RESEARCH ARTICLE

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# Testing Health Expenditure Convergence in 21 OECD Countries by Using Nonlinear Unit Root Tests

**ABSTRACT**

**Objective:** The purpose of this study is to analyze the stochastic time series behaviour of health expenditure in the 21 OECD countries between 1975 and 2019 using a variety of state-of-the-art (cutting-edge) unit root tests.

**Methods**: In this study, the linear ADF unit root test and eight relevant nonlinear unit root tests are used to empirically estimate whether the 21 OECD countries' health expenditure data show convergence.

**Results:** The empirical findings are in support the stationarity of health expenditure in 20 of the 21 OECD countries.

**Conclusions:** Health convergence hypothesis is confirmed in most OECD countries, indicating that health expenditure shocks have solely temporary effects on country-level health expenditure. The empirical study provides significant policy implications. The empirical part of the study indicated that policy measures chosen by the policymakers cannot be made without considering possible nonlinearities in health expenditure data. More investment in the policy proposals stated in the conclusion section in the low regime years, as well as the continuation of current ones in the high regime periods, have been determined to offer appropriate conditions for health spending convergence. Furthermore, it has been determined that structural changes outside of the regime have resulted in a change in health expenditure convergence in countries such as Japan and South Korea. It is essential to invest in these countries while taking into account the periods of structural change.

**Keywords:** Health Expenditure Convergence, OECD Countries, Nonlinear Unit Root Tests.

# Doğrusal Olmayan Birim Kök Testleri Kullanılarak 21 OECD Ülkesinde Sağlık Harcamaları Yakınsamasının Test Edilmesi

**ÖZET**

**Amaç:** Bu çalışma, 1975 ve 2019 yılları için 21 OECD ülkesinde sağlık harcamalarının stokastik zaman serisi davranışını bir dizi güncel birim kök testi kullanarak analiz etmeyi amaçlamaktadır.

**Gereç ve Yöntem:** Bu çalışmada, 21 OECD ülkesinin sağlık harcaması verilerinin bu ülkelerin sağlık harcamaları arasında bir yakınsama olup olmadığını ampirik olarak test etmek için doğrusal ADF birim kök testi ve sekiz ilgili doğrusal olmayan birim kök testi kullanılmıştır.

**Bulgular:** Ampirik bulgular, 21 OECD ülkesinin 20'sinde sağlık harcamalarının durağanlığını desteklemektedir.

**Sonuç:** OECD ülkelerinin çoğunda sağlık yakınsama hipotezi doğrulanmış olup, sağlık harcamaları şoklarının ülke düzeyinde sağlık harcamaları üzerinde yalnızca geçici etkileri olduğunu göstermektedir. Bu ampirik çalışma çok önemli politika sonuçları sunmaktadır. Politika otoritelerinin alacağı politika tedbirlerinin sağlık harcamaları verisindeki olası doğrusal olmayanlığı göz ardı edilerek yapılamayacağı çalışmanın ampirik kısmında teyit edilmiştir. Sonuç kısmında sıralanan politika önerilerine alt rejim dönemlerinde daha fazla yatırım yapılması ve yüksek rejim dönemlerde ise var olanın sürdürülmesinin sağlık harcamaları yakınsaması için yeter koşul sağladığı belirlenmiştir. Bunun yanı sıra Japonya ve Güney Kore gibi ülkelerde rejimden bağımsız yapısal değişimlerin sağlık harcamaları yakınsamasında da değişim yarattığı belirlenmiştir. Bu tarz ülkelerde yapısal değişimler gözetilerek yatırımların yapılması önem arz etmektedir.

**Anahtar Kelimeler:** Sağlık Harcamaları Yakınsaması; OECD Ülkeleri; Doğrusal Olmayan Birim Kök Testleri.

## INTRODUCTION

Health is an important component of people's and societies' well-being and standard of living. It can be seen that the United Nations Sustainable Development Goals aim to ensure a healthy and quality life for people of all ages. In this regard, countries' health expenditures are critical for the development of healthier and more productive structures. Consequently, global health expenditures increased between 2000 and 2019, with 2019 expenditures accounting for 9.8% of global GDP (1). When the distribution of countries' health expenditures is analysed, however, an unequal structure emerges. High-income countries, for example, accounted for an estimated 80% of global health expenditures (1).

According to OECD's definition, the level of health expenditure per capita and how it changes over time reveal that it is influenced by a wide range of demographic, social, and economic factors as well as the health systems's financing and organizational arrangements (3). In this context, the weight of countries on medical technologies, aging rates in society, and diseases exposed to different lifestyles can cause disparities in health expenditures (for detailed information, see (4-6)).

Convergence occurs when countries with a lower per capita GDP catch up with countries with higher per capita GDP, and the convergence approach is mainly used in the empirically measuring differences in health expenditure between countries. Even if this process is generally dealt with in terms of income, health expenditures between countries may also converge. As health expenditure increases, so may the integration of health-care markets, the improvement of working conditions in the health-care sector, and the expansion of medical research, insurance coverage, and health-care technologies (3). The resulting demands from all this may lead to a convergence of health expenditures across countries. This study compares time series to examine the convergence in per capita health expenditures for 21 OECD countries between 1975 and 2019.

The OECD country group, which we discussed in the study, has more regular data than other country groups and is longer, allowing unit root tests of the sample to produce better results. In addition to these good qualities, it is believed that this confusion can be reduced by testing this group with more advanced nonlinear tests, as the OECD country group has received more attention in the literature, with mixed results. We compare the health expenditure-convergence data generation processes using different nonlinear unit root tests.

There are two main economic reasons for the nonlinear nature of health expenditure data. First, state-dependent nonlinear structures can be found in nearly all economic variables. Granger and Teräsvirta, for example, claim that modeling economic growth due to the business cycle increases forecast accuracy (7). Furthermore, it is said that the stickiness of wages and other issues will last longer in recession periods than in economic expansion periods, and the persistency of the autoregressive parameter is greater in recession periods. As a result of this case, the lower and upper regime parameters are asymmetrical. During periods of high growth, economic expenditures will increase health expenditures. Similarly, it is natural for expenditures to fall during economic recessions. In this sense, such a pattern in health expenditures is the most natural outcome. Another nonlinearity mentioned in Perron's study is structural breaks, which cause changes in the long-term mean and trends of economic variables as a result of economic crises, wars, and similar events (8). A time-varying structure is also formed as a result of the structural break. In the empirical part, it was discovered that the health expenditure data contains both state-dependent and time-dependent nonlinearity, and thus tests that take into account both structures are successful in capturing stationarity. In this regard, it has been documented in the literature that the solution to the mixed evidence for OECD countries is to use the hybrid nonlinear model.

