. However, panel unit root test can extract more information by combining temporal and spatial dimensions to make it a more powerful procedure; implicitly increasing the sample size.

In the past decade or so, there has been an expanding literature on the presence of a unit root in a panel data. Baltagi and Kao (2000), and Hurlin and Mignon (2004) are surveys of recent developments. Breitung (2000), for instance, assumes that the panel data are generated by a deterministic trend and an unobservable autoregressive process. He proposes a linear transformation of the data, and constructs a statistic for testing a unit root process[4]. Bai and Ng (2004) use the factor structure of panels to examine the nature of stationarity. A time series with a factor structure can be nonstationary either due to the common factors or the idiosyncratic error; they come up with a test that can be applied to these two components separately. The Bai and Ng (2004) approach helps understand nonstationarity on a series by series basis, and from the viewpoint of a panel. Harris, Leybourne, and McCabe (2004) are concerned about the low power of Dickey Fuller, and Bai

[2] For a comparative study of the EU member states' health care system comparison, see Jakubowski and Busse (1998).

[3] In the first draft, $\overline{g}_t$ was the average of all 14 EU countries. We received comments from anonymous reviewers who suggested excluding the country under consideration. The results remain the same.

[4] Perron and Philips (2006), however, contend that the power of Breitung (2000) test is slower than claimed.

and Ng (2004) tests. They construct a new stationarity test that captures arbitrary unknown cross-sectional disparity, which allows flexible choice of stationary dynamics (including ARMA) and contemporaneous effect. The statistic is the sum of lag-k studentized autocovariance across panels that renders the temporal dynamic specification unnecessary.

Chang (2004) develops a bootstrap methodology testing nonstationarity in a cross-sectionally dependent panel. In his setup, each panel unit is characterized by a general linear process which is approximated by a finite autoregressive integrated process increasing with time. He, then, applies the bootstrap method to derive the critical values, limit distribution and asymptotic properties of the unit root process. Choi and Chue (2006) propose a subsampling test that includes panel unit root and cointegration tests as special cases. The series of interest can be cross-sectionally correlated and cointegrated. The panel data model is linear, semiparametric and a mixture process. One of the advantages of this subsampling procedure is that it can be applied to certain types of discontinuous distribution.

Based on the mean of the individual ADF t-statistics of each member in the panel, Im, Pesaran and Shin (2003) propose the LM - bar statistic (IPS test) for testing unit root in dynamic heterogeneous panels. In particular, they develop three LM-bar statistics when a) the errors are $i.i.d$; b) the errors are serially correlated and heterogenous across groups; c) the panels contain the same common trend[5]. Assume that the relative health care spending follows an autoregressive process with individual specific factor:

$$y_{i,t} = (1-\phi_i)\mu_i + \phi_i y_{i,t-1} + \varepsilon_{i,t}, i = 1,..., N; t = 1,...,T, \tag{1}$$

Rewriting it in first difference form, the null hypothesis is

$$H_0 : \beta_i = 0 \forall i = 1,..., N.$$

against the alternative:

$$H_0 : \beta_i < 0 \forall i = 1,..., N_1 . \beta_i = 0 \forall i = N_1 + 1,..., N.$$

where N_1 is the number of stationary series[6] and $\beta_i = -(1-\phi_i)$.

The alternative is more general that β_i can differ across groups; and it allows some individual series to have unit roots. Im, Pesaran and Shin (2003) proceed to derive the LM-bar statistic for the series with serially correlated error:

$$y_{i,t} = \mu_i \phi_i(1) + \sum_{j=1}^{p_i+1} \phi_{ij} y_{i,t-j} + \varepsilon_{i,t} \tag{2}$$

The first difference form is:

$$\Delta y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \sum_{j=1}^{p_i} \rho_{ij} y_{i,t-j} + \varepsilon_{i,t}$$

Where p_i is the number of lags, $\phi_i(1) = 1 - \sum_{j=1}^{p_i+1} \phi_{ij}$, $\alpha_i = \mu_i \phi_i(1)$, $\beta_i = -\phi_i(1)$, $\rho_{ij} = -\sum_{h=j+1}^{p_i+1} \phi_{ih}$

