31. BÖLÜM / CHAPTER 31

SMOOTH BREAKS AND MEAN REVERSION IN INFANT MORTALITY RATES

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ABSTRACT

In this study, we examine the time series characteristics of infant mortality rates (IMR) of 33 countries by employing the Fourier augmented Dickey-Fuller test with fractional frequencies (FFADF) to allow multiple temporary and permanent smooth structural breaks. The main results of the study show that Fourier functions are significant in 22 countries, that is, we must consider multiple smooth changes when testing the stationarity of these variables, so we apply the FFADF unit root test to examine the stationarity of the IMRs for these countries and the ADF unit root test for the remaining countries. The results show that the IMR series of 20 countries are stationary; that is, shocks have an only transitory effect on the IMR. Policymakers in the health sector should consider the integration levels of IMR since policy interventions have a transitory effect if the IMR is stationary.

Keywords: Fourier Functions, Infant Mortality Rates, Smooth Breaks

1. Introduction

Infant mortality rates are of crucial importance among economic and social policies. Studies show that there is a strong relationship between infant mortality rates (IMR) and level of socioeconomic development (Rydell, 1976; Lusting, 2004; Bloom and Canning, 2000). The risk of mortality of an infant in a country is mainly determined by factors such as the socioeconomic dynamics of that country, its cultural codes, poverty levels, income inequality and sufficiency of the health care services supported by the state (Ergin, Hassoy, 2011). Within the scope of sustainable development and the struggle against poverty, the fourth goal of the "Millennium Development Goals" accepted by 147 countries at the UN General Assembly in September 2000 is reducing IMR. The Millennium Development Goals are composed of 8 goals in total, and the fourth of these is "to reduce the under-five mortality rate by two-thirds in the period between 1990 and 2015". The fact that this issue has been addressed in the Millennium Development Goals also shows that the frequency of under-five child mortality is accepted as an important indicator of countries' social and economic status. Research has revealed that a vast majority of infant mortality in the world takes place in underdeveloped countries and is often due to a curable sickness (UNICEF, 2011).

The reduction speed of IMR is higher in underdeveloped and developing countries than developed countries because infant mortality in underdeveloped and developing countries is frequently caused by curable diseases with low treatment costs. Since the health of the population can be improved with low costs and easy treatment methods (such as a vaccine), the reduction speed of IMR is higher. However, since easily treatable diseases have already been prevented in developed countries, reduction in IMR in developed countries is slower than in underdeveloped or developing countries. This shows that a reduction in mortality rates takes place at high speed up to a certain welfare level, and after that point, IMR decreases at a slower speed (Ram, 2010). This is an application of the law of diminishing returns to the health of modern society. According to this law, as a society becomes healthier, the provision of health-improving inputs becomes harder and more expensive (Bishai, 2007). Another way of viewing the speed of IMR is through the lens of the Matthew Effect, which has an opposing view of changes in the speed of IMR from the law of diminishing returns. This term, which was first used in 1968 by the sociologist Robert K. Merton, is named after Matthew (25:29) verse in the Bible. Matthew (25:29): "*For to everyone who has will more be given, and he will have an abundance. But from the one who has not, even what he has will be taken away*". The Matthew Effect in sociology is used to describe a situation where the rich become even richer, and the poor become poorer. That is to say, the ones with high economic power will attain even more economic power and capital by utilizing this power. In the literature on the health of modern society, the Matthew Effect implies that if the IMR is low, the speed of decrease in the IMR will be higher. The Matthew Effect in infant mortality opposes the law of diminishing returns by suggesting an increase in the reduction of IMR, given that the IMR is already low. The Matthew Effect suggests that it is easier for societies to improve the health of babies as the IMR decreases.