The empirical study has important policy implications. The empirical part of the study confirmed that policy measures to be taken by policymakers cannot be made by ignoring potential nonlinearities in health expenditure data. It has been determined that increased investment in the policy proposals listed in the conclusion section during low regime periods and continuation of existing ones during high regime periods provide adequate conditions for health expenditure convergence. Furthermore, it has been determined that structural changes independent of the regime have resulted in a shift in health expenditure convergence in countries such as Japan and South Korea. It is essential to invest in such countries while keeping structural changes in mind.

The rest of the study will provide a, a short brief literature review will be given in the second section, an explanation of part, the methods used in the study's methods in the will be explained in the third section, empirical analysis in the will be done in the fourth section, and a conclusion in the final section.

## LITERATURE REVIEW

There is a significant amount of literature on the convergence of health expenditures, there have been few studies that use unit root tests in recent years. In light of the importance of the subject discussed in this study, studies dealing with the convergence of health expenditures in OECD countries with a nonlinear unit root test focus have been tried to be summarized in Table 1.

**Table 1.** Convergence of Health Expenditures Studies Using Unit Root Tests

| Author | Country Group and Period | The Econometric Technique used | Findings | Policy Recommendation |
|---|---|---|---|---|
| Albulescu (9) | 6 OECD Countries (1972-2019) | Bound unit root tests | It can be observed that the convergence process between countries is weak, and the heterogeneity of health systems is emphasized. | Effective strategies and efforts towards an integrated system of health education and research are necessary to achieve convergence. |
| Kızılkaya and Dag (10) | 17 OECD Countries (1975-2019) | Fourier unit root test | It is concluded that the convergence hypothesis is valid in most of the countries. | In countries where the convergence hypothesis is not valid, policies that support convergence through continuous improvement of health services are needed. |
| Akarsu, Cafri and Bidirdi (11) | 18 OECD (1979-2016) | Nonlinear unit root tests | This articles' findings show that total and public health expenditures per capita differ but converge in private health expenditures. | In order to increase the efficiency of these health expenditures, preventive health policies that take care of primary health care services and reduce risk factors should be introduced. |
| Lee and Tieslau (12) | 20 OECD Countries (1971-2015) | LM unit root tests | There is evidence in favor of convergence among selected country groups. | - |
| Albulescu, Oros and Tiwari (13) | 6 OECD Countries (1980-2012) | Bound unit root tests | It is seen that there is no significant convergence in terms of the ratio of health expenditures to GDP. | Policies should be implemented to eliminate the diversity and complexity of national health systems. |
| Nghiem and Connelly (14) | 21 OECD Countries (1975-2014) | Phillips & Sul's approach (15) | The results expose no evidence of convergence in health expenditures among OECD countries. | Microeconomic initiatives |
| Payne, Anderson, Lee and Cho (3) | 19 OECD Countries (1972-2008) | LM and RALS-LM unit root tests | Most OECD countries have convergence in per capita health expenditure. | Integration of the health market, improving working and insurance conditions, and disseminating health care technologies and products should be ensured. |
| Pekkurnaz (16) | 22 OECD (1980-2012) | Nonlinear asymmetric heterogeneous panel unit root test | Although the results do not support strong convergence for all countries, it seems most appropriate to consider the asymmetry in the convergence analysis in health expenditures. | Achieving a more effective and efficient health system by improving the quality of health systems can pave the way for convergence. |
| Lau, Fung and Pugalis (17) | 14 OECD (1970-2008) | Non-linear time series and panel tests | It is concluded that there is no convergence in per capita health expenditures for most countries. | Health policy reforms and laws concerning health services need to be reconsidered. |
| Aslan (18) | 19 OECD (1970-2005) | Panel data unit root tests | Health expenditures do not converge between countries. | In order to achieve convergence, differences in health expenditure inequalities between countries need to be reduced. |
| Narayan (6) | 6 OECD (1960-2000) | LM and IPS unit root tests | The health expenditures of the countries converge to the health expenditures of the USA. | It should be aimed to increase the efficiency of the health system. |

## ECONOMETRIC METHODOLOGY

In this study, the problem of convergence of health expenditure data of 21 OECD countries has been empirically examined. For this purpose, the ADF unit root test and eight related nonlinear unit root tests were used. Nonlinear unit root tests are classified as time-dependent nonlinearity, situational nonlinearity, and hybrid nonlinearity. Both types of nonlinearities of DGP simultaneously are called "hybrid unit root tests."

As we describe, we used the LNV, FFFFF, CEO, EG, KSS, AESTAR, OY, CL, and OEHa, b tests. OEH test proposed by Omay et al. is the most comprehensive among the unit root tests mentioned (19). Since the OEH test covers all other tests, we will only include the explanation of the OHS test. We will describe all other tests from the tests here.

*Omay, Emirmahmutoglu and Hasanov, OEH test;* The OEH test is the most comprehensive unit root test used in this study. This test, being the LNV-Sollis type test, is a hybrid test that covers both nonlinearities (20). The OEH test uses the following equation to model gradual structural breaks:

$$y_t = \phi(t) + u_t \qquad (1)$$

$\phi(t)$ is the deterministic nonlinear trend function and $u_t$ is the deviation from the trend. A logistics transition function and a Fourier function are used to model the deterministic nonlinear trend function of Equation (1). The following three logistic smooth transition equations are used:

$$y_t = \alpha_1 + \alpha_2 S_t(\gamma,\tau) + \varepsilon_t \qquad (2a)$$
$$y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma,\tau) + \varepsilon_t \qquad (2b)$$
$$y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma,\tau) + \beta_2 t S_t(\gamma,\tau) + \varepsilon_t \qquad (2c)$$

where t = 1,2,....,T; $\varepsilon_t$ is a zero mean process; and $S_t(\gamma,\tau)$ is the logistic smooth transition function with a sample size of T:

$$S_t(\gamma,\tau) = [1 + exp\{-\gamma(t - \tau T)\}]^{-1} \qquad (3)$$

$S_t(\gamma,\tau)$ is a continuous function and allows the transition between two different regimes having the extreme values as 0 and 1. The parameters $\gamma$ and $\tau$ denote the speed of transition and location between two regimes, respectively. Since the value of $S_t(\gamma,\tau)$ depends on the value of the parameter, the transition between two regimes is very slow for small values of $\gamma$ whereas the transition between the regimes becomes almost instantaneous at time $t = \tau T$ for very large values of $\gamma$. When $\gamma = 0$, then $S_t(\gamma,\tau) = 0.5$ for all values of t. Therefore, in Equation (2a), $y_t$ is stationary around a mean that changes from $\alpha_1$ to $\alpha_1 + \alpha_2$ Equation (2b) allows for a fixed slope term where the intercept term changes from $\alpha_1$ to $\alpha_1 + \alpha_2$ . In Equation (2c), in addition to the similar changes in the intercept, the slope changes from $\beta_1$ to $\beta_1 + \beta_2$ at the same time (Leybourne et al. (21)).