Notice that the Im, Pesaran and Shin (2003) do not impose restriction on the mean equation; each panel is heterogeneous in the sense that it allows different individual specific factor[7]. In matrix form,

$$\mathbf{\Delta y}_i = \beta_i \mathbf{y}_{i,-1} + \mathbf{Q}_i \gamma_i + \varepsilon_i \tag{3}$$

where $\mathbf{Q}_i = (\tau_T, \Delta\mathbf{y}_{i,-1}, \Delta\mathbf{y}_{i,-2},...., \Delta\mathbf{y}_{i,-p})$ and $\gamma_i = (\alpha_i, \rho_{i1,}\rho_{i2,}..., \rho_{ip_i,})'$

Nonetheless, there is no reason to stick to a linear mean process. Cerrato, De Peretti and Sarantis (2009) augment the Im, Pesaran and Shin (2003) heterogenous panel unit root methodology with the

[5] Im, Pesaran and Shin (2003) contend that the finite sample properties of the third scenario are better than that of Levin and Lin (1993).

[6] Im, Pesaran and Shin (2003) contend that the LM-bar statistic requires less strict convergence criteria ($\frac{N_1}{N} \to k$) than that of Levin and Lih(1993).

[7] For the case of panel with unobservable common time specific components, see section 4.1 of Im, Pesaran and Shin (2003).

Kapetanios *et al (2003)* approach, which is essentially a nonlinear panel unit root test.

Non-linear Panel Unit Root Test

This paper fills the literature gap by allowing the existence of nonlinearity in the growth dynamics of health expenditure. The health expenditure growth path of the EU member states may follow nonlinear dynamics. The equalization of prices of goods and factors of production follows a non-linear dynamics as shown by many researchers (e.g. Michael and Peel, 1997). These models suggest that exchange rate adjustment follows a non-linear path due to the existence of " bands of inaction" in the exchange rate adjustment process. Within the bands, arbitrage of tradable good is not profitable because transaction cost (i.e. the sum of transportation cost, cost of trade barriers, and distribution cost) is greater than the price difference. The existence of " bands of inaction" may come from market frictions such as trade protectionism or transaction costs. Similarly, health care expenditure per capita may converge due to structural change, namely policy shift after the integration of Europe.

In addition, Lau (2010) finds evidence of provincial income divergence using Cerrato's NCADF test for the period 1952-2005. His finding for Chinese provincial growth dynamics suggests further study on conditional convergence, whereas heterogeneous factor difference may hinder beta convergence across provinces. These factors include inflation rate, infrastructure, human capital, degree of openness, and use of foreign capital among provinces. There is reason to believe that health expenditure for EU members will follow nonlinear path because as we mentioned, health expenditure will follow the dynamic of income path, which is nonlinear in nature.

Therefore, we proceed to use the Exponential Smooth Transition Autoregressive (ESTAR) model to specify the price evolvement dynamics across countries. Cerrato et al. (2009) develop a non-linear panel ADF test under cross-sectional dependence, which is based on the following ESTAR specification:

$$y_{i,t} = \xi_1 y_{i,t-1} + \xi_t^* y_{i,t-1} Z(\theta_i; y_{i,t-d}) + u_{i,t} \quad i = 1,....N, t = 1,....T \tag{4}$$

$$Z(\theta_i; y_{i,t-d}) = 1 - e^{[-\theta_i (y_{i,t-d} - c)^2]} \tag{5}$$

where θ_i is a positive coefficient and c is the equilibrium value of relative expenditure difference between country i and the EU average, due to regional heterogeneous factors. The initial value, $\bar{y}_{i,0}$, is given, and the error term, $u_{i,t}$, has the one-factor structure:

$$u_{i,t} = \gamma_i f_t + \varepsilon_{i,t} \tag{6}$$

$$\{\varepsilon_{i,t}\}_t \sim i.i.d(0, \sigma_i^2)$$

in which f_t is the unobserved common factor, and $\varepsilon_{i,t}$ is the individual-specific (idiosyncratic) error. For simplification purpose, the delay parameter d is set to be equal to one so that equation (4) may be rewritten in first difference form:

$$\Delta y_{i,t} = \phi_i y_{i,t-1} + \xi_i^* y_{i,t-1}[1 - e^{-\theta_i (y_{i,t-d} - c)^2}] + \gamma_i f_t + \varepsilon_{i,t} \tag{7}$$

where $\phi_i = -(1 - \xi_i)$. Assuming that $\phi_i = 0$ and normalizing c to zero,

$$\Delta y_{i,t} = \xi_i^* y_{i,t-1}[1 - e^{(-\theta_i y_{i,t-1}^2)}] + \gamma_i f_t + \varepsilon_{i,t} \tag{8}$$

The null hypothesis of non-stationarity is $H_0 : \theta_i = 0 \quad \forall i = 1,....N_1,$ against the alternative of $H_A : \theta_i > 0 \quad \forall i = 1,....N_1,$: for i = 1,2,... , and for $\forall i = N_1 + 1,....N.$ Notice that the alternative allows some series to have unit roots.