By following the study of Bishai et al. (2007), one can estimate the following model for testing the validity of the Matthew Effect:

$$IMR_t = \alpha + \phi t + \delta IMR_{t-1} + \varepsilon_t \tag{1}$$

This model allows us to analyze the effect of the infant mortality rate of the previous year on the change in the infant mortality rate during the current year. This model shows that if $\delta<1$ occurs, the IMR_t series will be smaller than its value in the previous year, and IMR_t decreases as time passes. This validates the Matthew Effect. Subtracting IMR_{t-1} from both sides of Model (1) leaves us with the following model:

$$\Delta IMR_t = \alpha + \phi t + \beta IMR_{t-1} + \varepsilon_t \tag{2}$$

It is $\beta = \delta - 1$ here, therefore testing $\delta<1$ in Model (1) is equivalent to testing $\delta<1$ in Model (2). For the Matthew Effect to be valid, the necessary requirement Model (2) needs to satisfy (β parameter to be negative and significant) is that the IMR series does not econometrically include the unit root. This means that unit root tests can be utilized in testing the validity of the Matthew Effect hypothesis. Rejecting the null hypothesis, namely the series being stationary, results in the validity of the Matthew Effect hypothesis.

Since the IMR variable is accepted as a credible indicator of prosperity in countries, presenting the long-term time series characteristics of this variable is important due to three distinct reasons. The first reason is that the long-term time series characteristics of this variable inform what policymakers might implement in the fields of health and education. If the IMR variable is stationary, then the effect of shocks will be transitory, but if the series is not stationary, then the effect of shocks will be permanent and political interventions will become inevitable. The second reason is to determine the type of econometric methodology that should be used to test the relationship between IMR and other variables by considering the integration levels. For instance, in order to decide which method to utilize in analyzing the relationship between IMR and economic growth, one needs to know the time series characteristics of the IMR variable. Another crucial point is that countries having different levels of integration leads convergence theory to be invalid. These three reasons are why it is necessary to determine the stationarity of the IMR (Alana et al., 2017).

In this study, the time series characteristics of the IMR is analyzed for 34 countries. This enabled us to implement a cross country comparison. Fractional Frequency ADF (FFADF) Unit Root Test is used to test the stationarity of the IMR variable. With the help of the FFADF unit root test, we do not need to know the number, locations, and form of the structural breaks a priori. The studies in the literature that examine the stationarity of the IMR often do not take structural breaks into account. As mentioned in Perron (1989), not taking the structural changes into consideration could lead to biased results from unit root tests. To the best of our knowledge, this is the first study in which stationarity of infant mortality rates is tested while taking the structural changes into consideration.

The rest of the study is designed as follows: The second section includes the literature on the times series characteristics of the IMR variable. The econometric methodology used in the analysis of the IMR variable's time series characteristics is presented in the third section. The fourth section includes the data and implementation results. The fifth section consists of the political implications of the results.

2. Literature Review

Due to the IMR variable being an important welfare indicator and the controversial relationship between the changes in IMR and economic and socioeconomic indicators, the IMR variable has become a widely analyzed topic in the literature. In his study, Bishai (2007) tested the validity of the Matthew Effect hypothesis by applying the DFGLS unit root test using data from 21 countries covering the time period from 1870-1988. The results of this study show that the majority of countries studied the IMR series are not stationary, and the Matthew Effect is not valid.

Rydell (1976) analyzed the movement of the IMR variable against social and medical developments. He stated that a decrease in IMR could take place due to social reforms, not just medical progress. Rydell also claimed that the difference between infant mortalities in rural and urban areas could only be eliminated by implementing social policies. Hunt and Chenoweth (1961) analyze the tendency of IMR in the US by examining the data- from age groups, cities, and racial perspectives using regression analysis and Chi-square analysis. According to them, the interruption in the downwards trend in IMR that began in 1957 and the tendency of increase in the post-1957 period is due to a changing population and changing needs. Bishai (2009) analyzed the IMR series in 18 countries and reached the conclusion that the speed of infant mortality decreased exponentially in only one country, and for the other 17 countries, the slope of the IMR variable was not compatible with the logarithmic conversion. Caporale and Gil-Alana (2014) analyzed the tendency of the IMR variable over time for 24 countries using the fractional unit root test, which enables time series variables to have fractional levels of integration. They found that the IMR's levels of integration differed from country to country. Another study, which analyzes the time series characteristics of IMR was completed by Gil-Alana, Cumado, and Gupta (2017). They concluded that the degrees of linearity and integration differ for several series. They argued that convergence would not take place between countries due to the differences in the level of integration of the IMR variable.