The logistic smooth transition function given in Equation (3) is able to capture only one gradual structural break. Therefore, the OEH test utilizes the following Fourier function to capture multiple structural breaks:

$$\phi(t) = \alpha_0 + \delta t + \sum_{k=1}^{n} a_k \sin\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{n} b_k \cos\left(\frac{2\pi kt}{T}\right) u_t \qquad ; N\frac{T}{2} \qquad (4)$$

N represents the number of cumulative frequencies contained in the approximation while k is the selected frequency in the approximation process. $a_i$ and $b_i$ are the measurements for the amplitude and displacement of the sinusoidal components of the deterministic function. As stated in Omay et al. (22), under some circumstances, the Fourier series with an appropriate lag order in Equation (4) might approximate any function with unknown numbers of breaks of unknown forms. However, under the assumption of $a_i = b_i = 0$ for all *i*, the Fourier function becomes a linear model without a structural break. If Equation (4) allows for a structural break, the min frequency component must be at least one. As a result, the rejecting the null of $a_i = b_i = 0$, implies a structural break in the series.

The OEH test also utilizes an asymmetric exponential smooth transition autoregressive (AESTAR) model to capture the nonlinear asymmetric adjustment process as in Sollis (20). The AESTAR model considers both a logistic function and an exponential function as follows:

$$\Delta u_t = G_t(\theta_1, u_{t-1})\{F_t(\theta_2, u_{t-1})\rho_1 + (1 - F_t(\theta_2, u_{t-1}))\rho_2\}u_{t-1} + \epsilon_t \qquad (5)$$

$$G_t(\theta_1, u_{t-1}) = 1 - \exp(-\theta_1(u_{t-1}^2)) \qquad \theta_1 > 0 \qquad (6)$$

$$F_t(\theta_2, u_{t-1}) = [1 + \exp(-\theta_2(u_{t-1}))\ ]^{-1} \qquad \theta_2 > 0 \qquad (7)$$

where $\epsilon_t \sim iid(0, \sigma^2)$.

As $u_t$ is a zero mean variable, $F_t(\theta_2, u_{t-1})$, the logistic transition function for two regimes is determined by the positive and negative deviations from the equilibrium of $u_t$ (i.e. the sign of disequilibrium) $G_t(\theta_1, u_{t-1})$, the U-shaped symmetric exponential transition function, ranged from 0 and 1 determines the small and large deviations from the equilibrium in absolute terms.

The AESTAR function implies a globally stationary process. The globally stationarity of AESTAR function requires $\theta_1 > 0$ , $\rho_1 < 0$ and $\rho_2 < 0$ as stated in Sollis (20). If $\rho_1 \neq \rho_2$ is the case, the adjustment process captures not only sign but also size adjustment to the equilibrium. On the other hand, if $\rho_1 = \rho_2$ is the case, the adjustment to the equilibrium becomes a symmetric exponential smooth transition autoregressive (ESTAR) process.

The null hypothesis of a linear unit root can be tested against the alternative hypothesis of a globally stationary AESTAR process. The hypotheses are as follows;

$$H_0 = \theta_1 = 0 \qquad (8)$$

$$H_1 = \theta_1 > 0 \qquad (9)$$

Nevertheless, due to the existence of unidentified nuisance parameters under the null, testing the null hypothesis directly is not suitable. Hence, Kapetanios et al. and Sollis suggest rearranging the transition functions by using a first order Taylor approximation and the model is follows (23,20):

$$\Delta u_t = \varphi_1 u_{t-1}^3 + \varphi_2 u_{t-1}^4 + \omega_t \qquad (10)$$

Equation (5) assumes a serially uncorrelated error term. After the rearrangement above, the null hypothesis in Equation (8) takes the form of $H_0: \varphi_1 = \varphi_2 = 0$ . In order to allow for serial correlation, the regression equation is augmented as follows:

$$\Delta u_t = G_t(\theta_1, u_{t-1})\{F_t(\theta_2, u_{t-1})\rho_1 + (1 - F_t(\theta_2, u_{t-1}))\rho_2\}u_{t-1} + \sum_{j=1}^{p} \delta_j \Delta u_{t-j}\, \epsilon_t \qquad (11)$$

where $\epsilon_t \sim iid(0, \sigma^2)$. Therefore, the following auxiliary regression is used to test the null hypothesis $H_0: \varphi_1 = \varphi_2 = 0$:

$$\Delta u_t = \varphi_1 u_{t-1}^3 + \varphi_2 u_{t-1}^4 + \sum_{j=1}^{p} \delta_j \Delta u_{t-j} + \vartheta_t \qquad (12)$$

The testing procedure of the OEH test consists of two steps. As a first step, one estimates the preferred component form the Equations (2)-(4) and obtain residuals, $\hat{u}_t$. In the second step, one uses the residuals and estimate the regression in Equation (12) by OLS and testing the null hypothesis by using F test. For the case of logistic trend functions, nonlinear least squares (NLS) can be used for estimating the deterministic trend. By using OLS, the coefficients of Fourier series can be estimated for the frequency, k. k is determined by the estimation of the trend function in the range of $1 \leq k \leq k_{max}$ and chosen the one with having the smallest sum of squared residuals.

OEH suggests two test statistics as $F_{LBAE}$ and $F_{FSAE}$. $F_{LBAE}$ is the test statistics for modelling the gradual break by using logistic transition functions given in the Equations (2a) - (2c). $F_{FSAE}$ is the test statistics of the case of modelling breaks by using the Fourier series given in Equation (4).

The Omay test is proposed by the fractional estimation of the kt integer frequency in equation 4 (24). After estimating Equation 4 with fractional frequency, the ADF test is applied to the remaining series $\tau^{fr}_{DF\_\tau}$.

The CEO (2017) test uses exponential smooth transition instead of the logistics function of the OHE 1 test. The Omay test applies the ADF test to the remaining series after the nonlinear trend estimation (24).

$$F_t(\gamma,\tau) = 1 - exp[-\gamma(t-\tau)^2] \quad ,\gamma > 0 \qquad (13)$$

In CEO test, after de-trending the nonlinear trend from the series, the remaining residuals are used in ADF test for smooth temporary structural break unit root test. The t statistics of the test are labelled as $\tilde{s}_{\alpha}, \tilde{s}_{\alpha(\beta)}$ *and* $\tilde{s}_{\alpha\beta}$ for the models used, respectively.

The EG test uses the indicator function instead of the smooth logistic transition in Equation (7). The TAR type unit root test can be classified as a state-dependent nonlinear unit root test.

The KSS test is a state-dependent non-linear unit root test that uses ESTAR as a transition function. It considers Equation (2a)-(2c) and uses the exponential transition function given in Equation (6). The KSS test enables the symmetrical adjustment to be modeled towards equilibrium (Kapetanios et al. (23)).