Because ξ_i^* is not identified under the null, it is not feasible to test the null hypothesis directly. Thus, Cerrato et al. (2009) reparameterize equation (8) by first-order Taylor series approximation and obtain the auxiliary regression

$$\Delta y_{i,t} = a_i + \delta y_{i,t-1}^3 + \gamma_i f_t + \varepsilon_{i,t} \tag{9}$$

Cerrato et al. (2009) further prove that the common factor can be approximated by a linear function of mean lagged values of $y_{i,t}$.

$$f_t \approx \frac{1}{\bar{\gamma}_\omega} \Delta \bar{y}_{\omega,t} + \frac{b}{\bar{\gamma}_\omega} \bar{y}_{\omega,t-1}^3$$

where $\Delta \bar{y}_{\omega,t} = \sum_{i=1}^{N} \omega_i \Delta y_{i,t}$, $\bar{y}_{\omega,t-1}^3 = \sum_{i=1}^{N} \omega_i y_{i,t-1}^3$, $\bar{\gamma}_\omega = \sum_{i=1}^{N} \omega_i \gamma_i$

Therefore, it follows that equation (9) can be written as the following non-linear cross-sectionally augmented DF (NCADF) regression[8]:

$$\Delta \bar{y}_{i,t} = a_i + \delta y_{i,t-1}^3 + c_i \Delta \bar{y}_t + d_i \bar{y}_{t-1}^3 + e_{i,t} \tag{10}$$

Given the framework above, the authors develop a unit root test in the heterogeneous panel model based on equation (10). Extending the idea of $\bar{y}_{i,t}$, Kapetanios, Shin and Snell (2003) derive t-statistics on $\hat{\delta}$, which are denoted by:

$$t_{i,NL}(N,T) = \frac{\hat{\delta}_i}{s.e.(\hat{\delta}_i)}$$

where $\hat{\delta}_i$ is the OLS estimate of δ_i, and $s.e.(\hat{\delta}_i)$ is its associated standard error. Following Pesaran (2007), the t-statistic in equation (10) can be used to construct a panel unit root test by averaging the individual test statistics:

$$\bar{t}_{i,NL}(N,T) = \frac{1}{N} \sum_{i=1}^{N} t_{i,NL}(N,T)$$

This is a non-linear cross-sectionally augmented version of the IPS test (NCIPS). Consequently, Pesaran (2007) calculates critical values of both individual and panel NCADF tests for varying cross section and time dimensions. Difference in health expenditure among EU states is possible due to either time lead effect or policy consensus, and this will also form the so-called " bands of inaction" in the health expenditure adjustment process among EU members.

Data and Results

Conventional Linear Unit Root Test

Our empirical analysis is based on 14 EU countries, namely Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Spain, Sweden, and the U.K. This sample of countries is dictated by data availability. All time series data are annual and have been PPP-adjusted into US

[8] For a more general case where the errors are serially correlated, equation (9) is extended to:

$$\Delta y_{i,t} = a_i + \delta y_{i,t-1}^3 + \sum_{h=1}^{h-1} \vartheta_{ih} \Delta y_{i,t-h} + \gamma_i f_t + \varepsilon_{i,t}$$

Dollar for the period 1970–2008. All data are obtained from the OECD health database 2010. Figures 1a and 1b show upward trending of health care expenditure per capita from 1970 to 2008. While most of the countries' health care spendings have been growing linearly, those of Austria, Luxembourg, Netherlands and Ireland seem to be exponential. Spain and Greece are the member countries with lowest per capita spending; Luxembourg and Austria are the highest. There is virtually no change of the ranking except Ireland, which had been the second lowest before 1987 but passed Spain, Italy, U.K. and Sweden in 2005. Hence, by the level of health care expenditure per capita, convergence is not noticeable.

[Figure 1a and 1b insert here]

Figures 2a and 2b show the relative health expenditures of the 14 EU member states. By 2008, Austria and U.K have the highest and lowest per capita health care expenditure, respectively. Finland, on the other hand, exhibits relatively large temporal variation. One can see that there is apparent convergence among different EU countries toward the mean. The range reduced significantly for Spain, U.K, Sweden and Portugal. The convergence appears to accelerate after mid-1990's, coincident with gradual integration of the EU. Notice that there is a structural break in 1969-1970 for these four countries followed by strongly positive co-movement.