3. Method

While Bishai (2007) uses the Augmented Dickey-Fuller unit root test, whether the Matthew effect is valid or not, Caporale and Gil-Alana (2015) and Gil-Alana et al. (2017) apply fractional unit root tests to examine the stationarity of IMR. That is, these studies ignore structural breaks in the data generating process. As emphasized by Perron (1989), in the existence of structural breaks, standard unit root tests produce biased results. In light of that consideration, in this study, we consider structural breaks by using the following equation introduced by Enders and Lee (2012):

$$\Delta IMR_t = \alpha + \phi t + \beta IMR_{t-1} + \delta_1 \sin\left(2\pi kt/T\right) + \delta_2 \cos\left(2\pi kt/T\right) + \varepsilon_t \tag{2}$$

Where $\pi = 3.1416$, T and k indicate the number of observations and number of frequencies in the Fourier function. The underlying reason for including the Fourier function in the equation is to consider the effect of the unknown nature of structural breaks. We follow the method of Ludlow and Enders (2000) who showed that a single frequency is enough for structural break determination and use a single frequency.

To find the optimal frequency, we estimate Equation 2, for values of k between the intervals $0 < k \leq 5$ and select the value that yields the smallest residual sum of squares. Based on the suggestions of Christopoulos and Leon-Ledesma (2011) and Omay (2015), we also allow fractional values for k. After determining the optimal k value, we test whether the Fourier function is significant or not. In other words, we determine the linearity of the series by performing the usual F test for the null $\delta_1 = \delta_2 = 0$. The critical values for the null are obtained from Table 1 in Becker et al. (2006). Non-rejection of the null leads us to use standard unit root tests such as ADF. In the case of rejection of the null, we compute the t-statistic for the null hypothesis of the unit root $\beta = 0$. By using the FFADF unit root test, we do not need to determine the location, number, or forms of the breaks. The critical values for the FFADF unit root test are obtained from Bozoklu et al. (2020).

4. Data and Results

We tested the stationarity of the IMR for 33 countries using infant mortality rate data that corresponds to the number of infants dying before reaching one year of age, per 1000 live births, in a given year. We obtained this data from the Human Mortality Database at the University of California.

The start and end date of the series varies and is reported in the second column of Table 1.

Table 1
Date range for the IMR Series

Countries	Date Range	No. Of Observations
Australia	1921-2014	94
Austria	1947-2017	71
Belarus	1959-2016	58
Canada	1921-2011	91
Czechia	1950-2016	67
Denmark	1853-2016	182
Estonia	1959-2017	59
Finland	1878-2015	138
France	1816-2016	201
Greece	1981-2013	33
Hungary	1950-2017	68
Iceland	1838-2016	179
Ireland	1950-2014	65
Israel	1983-2016	34
Italy	1872-2014	143
Japan	1947-2016	70
Latvia	1959-2017	59
Lithuania	1959-2017	59
Luxembourg	1960-2014	55
Netherlands	1850-2016	167
New Zealand	1948-2013	66
Norway	1846-2014	169
Poland	1958-2016	59
Portugal	1940-2015	76
Russia	1959-2014	56
Slovakia	1950-2014	65
Slovenia	1983-2014	32
Spain	1908-2016	109
Sweden	1751-2016	266
Switzerland	1876-2016	141
Taiwan	1970-2014	45
Ukraine	1959-2013	55
United Kingdom	1922-2016	95
USA	1933-2016	84

We first tested the null hypothesis of the insignificance of the trigonometric terms via F statistics and tabulated the results in Table 2.

Table 2

The Results of the F tests

Countries	Frequency	Min. SSR	F Test Statistic
Australia	0.1	0.0003	12.1307*
Austria	0.8	0.0001	4.5713
Belarus	3.3	0.0001	5.8442
Canada	0.2	0.0006	18.6189*
Czechia	0.8	0.0001	10.8888*
Denmark	1.9	0.0191	7.1979
Estonia	1.7	0.0001	4.1709
Finland	0.8	0.0079	23.2435*
France	1.4	0.0319	32.9968*
Greece	0.1	0.0001	13.2308*
Hungary	0.1	0.0003	5.2562
Iceland	0.9	0.5960	21.0263*
Ireland	0.4	0.0001	12.2326*
Israel	0.7	0.0001	9.9295*
Italy	0.1	0.0094	14.1362*
Japan	0.1	0.0001	118.7691*
Latvia	3.6	0.0001	3.4056
Lithuania	4.1	0.0001	3.6701
Luxembourg	0.1	0.0002	9.6984*
Netherlands	1.2	0.0249	39.2381*
New Zealand	0.1	0.0001	18.5623*
Norway	1.2	0.0038	16.9750*
Poland	0.1	0.0002	1.6998
Portugal	0.1	0.0020	12.6007*
Russia	2.9	0.0001	6.6725
Slovakia	1.8	0.0007	0.6924
Slovenia	0.1	0.0001	10.0716*
Spain	1	0.0091	10.5701*
Sweden	0.7	0.0420	24.9857*
Switzerland	0.7	0.0042	13.6471*
Taiwan	2	0.0001	4.0359
Ukraine	3.3	0.0001	5.9498
United Kingdom	0.8	0.0006	7.8765*
USA	0.1	0.0002	9.4973*