The other important state dependent nonlinear unit root test is Sollis test (20).[1] Sollis uses the Equations (5)-(7). Sollis is an extension of KSS test and suggests testing the asymmetric state dependent nonlinearity with intercept and trend deterministic terms in its alternative hypothesis. Sollis has allowed that test can cover the sign and size of the adjustment towards equilibrium at the same time by employing the AESTAR function which uses LSTR and ESTAR function together (20). OY[2] test is one of the first hybrid tests which use the LNV and KSS tests together. OY test depend on the Equations (2a)-(2c) and applies the transition function given in Equation (3) for smooth structural break or nonlinear trend. After de-trending the nonlinear trend from the series, the residuals are used in KSS test. In this test, the null of linear unit root can be tested against nonlinear and stationary around smoothly changing trend and intercept (Omay and Yildirim, (25)).

## EMPIRICAL ANALYSIS

This study compares time series to examine the convergence in per capita health expenditures for 21 OECD countries between 1975 and 2019. As we used a time series version of the unit root tests, first, we will give summary statistics.

**Table 2.** Summary Statistics

| | Mean | Var | Min | Max | Median |
|---|---|---|---|---|---|
| Australia | 2188.98 | 2245283.08 | 374.28 | 4919.24 | 1537.00 |
| Austria | 2575.06 | 3091851.54 | 386.50 | 5705.10 | 2083.04 |
| Belgium | 2371.14 | 2708351.86 | 334.85 | 5458.40 | 1668.27 |
| Canada | 2568.51 | 2432718.63 | 487.35 | 5370.44 | 1984.33 |
| Denmark | 2470.76 | 2501558.36 | 508.06 | 5477.57 | 1712.49 |
| Finland | 2022.57 | 1954966.72 | 285.36 | 4558.54 | 1349.42 |
| Germany | 2840.50 | 3171773.76 | 532.48 | 6518.00 | 2345.67 |
| Iceland | 2290.19 | 1659924.05 | 358.57 | 4540.76 | 1807.99 |
| Ireland | 2111.29 | 2856423.12 | 251.84 | 5083.21 | 1128.83 |
| Japan | 2026.35 | 2121482.90 | 283.20 | 4691.46 | 1414.91 |
| Korea | 996.28 | 965482.15 | 31.48 | 3406.26 | 515.61 |
| Netherlands | 2640.73 | 3172195.44 | 452.20 | 5739.20 | 1746.06 |
| New Zealand | 1804.24 | 1511543.68 | 404.54 | 4211.85 | 1306.06 |
| Norway | 2808.83 | 4424520.52 | 327.21 | 6744.62 | 1767.05 |
| Portugal | 1411.86 | 1107148.70 | 149.39 | 3347.43 | 1008.24 |
| Spain | 1556.26 | 1265291.83 | 185.28 | 3600.28 | 1124.88 |
| Sweden | 2456.38 | 2591641.60 | 501.20 | 5551.94 | 2456.38 |
| Switzerland | 3328.44 | 4375425.83 | 584.20 | 7138.06 | 2622.54 |
| Turkey | 458.25 | 165716.46 | 37.81 | 1266.93 | 196.97 |
| UK | 1899.96 | 2119982.41 | 225.09 | 4500.14 | 1092.41 |
| US | 4731.13 | 10933121.37 | 560.75 | 10948.48 | 3586.72 |

[1] See, Sollis (20) for details.

[2] See Omay and Yildirim (17) for details.

We followed the Canarella et al. study and performed preliminary structural break and nonlinearity tests to investigate the a priori existence of 8 nonlinear unit root tests that we will perform throughout the study (26). We also tried to explain the meanings of the tests we carried by mentioning the economic relationships that led to these tests.

Economically, two main reasons can explain the nonlinear nature of health expenditure data. First, state-dependent nonlinear structures appear in almost all economic variables. For example, Granger and Teräsvirta state that modeling economic growth due to the business cycle increases forecast accuracy (7). In addition, it is said that the stickiness of wages and other issues will last longer in recession periods than in economic expansion periods, and the persistency of the autoregressive parameter is greater in recession periods. This case causes the lower and upper regime parameters to be asymmetrical. Economic expenditures will increase health expenditures in periods of high growth. Likewise, it is natural that expenditures tend to decrease during economic recession periods. In this sense, it is the most natural result for health expenditures to follow such a pattern. Another nonlinearity is the structural breaks mentioned in Perron's study (8). These structural breaks cause changes in the long-term mean and trends of economic variables due to economic crises, wars, and similar events. The structural break also causes the formation of a time-varying structure. The time-varying structure of the time series variable influences both its deterministic and autoregressive components. The Trig test structure proposed by Beckers Enders and Hurn was primarily used to test these two different types of structures (27). In determining the stochastic structure of the data, Canarella et al. have been used (26):

We will conduct preliminary tests to determine the processes for generating health expenditure convergence data. We conducted the following tests in the direction of Canarella et al. (26).

1. Use the linearity test developed by Luukkonen, Saikkonen, and Teräsvirta to determine whether the data is state-dependent, time-varying nonlinear, or both (28).
2. Determine whether the nonlinear trend is logistic (LSTR), exponential (ESTR), integer frequency Fourier (IFFF), or fractional frequency (FFFF) Fourier if the data is time-dependent,

Becker, Enders, and Lee Trig-test and Luukkonen, Saikkonen and Teräsvirta tests are used for these purposes (29, 28).