[Figure 2a and 2b insert here]

However, the statistical test of linear unit root test shows weak evidence of such a convergence hypothesis. Table 1 shows the results of univariate unit root tests; we can see that only three countries converge to the EU mean in the long run at the 5% significance level - they are Netherlands, Spain, United Kingdom, and, to a lesser extent, Austria. Table 2 reports the results of Im, Pesaran and Shin (2003), Choi (2001) and Maddala and Wu (1999) linear panel unit root tests[9]. The null hypothesis of unit root is uniformly rejected, suggesting that there is at least one country converging to the EU mean; however these tests fail to indicate which countries are converging to the mean. More importantly, they fail to capture nonlinearity that the test has low power to distinguish between structural change and non-convergence. For instance, by simulating a stationary autoregressive process with a time dummy variable indicating structural change, the Dickey-Fuller and Philips-Perron test fail to reject the null hypothesis. Both statistics are biased toward nonrejection.

[Table 1 and 2 insert here]

Why nonlinearity in health expenditure?

We contend in section 2 that, the national income follows a nonlinear dynamic, since there is strong evidence that health care spending is strongly correlated to income, it is plausible that health care spending can follow nonlinear dynamic. For example, Shelley and Wallace (2011) could not reject the null hypothesis of unit using data since the Great Depression. They argue that prior study failed to correct for non-normality and heteroscedasticity in a nonlinear unit root test. Beyart and Camacho (2008) combined threshold model, panel data unit root and bootstrap standard error. Using 1950-2004 as the sample period, they fail to detect real GDP convergence in the enlarging EU. Chong et al. (2008) applied the nonlinear unit root test of Kapetanios et al. (2003) to test for nonlinear convergence of 12 OECD countries. Only two cases converge in the long run.

To provide a heuristic proof of nonlinearity[10], we proceed to carry out the famous BDS (Brock, Decher, Scheinkman (1987)) test for the log relative expenditure of ten EU countries[11]. The test is performed for series with at least 30 consecutive observations; and these countries are Austria, Belgium, Denmark, Finland, Ireland, Netherlands, Portugal, Spain, Sweden and the United Kingdom. Correlation integral is the

[9] The trend is assumed to have a constant and linear trend.
[10] Our analysis is 'heuristic' since the minimum sample size for BDS statistic to have reasonable performance is 500.
[11] Due to small sample size, the BDS test is limited to ten countries.

core of BDS test; it measures the frequency with which temporal patterns are repeated in the data. The sample correlation integral at embedding dimension n is:

$$C_{n,\varepsilon} = \frac{2}{T_n(T_n-1)} \sum_{n \le s} \sum_{< t \le T} I(x_t^n, x_s^n, \varepsilon) \tag{11}$$

where $x_t^n = (x_{t,} x_{t-1,} ..., x_{t-n+1})$, $T_n = T - n + 1$ and $I(x_t^n, x_s^n, \varepsilon)$ is an indicator function which is equal to one if the absolute distance of two series is bigger than ε and zero otherwise. The BDS statistic is defined as follows:

$$V_{n,\varepsilon} = \sqrt{T}\, \frac{C_{n,\varepsilon} - C_{1,\varepsilon}^n}{s_{n,\varepsilon}} \tag{12}$$

The denominator is the standard deviation of $\sqrt{T}(C_{n,\varepsilon} - C_{1,\varepsilon}^n)$. Under some fair regularity conditions, the asymptotic distribution converges to standard normal. Table 3 reports the nonlinearity test results for these countries. The values of ε and n are set to be 0.7 and 6, respectively. Clearly, all series exhibit nonlinear dynamics, casting doubt on the traditional linear panel data method.

[Table 3 insert here]

Non-linear Panel Unit Root Test Results

Table 4 shows the results for nonlinear panel unit root test. It indicates that three countries - Greece, Sweden and the U.K - converge to the EU mean even after taking nonlinearity into account. The average t-statistic (-1.59) also refutes the conclusion of Im, Pesaran and Shin (2003) test.