Note: the 10% critical values for T=100 and T=200 are 7.78 and 7.62 respectively. * indicates statistical significance.

We find strong evidence of nonlinearity for the IMR series of Australia, Canada, Czechia, Finland, France, Greece, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, and the USA since the F statistics for the null of $d_1 = d_2 = 0$ are greater than the critical value at the 10% level. As can be seen in Appendix 1, the fitted function fit well with the IMR series for these countries.

We test the stationarity of the IMR series of the countries in which the Fourier function is significant by implementing the FFADF unit root test, and we apply the ADF unit root test for the remaining IMR series. Both the results of ADF and FFADF unit root tests are reported in Table 3.

Table 3

Results of the Unit Root Tests

Countries	**ADF**	**FADF**
Australia	-	-4.6683 (7)*
Austria	-4.9414 (5){0.0001}*	-
Belarus	-1.3273 (4){0.6103}	-
Canada	-	-2.4768 (10)
Czechia	-	-5.4514 (8)*
Denmark	-1.473 (10){0.545}	-
Estonia	-2.0783 (2){0.254}	-
Finland	-	-4.9023 (14)*
France	-	-5.2032 (17)*
Greece	-	-4.1720 (5)*
Hungary	-2.8346 (10){0.0598}*	-
Iceland	-	-4.4102(16)*
Ireland	-	-3.7280 (8)*
Israel	-	-4.2275 (3)*
Italy	-	-5.3083 (3)*
Japan	-	-0.5413 (10)
Latvia	-0.4496 (10){0.8918}	-
Lithuania	-5.8614 (0){0.000}*	-
Luxembourg	-	-2.5327 (11)
Netherlands	-	-3.3121 (13)
New Zealand	-	-4.1496 (3)*
Norway	-	-3.1623(15)
Poland	-2.8174 (10){0.0633}*	-
Portugal	-	-3.3882 (1)

Russia	-1.3553 (1){0.5972}	-
Slovakia	-0.9612 (10){0.7607}	-
Slovenia	-	-5.0426 (3)*
Spain	-	-5.1496 (12)*
Sweden	-	-5.7003 (13)*
Switzerland	-	-4.0466 (14) *
Taiwan	-3.2395 (0){0.0242}*	-
Ukraine	0.4140 (10) {0.9814}	
United Kingdom	-	-2.6277 (10)
USA	-	-6.0530 (10)*

Note: * shows significance. Numbers in parentheses show the optimal lag length that is determined using general to specific lag length criteria. Numbers in the braces show the p-values.

The results of the ADF unit root tests show that the IMR series of Austria, Hungary, Lithuania, Poland, and Taiwan are stationary. On the other hand, when we analyze the results of the FFADF test, we first notice that values of the frequencies are generally smaller than 2. When we analyze the results of the FFADF test, we see evidence in favor of the alternative hypothesis of stationarity for the IMR series of Australia, Czechia, Finland, France, Greece, Iceland, Ireland, Israel, Italy, New Zealand, Slovenia, Spain, Sweden, Switzerland, and the USA. That is, we see that shocks have only transitory effects on the IMR series of these countries. On the other hand, by considering Bishai (2007), we can conclude that the Matthew effect is valid for these countries. We find no evidence of stationarity for the IMR series of Belarus, Canada, Denmark, Estonia, Japan, Latvia, Luxembourg, Netherlands, Norway, Portugal, Russia, Slovakia, and Ukraine that shows that transitory shocks will not disappear in the long run.