**Table 3.** Time varying and Structural Break Tests (Trig, Logistic and Exponential break tests)

| Country | Logistic Smooth Transition Test | | | ESTT Test | Fourier | | Test Result |
|---|---|---|---|---|---|---|---|
| | Model A | Model B | Model C | Model A | Intercept | Intercept &Trend | |
| **Australia** | 206.951 | 14.507 | 126.060 | 151.580 | 82.067 | 96.938 | LSTT Model A |
| **Austria** | 19.020 | 54.085 | 99.834 | 103.361 | 48.935 | 38.112 | ESTT Model A |
| **Belgium** | 23.572 | 5.479 | 14.639 | 31.440 | 11.867 | 9.523 | ESTT Model A |
| **Canada** | 1773.332 | 1015.482 | 780.004 | 34.551 | 467.740 | 561.389 | LSTT Model A |
| **Denmark** | 2269.745 | 410.685 | 1631.248 | 115.982 | 997.835 | 1044.400 | LSTT Model A |
| **Finland** | 76.890 | 30.199 | 89.801 | 65.599 | 87.088 | 74.206 | LSTT Model C |
| **Germany** | 1027.997 | 241.669 | 1050.955 | 52.111 | 723.547 | 483.623 | LSTT Model C |
| **Iceland** | 265.419 | 50.468 | 195.817 | 77.651 | 269.593 | 206.660 | LSTT Model A |
| **Ireland** | 1088.174 | 684.262 | 455.426 | 44.255 | 227.922 | 686.930 | LSTT Model A |
| **Japan** | 45.714 | 15.794 | 44.930 | 57.830 | 82.698 | 66.170 | Fourier Intercept |
| **Korea** | 4909.650 | 5833.574 | 3842.821 | 124.367 | 2279.207 | 3523.441 | LSTT Model B |
| **Netherlands** | 195.041 | 137.057 | 374.976 | 129.299 | 88.472 | 218.018 | LSTT Model C |
| **New Zea.** | 325.454 | 19.382 | 153.730 | 291.060 | 64.474 | 93.967 | LSTT Model A |
| **Norway** | 620.235 | 299.013 | 276.777 | 37.288 | 238.332 | 230.636 | LSTT Model A |
| **Portugal** | 1025.889 | 117.019 | 557.051 | 106.494 | 564.246 | 543.585 | LSTT Model A |
| **Spain** | 1317.423 | 648.623 | 434.235 | 55.498 | 368.124 | 391.102 | LSTT Model A |
| **Sweden** | 888.055 | 821.483 | 563.541 | 108.933 | 544.746 | 722.673 | LSTT Model A |
| **Switzerland** | 1767.073 | 797.560 | 608.984 | 37.499 | 355.575 | 1418.244 | LSTT Model A |
| **Turkey** | 1300.312 | 724.856 | 502.488 | 33.083 | 530.958 | 515.008 | LSTT Model A |
| **UK** | 1880.664 | 717.758 | 1519.872 | 39.957 | 409.000 | 382.669 | LSTT Model A |
| **US** | 31.865 | 17.750 | 164.188 | 87.934 | 141.953 | 102.385 | LSTT Model C |

**Table 4.** Linearity (Nonlinearity test - LM3E) Lukonnen et al. (28)

| Country | LM F test | Lag Selected | OverAllTest Result |
|---|---|---|---|
| **Australia** | 0.411 | 1 | TV Time Varying |
| **Austria** | 8.345 | 7 | State Dependent TV |
| **Belgium** | 3.936 | 5 | State Dependent TV |
| **Canada** | 5.152 | 1 | State Dependent TV |
| **Denmark** | 2.447 | 1 | TV |
| **Finland** | 8.010 | 2 | State Dependent TV |
| **Germany** | 0.168 | 1 | TV |
| **Iceland** | 5.307 | 10 | State Dependent TV |
| **Ireland** | 4.483 | 7 | State Dependent TV |
| **Japan** | 2.512 | 3 | TV |
| **Korea** | 3.185 | 5 | State Dependent TV |
| **Netherlands** | 1.252 | 1 | TV |
| **New Zealand** | 0.206 | 1 | TV |
| **Norway** | 1.939 | 1 | TV |
| **Portugal** | 2.015 | 5 | TV |
| **Spain** | 4.902 | 2 | State Dependent TV |
| **Sweden** | 4.600 | 1 | State Dependent TV |
| **Switzerland** | 1.977 | 1 | TV |
| **Turkey** | 1.807 | 1 | TV |
| **UK** | 1.643 | 1 | TV |
| **US** | 3.187 | 1 | State Dependent TV |

With these specific tests, our study confirmed the existence of nonlinear structures. We found a structural break in all of the data and state-dependent nonlinear structure in some data of the data. Since these specific tests are related to the unit root tests we use, they have also ensured that the unit root tests we use are approved at the concurrently. We do not have the opportunity to test the nature of nonlinearity using BDS or other general nonlinearity tests. We accept the general hypothesis that the data is nonlinear with the BDS test, but we cannot determine which specific type of functional structure it is. Moreover, the results of the test show that using a hybrid test, such as logistic smooth transition trend with exponential smooth transition state-dependent structures, namely the OY test, will fit better with the health expenditure data structure (25).

As shown in Table 1, the heath convergence hypothesis was provided by hybrid tests which are consistent with the Table 2 and Table 3 test results. The first finding from these results is that the health expenditure data cannot be explained by either a state-dependent or a time-dependent structure. In other words, health expenditure data do not contain singular dynamics that we can call time-dependent or state-dependent in the data generating process. However, as we said above, it is a hybrid; that is, it contains both structures simultaneously. In this sense, policymakers should carry out the policy-making process by paying attention to the structural breaks that occur over time and the cycles that develop within the business cycle while doing health expenditures. The health expenditure convergence hypothesis was explicitly provided in Australia, Austria, Canada, Denmark, Finland, Germany, Iceland, Ireland, Japan, Korea, Netherlands, Spain, Switzerland, New Zealand, and Norway, Portugal, Sweden, Turkey, UK, and US. Belgium appears to be the only country not provided by this group. In addition, it is seen that health convergence is achieved only with time-dependent tests in Japan and Korea where the Japanese data found to be best described with Fourier intercept case.