[Table 4 insert here]

As a robustness check, we proceed to conduct the nonlinear unit root test by varying the benchmark country. Table 5, 6 and 7 report the results using U.K (lowest per capita health care expnediture), Spain and Austria (highest per capita health care expnediture) as the benchmark countries[12]. Table 5 shows that Greece and Netherlands, individually converge to the EU mean. Using Spain as the reference country, only Austria shows convergence property. If Austria is used as the reference country, France and Netherlands converg to the EU mea. However, all *the average t-statistics still convincingly rejects the* Im, Pesaran and Shin (2003) *result.*

[Table 5, 6 and 7 insert here]

Discussion

In this paper, we examine the convergence hypothesis of the health care expenditures of 14 EU countries. The evidence indicates that one cannot reject the null hypothesis of unit root for the health care expenditures of most EU member states relative to the EU average, even after taking nonlinearity into account. The use of nonlinear unit root test is motivated by both theoretical justification (real income following a nonlinear path) and formal statistical test (BDS test). Although some studies (Nixon, 2000; Hitiris & Nixon, 2001) have claimed to demonstrate a convergence of health care expenditure among EU members, this study asserts that current EU policy may not be able to advance convergence within EU.

What are the possible reasons for nonconvergence of health care expenditure in EU? Spencer and Walshe (2009) find varying degree of adaptations and implementation of both health care policies and strategies throughout 24 EU member states; they argue that this can cause " varying levels of progress in implementation". Cucic (200) suggests that it would take much more than equalizing health care expenditure to synchronize the health care systems throughout the EU. However, it is possible that, because there is

[12] The choice of benchmark countries is dictated by data availability. The panel of 14 EU countries is unbalanced.

substantial variation in EU health care systems and health care financing, that the desired convergence will be a long and complicated process. Leiter and Engelbert (2009) also point to the mobility of the labor market across borders, i.e. the ability of people to cross countries to shop for health care as an interesting phenomenon of convergence. Nonetheless, they found in their study that, over the long term, "countries do not move towards a common mean". With different structure of health care financing in EU countries (e.g., private or public funding), it might be interesting to take a deeper look into the financing structure of each EU member and the different sectors of health care providers.

One of the limitations of this study is the power of the test. The asymptotic properites of nonlinear unit root is still not well established in the literature. In any case, the policy implications of our finding is clear - that the existing EU health policy reforms and European law on health care provision may not able to encourage greater convergence in EU. Further research is encouraged to investigate the determinants affecting health care expenditure differences across countries in EU.