5. Conclusion

The stationarity of the IMR series of the 33 countries was tested by utilizing the FFADF unit root test, which takes smooth breaks into consideration. Test results indicated that Fourier functions were significant in 22 countries, so we tested the stationarity of the series by employing the FFADF unit root test for these countries. For the remaining countries, we utilized the ADF unit root test. According to the results of the unit root tests, the IMR was found to be stationary in Australia, Austria, Czechia, Finland, France, Greece, Hungary, Iceland, Ireland, Israel, Italy, Lithuania, New Zealand, Poland, Slovenia, Spain, Sweden, Switzerland, Taiwan, and the US, but non-stationary in Belarus, Canada, Denmark, Estonia, Japan, Latvia, Luxembourg, the Netherlands, Norway, Portugal, Russia, Slovakia, and Ukraine.

Given that the shocks in IMRs in the countries in which the IMR variable is stationary are not permanent, changes in IMR over time can be used as an important health indicator for policymakers. In countries where the IMR variable is non-stationary, on the other hand, attention should be paid to the effects of shocks because the effect of shocks on non-stationary series will not disappear over time. State intervention may be needed in such countries. In addition to this, countries having different levels of integration indicates that inter-country convergence is not possible.

Additionally, based on the research of Bishai (2007), one can claim that the Matthew Effect is valid in countries in which IMR is stationary. In these countries, increasing support for novelties in the health sector increases the speed of decrease in IMR. On the other hand, the 13 countries where the Matthew Effect hypothesis was not valid seem to support Bishai (2007) in arguing that it would not be correct to accept the Matthew Effect hypothesis as fact and use it to make generalizations in health reforms.

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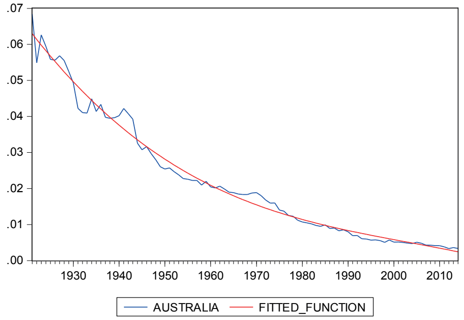
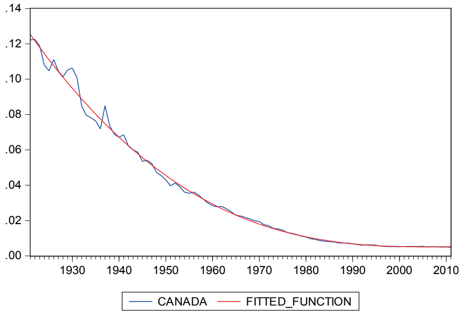
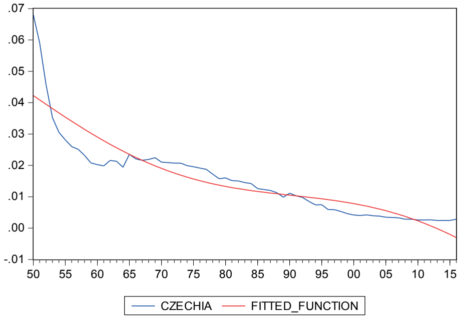
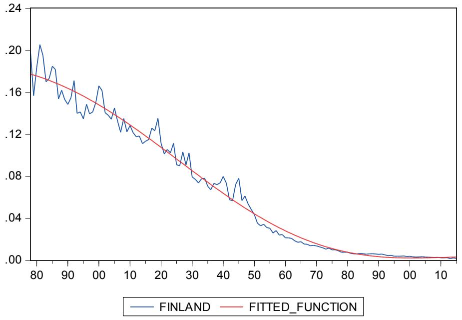
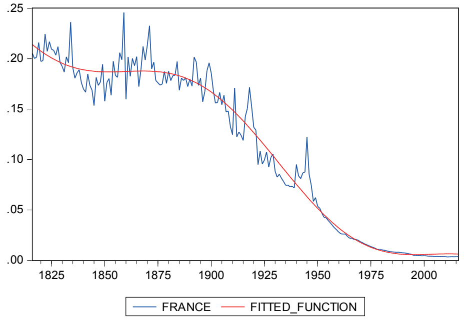
Appendix 1. IMR and Fitted Functions