**Table 5.** Results of Time Series Unit Root Tests[3]

| –Time Series Tests– 1975-2019 | KSS Test (KSS) Model : Intercept Only (23) | | KSS Test(2003) (KSS) Model : Intercept and Trend (23) | | LNV Test Model A (21) | | LNV Test Model B (21) | | LNV Test Model C (21) | | Omay Test (FFFFF) Model : Intercept Only (24) | | Omay Test(2015) (FFFFF) Model : Int&Trend (24) | | SOR Test (LSTR-Fourier-ADF) Model A (30) | | SOR Test (LSTR-Fourier-ADF) Model B (30) | | SOR Test (LSTR-Fourier-ADF) Model C (30) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value |
| Australia | 14 | 0.314 | 15 | 0.516 | 14 | -1.417 | 5 | -1.533 | 14 | 0.918 | 6 | -1.474 | 7 | -1.136 | 4 | -2.884 | 4 | -5.189** | 7 | -3.219 |
| Austria | 13 | 0.212 | 14 | 1.541 | 7 | -3.868 | 7 | -5.290** | 7 | -6.652 | 9 | -1.049 | 7 | -2.712 | 7 | -3.410 | 14 | -1.303 | 7 | -2.776 |
| Belgium | 8 | 0.292 | 9 | -0.219 | 7 | -2.285 | 6 | -2.593 | 7 | -1.767 | 6 | -1.881 | 7 | -2.197 | 7 | -3.361 | 7 | -3.270 | 7 | -3.352 |
| Canada | 5 | -1.407 | 6 | -0.335 | 5 | -4.074* | 7 | -2.615 | 7 | -4.305 | 6 | -2.339 | 3 | -2.732 | 4 | -4.629** | 5 | -3.131 | 5 | -3.150 |
| Denmark | 5 | -1.075 | 5 | -3.019** | 5 | -3.279 | 4 | -0.453 | 3 | -3.365 | 3 | -2.679 | 7 | -1.452 | 6 | -4.407* | 5 | -3.148 | 4 | -3.491 |
| Finland | 4 | 0.540 | 5 | 0.938 | 3 | -3.234 | 5 | -1.839 | 4 | -1.582 | 4 | -1.306 | 4 | -1.558 | 3 | -4.645** | 3 | -3.544 | 3 | -3.741 |
| Germany | 3 | -1.712 | 4 | -1.940 | 7 | -2.196 | 3 | -0.226 | 3 | -2.971 | 3 | -3.619* | 3 | -3.538* | 3 | -4.265* | 7 | -3.548 | 7 | -5.510** |
| Iceland | 14 | -2.875*** | 14 | -0.400 | 14 | -3.023 | 14 | -3.871 | 7 | -0.980 | 14 | -2.702 | 14 | -2.493 | 7 | -2.878 | 14 | -3.247 | 14 | -2.516 |
| Ireland | 14 | 1.898 | 15 | 1.221 | 7 | -4.421** | 7 | -6.266*** | 7 | -6.323*** | 14 | -1.017 | 7 | -2.526 | 7 | -4.478* | 7 | -2.862 | 7 | -3.076 |
| Japan | 5 | 0.365 | 6 | 0.334 | 4 | -4.081* | 5 | -1.693 | 5 | -0.987 | 3 | -2.472 | 4 | -1.592 | 4 | -4.020 | 4 | -4.703* | 4 | -5.053* |
| Korea | 13 | 0.909 | 14 | -0.198 | 6 | -1.665 | 14 | -3.628 | 14 | -3.725 | 6 | -2.820 | 7 | -3.701* | 6 | -2.644 | 7 | -3.401 | 7 | -3.281 |
| Netherlands | 3 | -1.266 | 4 | -1.324 | 3 | -1.932 | 3 | -2.736 | 4 | -1.547 | 3 | -3.311 | 3 | -2.351 | 3 | -2.619 | 4 | -5.570*** | 7 | -3.770 |
| New Zealand | 14 | 0.336 | 15 | -1.994 | 14 | -0.089 | 14 | -3.046 | 7 | -2.274 | 14 | -0.726 | 14 | -2.487 | 14 | -1.422 | 14 | -2.293 | 14 | -1.132 |
| Norway | 6 | 1.687 | 7 | 1.575 | 14 | -2.591 | 3 | -3.779 | 5 | -2.776 | 3 | -3.237 | 3 | -2.137 | 14 | -1.989 | 3 | -4.541* | 14 | -3.181 |
| Portugal | 13 | 0.382 | 14 | 0.266 | 7 | -2.527 | 7 | -1.276 | 7 | -1.597 | 3 | -1.672 | 14 | -2.042 | 7 | -2.466 | 7 | -2.890 | 7 | -3.374 |
| Spain | 3 | 0.820 | 15 | 3.319** | 3 | -3.543 | 5 | -1.765 | 3 | -1.996 | 14 | -2.705 | 14 | -4.576*** | 14 | -3.436 | 14 | -3.116 | 14 | -2.150 |
| Sweden | 3 | -1.578 | 5 | -2.860* | 3 | -2.436 | 3 | -2.081 | 3 | -2.182 | 14 | 2.279 | 3 | -2.412 | 4 | -2.500 | 3 | -4.487* | 3 | -4.464 |
| Switzerland | 14 | -2.478** | 15 | -1.791 | 7 | -2.892 | 3 | -4.595 | 2 | -1.260 | 10 | -1.181 | 3 | -2.537 | 7 | -3.400 | 14 | -1.325 | 7 | -3.335 |
| Turkey | 4 | 1.629 | 5 | 0.338 | 14 | -1.288 | 14 | -1.145 | 14 | -1.386 | 14 | -1.069 | 14 | -0.902 | 14 | -1.253 | 3 | -4.726* | 14 | -1.810 |
| UK | 3 | 1.338 | 4 | 1.005 | 4 | -2.525 | 4 | -2.226 | 3 | -3.015 | 3 | -1.347 | 5 | -1.814 | 7 | -3.107 | 3 | -4.031 | 7 | -3.525 |
| US | 3 | -0.047 | 6 | 1.483 | 5 | -2.539 | 5 | -1.458 | 7 | -1.371 | 3 | -1.960 | 3 | -1.815 | 3 | -2.393 | 4 | -4.126 | 3 | -3.691 |

[3] Note*, ** and *** are representing the 10%, 5% and 1% significance level, respectively. ADF test, available upon request