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APPENDIX

Figure. 1a **Health Care Expenditure per capita (US$ PPP adjusted)**

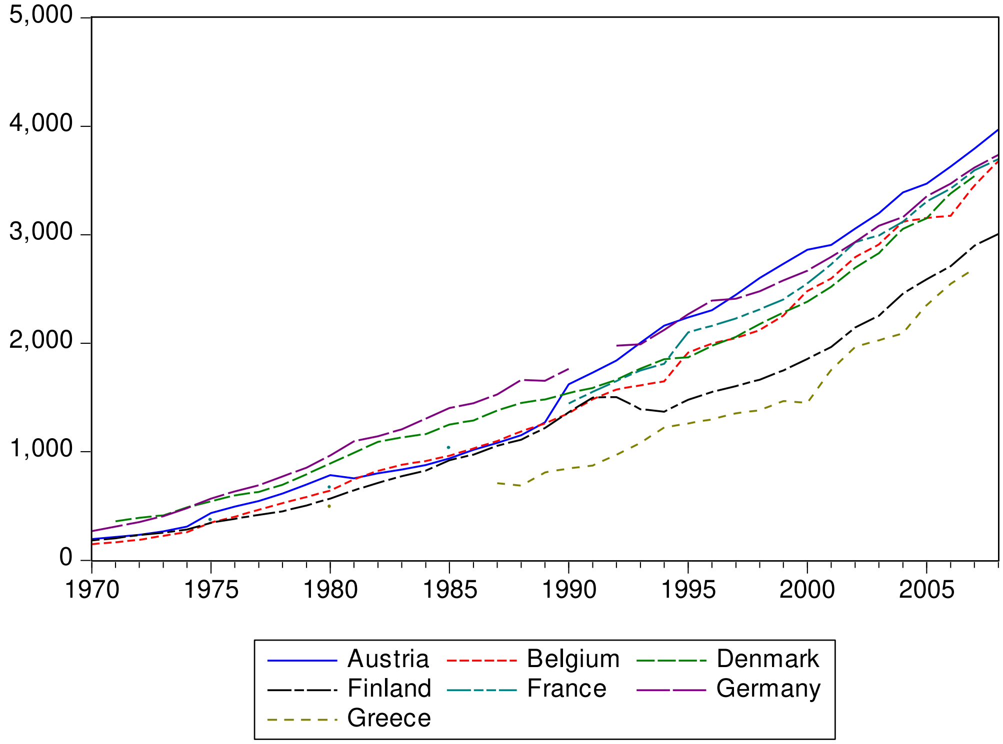

Figure. 1b **Health Care Expenditure per capita (US$ PPP adjusted)**

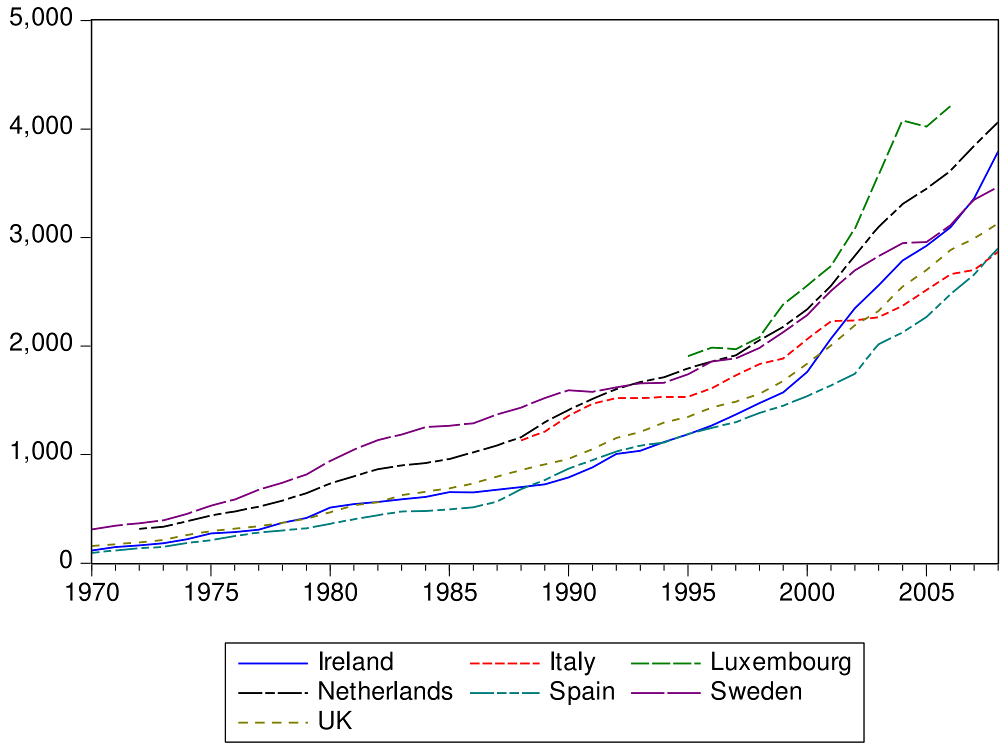

Figure 2a. **Log Health Expenditure Differential from EU Average**

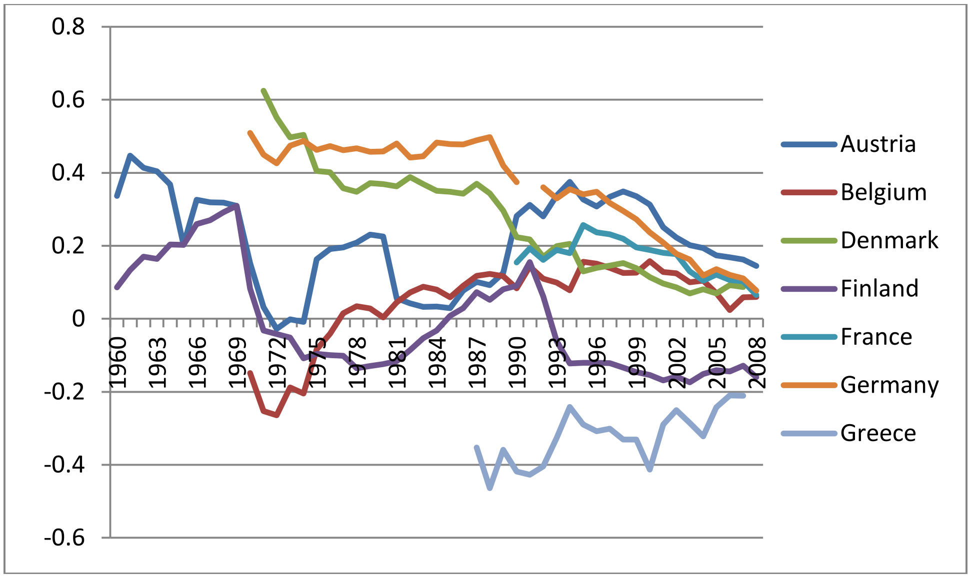

Figure 2b. **Log Health Expenditure Differential from EU Average**

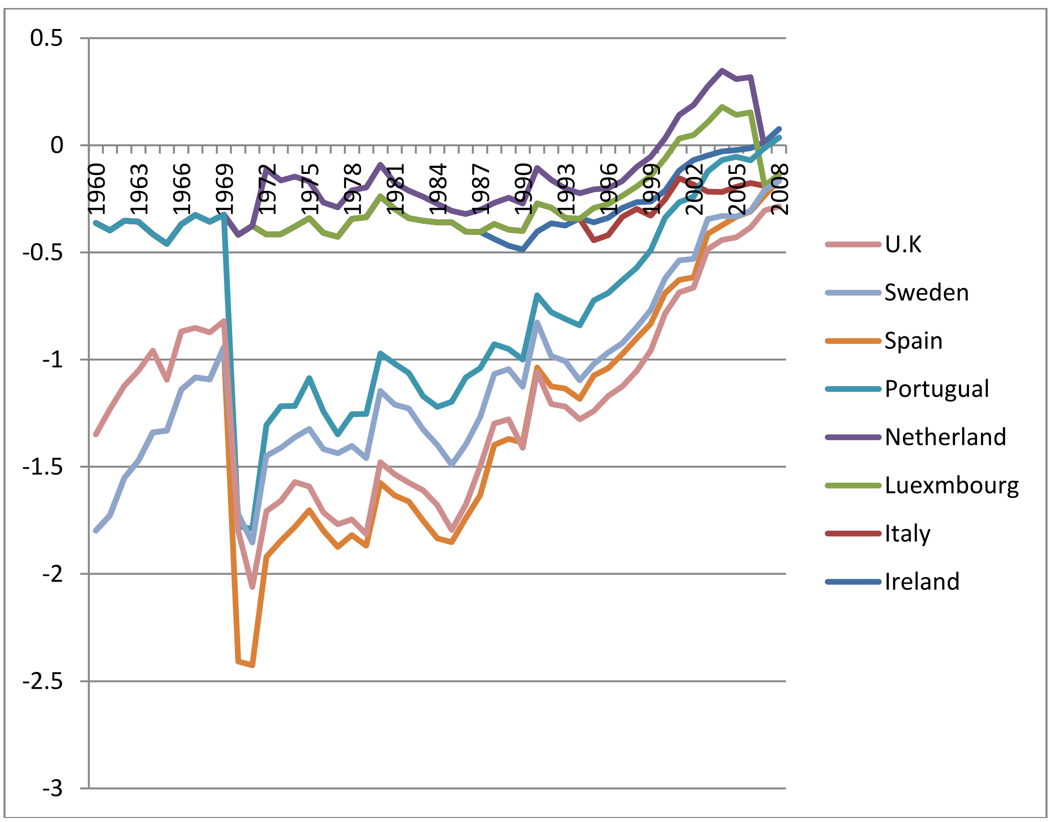

Table 1: Univariate Unit Root Test:

Null Hypothesis: Unit root (individual unit root process)

Series	t-Stat	Prob.	Lag	N
Austria	2.645	0.0915	1	47
Belgium	-1.802	0.3738	0	38
Denmark	-2.461	0.1331	0	36
Finland	-1.8	0.3771	1	47
France	-0.334	0.9014	0	18
Germany	0.82	0.9930	0	36
Greece	-1.767	0.3845	0	20
Ireland	0.671	0.9903	1	48
Italy	-0.488	0.8745	0	20
Luxemburg	0.669	0.982	2	9
Netherlands	-3.22	0.0271	2	34
Portugal	-1.612	0.465	4	32
Spain	-4.25	0	0	48
Sweden	-2.168	0.2203	0	38
United Kingdom	-3.283	0.0213	2	47

Table 2: Linear Panel Unit Root Test:

Method	Statistic	Prob.
Im, Pesaran and Shin (2003) LM-bar	2.36827	0.0089**
Choi (2001) Z-stat	53.9183	0.0023**
Maddala and Wu (1999) ADF-Fisher Chi Square	-2.04624	0.0204**

***1 percent significance
**5 percent significance

Table 3: A Nonlinearity test by the BDS test statistic

		Dimension				
Country		2	3	4	5	6
Austria	BDS Statistic	0.124924	0.212906	0.257188	0.271308	0.270649
	z-statistic	17.72289	18.71077	18.69247	18.63180	18.97932
Belgium	BDS Statistic	0.193919	0.328728	0.416938	0.480369	0.519520
	z-statistic	10.29639	10.76369	11.22616	12.14380	13.31962
Denmark	BDS Statistic	0.184263	0.300988	0.376802	0.423680	0.454622
	z-statistic	20.39401	20.81206	21.72485	23.26582	25.69032
Finland	BDS Statistic	0.146383	0.249426	0.305569	0.329476	0.333942
	z-statistic	16.14890	17.18125	17.54205	18.00839	18.77935
Ireland	BDS Statistic	0.154726	0.238968	0.276226	0.278260	0.247161
	z-statistic	9.492884	9.025660	8.565888	8.090826	7.279910
Netherlands	BDS Statistic	0.131230	0.203714	0.232710	0.238733	0.234856
	z-statistic	8.638550	8.229251	7.695211	7.379740	7.331345
Portugal	BDS Statistic	0.162041	0.275905	0.354044	0.407782	0.445381
	z-statistic	18.72861	19.84527	21.15269	23.11607	25.88230
Spain	BDS Statistic	0.179150	0.299220	0.384258	0.451690	0.509173
	z-statistic	12.55574	12.95718	13.71505	15.17684	17.40113
Sweden	BDS Statistic	0.167996	0.276224	0.350829	0.396661	0.427480
	z-statistic	24.01648	24.37018	25.50081	27.13654	29.74213
United Kingdom	BDS Statistic	0.202051	0.348496	0.448492	0.512722	0.552890
	z-statistic	13.90514	14.79894	15.67668	16.84824	18.45379

Table 4: Non-linear Panel Unit Root Test (EU Average as Benchmark):

Countries	t-stat	Average t-stat
Austria	-1.728196	
Belgium	-2.144450	
Denmark	-0.918698	
Finland	-2.659496	
France	-0.595192	
Germany	--2.202349	
Greece	-3.822742	
Ireland	-0.841108	
Italy	-2.356835	
Luxemburg	-1.134087	
Netherlands	-1.484163	
Portugual	-0.391041	
Spain	-1.690309	
Sweden	-3.161806	
United Kingdom	-3.177530	
		-1.59

Critical Values (N=14, T= 38)

1%	-3.81	**5%**	-3.06	**10%**	-2.69

*** 1% significance
** 5% significance

Table 5: Non-linear Panel Unit Root Test (U.K as Benchmark):

Countries	t-stat		Average t-stat
Austria	-2.428		
Belgium	-1.293		
Denmark	-2.493		
Finland	-1.556		
France	-0.519		
Germany	0.207		
Greece	-4.193	***	
Ireland	-2.073		
Italy	-2.234		
Luxemburg	-1.161		
Netherlands	-3.604	**	
Spain	-2.532		
Sweden	-2.148		
			-2.0

Table 6: Non-linear Panel Unit Root Test (Spain as Benchmark):

Countries	t-stat		Average t-stat
Austria	-4.30233	***	
Belgium	-2.54227		
Denmark	-1.53544		
Finland	-1.52781		
France	-2.15527		
Germany	-1.27546		
Greece	-2.14113		
Ireland	-0.9605		
Italy	-1.68132		
Luxemburg	-1.62452		
Netherlands	-2.39347		
Sweden	-1.33389		
United Kingdom	-2.53212		
			-2.0

Table 7: Non-linear Panel Unit Root Test (Austria as Benchmark):

Countries	t-stat		Average t-stat		
Belgium	-0.7785				
Denmark	-1.9262				
Finland	-0.6954				
France	-4.4253	***			
Germany	-0.9448				
Greece	-1.1691				
Ireland	0.9743				
Italy	-0.7132				
Luxemburg	-2.22				
Netherlands	-3.1774	**			
Spain	-1.9253				
Sweden	-1.6879				
United Kingdom	-0.7006				
			-1.49		
		Critical Values (N=14, T= 38)			
1%	-3.81	**5%**	-3.06	**10%**	-2.69