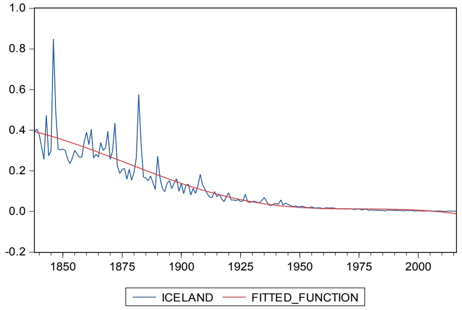


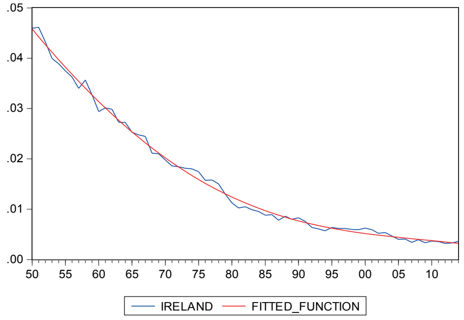


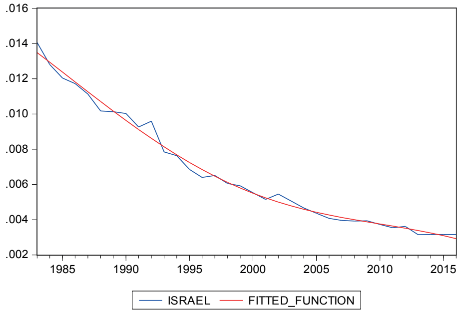


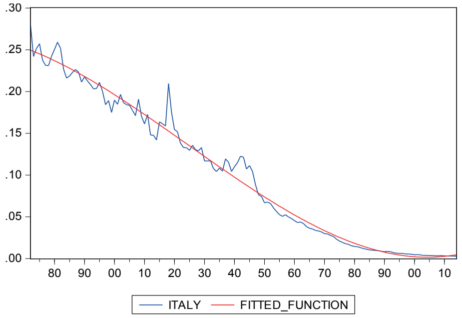








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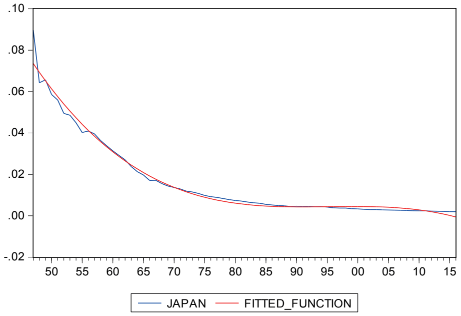
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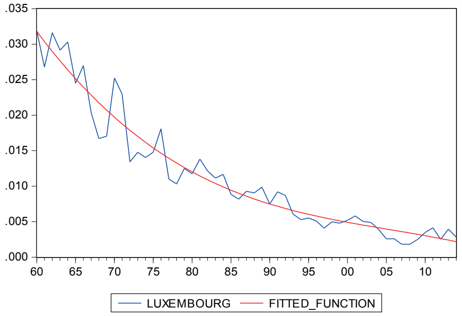
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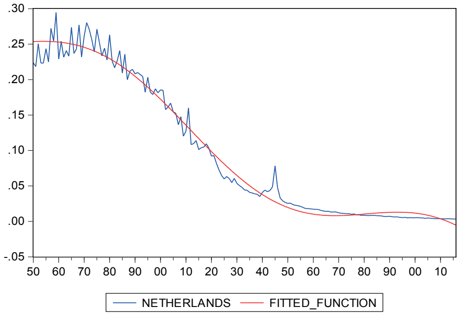
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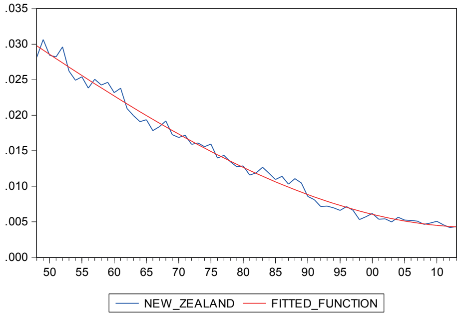
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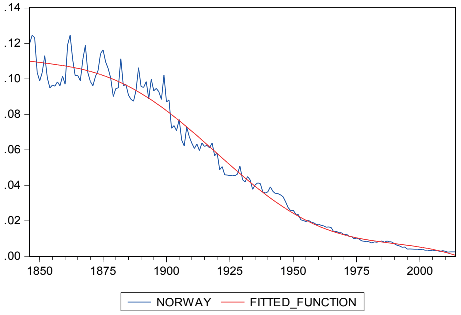
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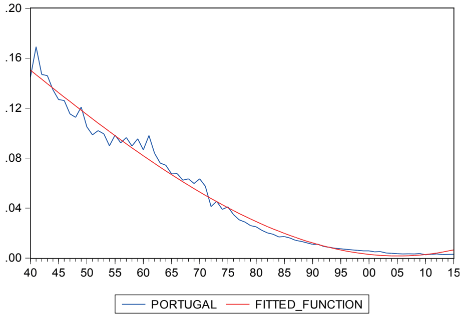