**Table 6.** Results of Time Series Unit Root Tests (Continue)[4]

| –Time Series Tests– 1975-2019 | CEO Model A: Corakci et. al. Test (31) | | CEO Model B: Corakci et. al Test (31) | | CEO Model C Corakci et.al. Test (31) | | OY Test (LNV-KSS) Model A (25) | | OY Test (LNV-KSS) Model B (25) | | OY Test (LNV-KSS) Model C (25) | | OEH Test (FKSS) Model : Intercept Only (18) | | OEH Test (FKSS) Model : Intercept and Trend (19) | | OSH Model A (32) | | OSH Model B (32) | | OSH Model C (32) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value | lag | t value |
| Australia | 7 | -1.043 | 7 | -1.096 | 7 | -1.085 | 3 | -2.593 | 6 | -2.183 | 7 | -4.164 | 4 | -3.567 | 14 | -0.548 | 14 | -0.120 | 7 | -0.064 | 7 | -0.081 |
| Austria | 4 | -1.725 | 14 | -0.782 | 14 | -0.765 | 7 | -4.275** | 7 | -5.487*** | 14 | -0.248 | 13 | -1.480 | 13 | -0.154 | 7 | -0.998 | 7 | -2.417 | 3 | -3.575 |
| Belgium | 7 | -2.241 | 7 | -2.264 | 7 | -1.447 | 7 | -3.568* | 7 | -3.611 | 7 | -3.449 | 7 | -1.851 | 7 | -1.346 | 7 | -1.900 | 6 | -3.584 | 7 | -3.481 |
| Canada | 7 | -0.688 | 7 | -3.207 | 7 | -2.142 | 7 | -3.554* | 7 | -2.319 | 7 | -5.272** | 5 | 1.260 | 4 | -2.419 | 5 | -2.066 | 6 | -2.460 | 5 | -2.159 |
| Denmark | 14 | -2.282 | 6 | -1.451 | 6 | -1.447 | 3 | -3.147 | 4 | -0.267 | 4 | -1.704 | 5 | 0.215 | 5 | -3.933 | 5 | -3.771* | 3 | -3.332 | 3 | -3.331 |
| Finland | 4 | -1.212 | 5 | -1.464 | 14 | -1.068 | 4 | -2.750 | 6 | -3.169 | 4 | -4.378* | 3 | -4.786 | 4 | -2.692 | 3 | -3.687* | 4 | -2.690 | 4 | -2.706 |
| Germany | 14 | -1.008 | 3 | -0.872 | 3 | -0.922 | 3 | -6.255*** | 3 | 0.201 | 3 | -4.386* | 9 | -2.196 | 3 | -4.593 | 3 | -4.856*** | 3 | -6.903*** | 3 | -6.677*** |
| Iceland | 14 | -0.664 | 14 | -2.747 | 14 | -2.735 | 14 | -4.540** | 14 | -4.675** | 7 | -2.246 | 14 | -2.185 | 13 | -2.002 | 7 | -2.386 | 14 | -2.130 | 14 | -2.165 |
| Ireland | 5 | -1.541 | 7 | -0.125 | 7 | -0.173 | 14 | -2.144 | 7 | -6.540*** | 7 | -6.526*** | 14 | -1.329 | 13 | -2.195 | 7 | -3.920* | 7 | -3.824 | 7 | -3.411 |
| Japan | 7 | -1.293 | 5 | -0.955 | 5 | -0.957 | 14 | -3.720* | 5 | -3.577 | 3 | -3.107 | 13 | 0.375 | 5 | -1.137 | 14 | -2.237 | 5 | -2.267 | 5 | -0.817 |
| Korea | 7 | -0.711 | 7 | -0.512 | 7 | -0.507 | 6 | -3.599* | 14 | -2.338 | 14 | -2.438 | 7 | 0.942 | 6 | -2.038 | 7 | -1.759 | 7 | -3.760 | 7 | -3.787* |
| Netherlands | 3 | -1.908 | 3 | -2.923 | 3 | -2.928 | 3 | -4.397** | 3 | -5.960*** | 4 | -2.820 | 5 | -3.312 | 3 | -4.641 | 3 | -3.008 | 3 | -4.906** | 3 | -5.542*** |
| New Zealand | 14 | -1.978 | 14 | -1.736 | 14 | -1.721 | 14 | -2.647 | 14 | -4.000* | 7 | -4.372* | 14 | -0.227 | 13 | -4.158 | 14 | -0.689 | 7 | 0.219 | 7 | 0.238 |
| Norway | 3 | -1.916 | 3 | -3.598 | 3 | -3.615 | 7 | -1.530 | 4 | -3.077 | 6 | -4.137 | 8 | -1.591 | 6 | -3.208 | 14 | -2.056 | 6 | -4.086* | 6 | -4.021* |
| Portugal | 7 | -1.453 | 7 | -1.030 | 7 | -1.024 | 4 | -0.354 | 7 | -3.274 | 14 | -2.892 | 13 | 1.045 | 11 | -4.805 | 14 | 0.214 | 3 | -2.972 | 3 | -2.991 |
| Spain | 14 | -1.044 | 14 | -2.125 | 14 | -2.100 | 4 | -3.239 | 4 | -3.558 | 3 | -2.374 | 3 | 0.433 | 14 | -3.282 | 14 | -2.789 | 14 | -4.241** | 14 | -4.314** |
| Sweden | 7 | -1.160 | 14 | 1.094 | 14 | 1.090 | 3 | -1.734 | 3 | -2.384 | 3 | -2.525 | 3 | 0.119 | 14 | -4.184 | 3 | -1.438 | 3 | -2.841 | 3 | -2.867 |
| Switzerland | 3 | -0.697 | 3 | -1.682 | 3 | -1.667 | 7 | -2.236 | 3 | -4.902** | 5 | -1.905 | 13 | 1.105 | 3 | -1.897 | 14 | -3.685* | 4 | -2.504 | 7 | -2.564 |
| Turkey | 7 | -0.994 | 4 | -1.81 | 7 | -1.459 | 14 | -2.962 | 14 | -1.395 | 14 | -1.435 | 3 | -3.098 | 14 | -7.295* | 14 | -6.670*** | 14 | -2.539 | 14 | -1.893 |
| UK | 7 | -0.969 | 3 | -2.548 | 3 | -2.534 | 7 | -1.070 | 4 | -2.197 | 3 | -1.900 | 3 | -1.355 | 7 | -7.521* | 7 | -5.378*** | 3 | -2.523 | 3 | -1.813 |
| US | 7 | -1.254 | 4 | -2.271 | 4 | -2.289 | 7 | -2.984 | 5 | -5.346*** | 7 | -2.198 | 3 | -2.848 | 3 | -3.149 | 5 | -3.450 | 7 | -2.871 | 7 | -2.833 |

[4] Note*, ** and *** are representing the 10%, 5% and 1% significance level, respectively. ADF test, available upon request.

**CONCLUDING REMARKS**

Various policy recommendations have previously been presented in the literature. The general principle upon which these policy recommendations are based is that if countries' health expenditures do not converge, their implementation will result in convergence. The following recommendations are made in this regard.

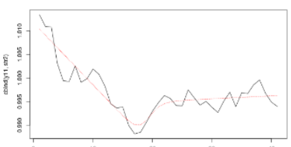
1. To improve the efficiency of these health expenditures, preventive health policies that focus on primary health care services and risk factors should be implemented.
2. Policies should be put in place to reduce the diversity and complexity of nations.
3. It is necessary to ensure the integration of the health market, the improvement of working and insurance conditions, and the dissemination of health care technologies and products.
4. Improving the quality of health systems can pave the way for a more effective and efficient health system, laying the foundation for convergence.
5. Health policy reforms and laws governing health care services must be revisited.
6. In order to achieve convergence, disparities in health expenditure between countries must be reduced.
7. It should aim to improve the health-care system's efficiency.

It is also critical to consider what the unit root test results for the policy recommendations listed above suggest. To improve the efficiency of health expenditures, we must first understand of the functional structure of health expenditures. The nonlinear unit root tests used in this study successfully identified the data generation processes of health expenditures. As a result, the types of structures exhibited by health expenditures exhibit by country were tested using state-dependent, time-varying, and hybrid tests. According to the findings of these tests, health expenditure convergence is provided with a structural break in Japan and Korea. As a result, it has been determined that these two countries' expenditure patterns are suitable for convergence until the next break or the economic phenomenon which leads to a break in health expenditure series of that country. Furthermore, with the exception of Belgium, convergence has been achieved when considering the real business cycle and structural break. This case demonstrates that at least prior to Covid 19 Pandemic, 20 of 21 OECD countries made the right decisions in terms of health policies and effectiveness. Due to pandemic conditions, we did not include post-2019 study. In this regard, after gathering the necessary data, it is useful to investigate how their performance under pandemic conditions is affected..

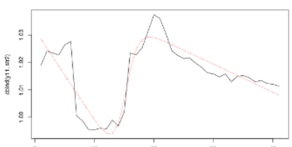
**APPENDIX**

**LNV Test (1998) Model C**

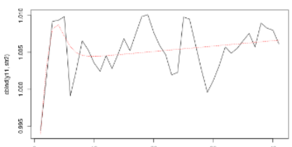
Australia



Austria



Belgium



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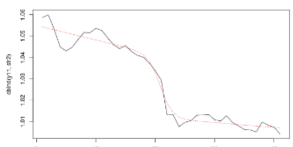
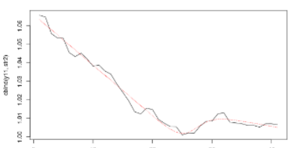
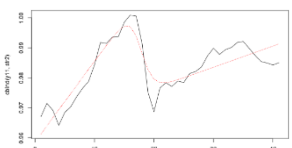


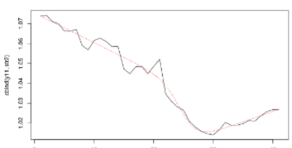
Denmark



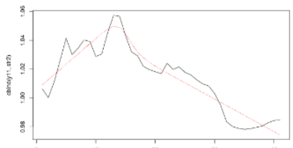
Finland



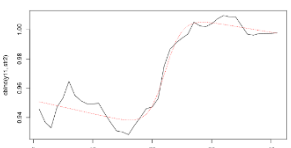
Germany



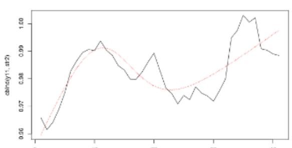
Iceland



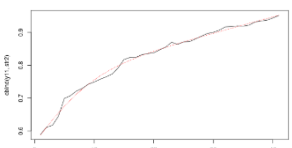
Ireland



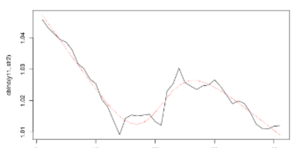
Japan



Korea



Netherlands



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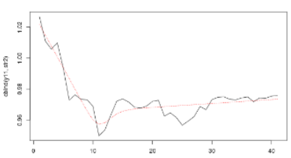
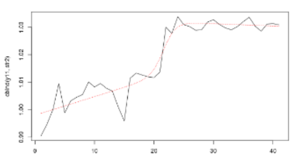
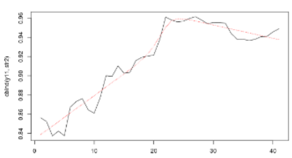


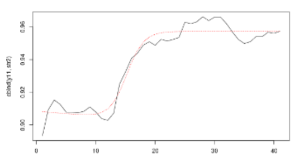
Norway



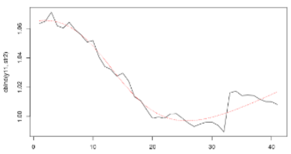
Portugal



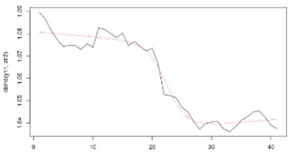
Spain



Sweden



Switzerland



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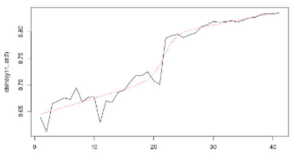
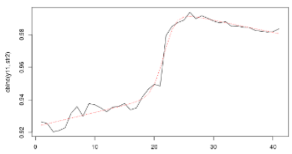
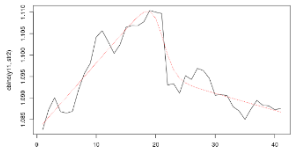


United Kingdom

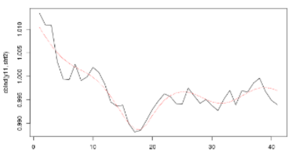


United States

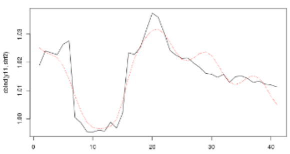


**SOR Test (LSTR-Fourier-ADF) Model C**

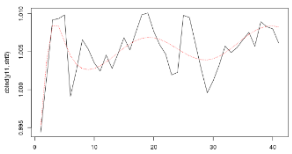
Australia



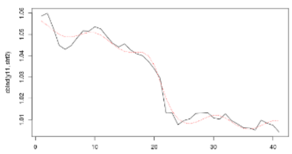
Austria



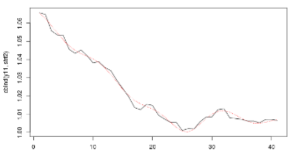
Belgium



Canada



Denmark



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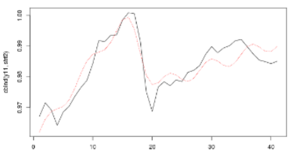

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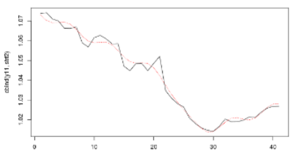

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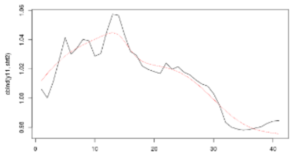

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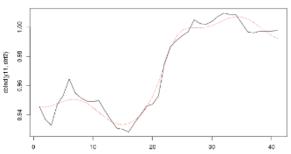

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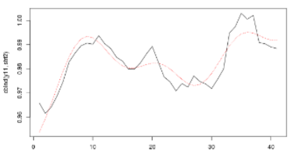

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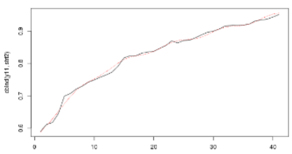

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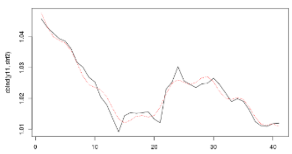

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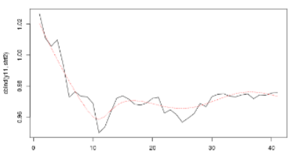

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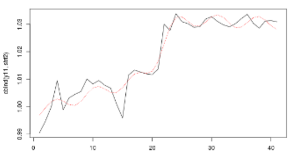

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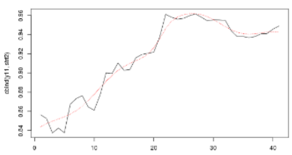

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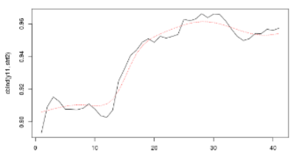

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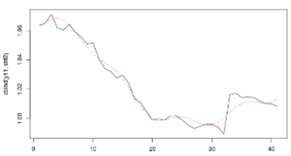

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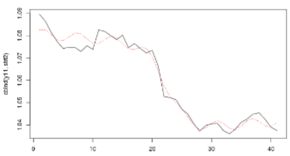

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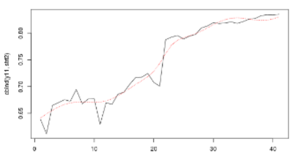

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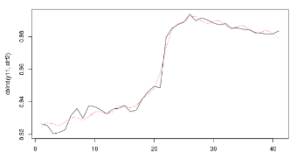

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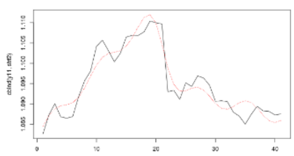

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