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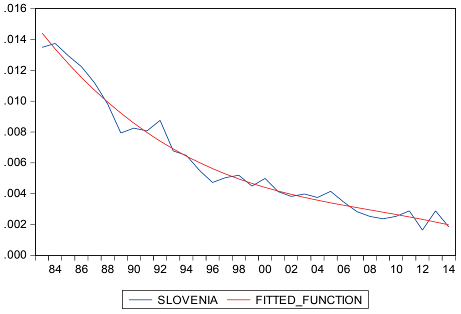
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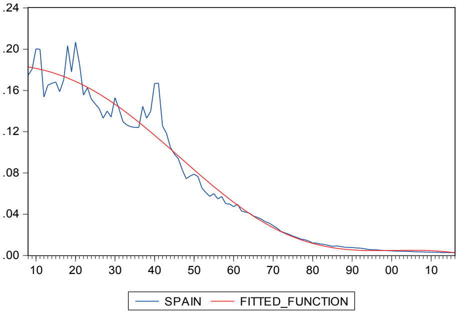
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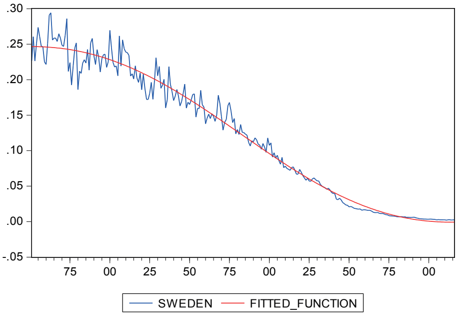
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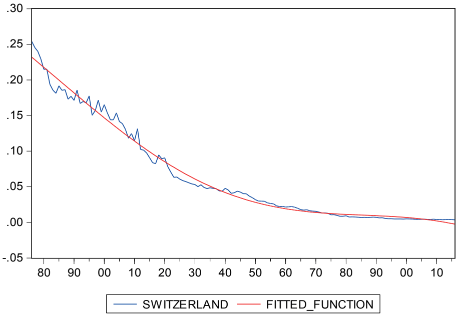
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SWITZERLAND
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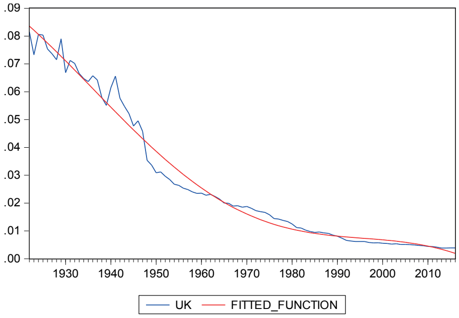
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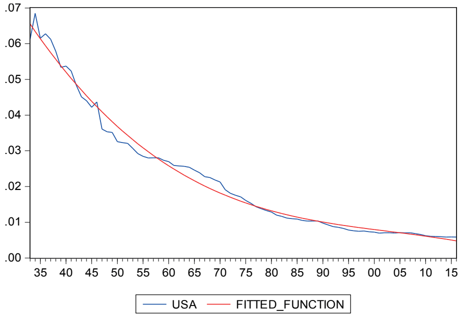
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USA
FITTED_FUNCTION