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Mortality (Dis)Similarities in the Context of Demographic Aging: The Countries of Ex-Yugoslavia

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Abstract

Generally, mortality declines at all ages, with varying intensities, as a result of heterogeneous factors affecting human lifespan. This paper considers switching regression estimation for six ex-Yugoslavian countries with the specification of a time-varying transition probability model of crude death rate. A two-state Markov switching means VAR estimates are used in which the mean growth rate of crude death rate is subject to regime switching, where the errors follow a constant transition probability. The UN data were employed consisting of the crude mortality rate series containing the log difference of yearly crude mortality rate in the six countries of ex-Yugoslavia for 1990–2021. The results show that the estimates of coefficients on the intercept in the mean equation both differ from zero in Bosnia & Herzegovina, Serbia, Montenegro, and Slovenia and are with opposite and statistically significant signs only for Montenegro and Slovenia. The transition probability summaries show a higher probability of remaining in the first high regime state for Macedonia, Serbia, and Bosnia & Herzegovina (0.96, 0.94, and 0.87, respectively). The higher probability of remaining in the second low-medium regime state was found in Slovenia, Croatia, and Montenegro (0.96, 0.87, and 0.56, respectively). The appropriate expected durations in the first regime are approximately 26.41, 16.19, and 7.78 years for Macedonia, Serbia, and Bosnia & Herzegovina, and 28.30, 7.80, and 2.28 years were the corresponding expected durations in the second regime for Slovenia, Croatia, and Montenegro.

Keywords: crude death rate, longevity, demographic aging, ex-Yugoslavia, Switching VAR, regime-switching, transition probability, Markov switching means

1. Introduction

The challenges to human mortality and longevity have not only increased significantly in recent decades but are also increasing with the process of population aging (Basellini et al., 2022). Population aging defined as an increasing share of elderly people in the population is a phenomenon that has gained significant importance during the last decades and will remain one of the most significant social dramatic changes in the 21st century, with challenges for almost all sectors of society (Cameron, 2023; Miladinov, 2024). The demographic transition, which refers to the reduction of fertility and mortality over a longer period, results in a significant shift in the age structure of the population towards older ages (Yin & Bennett, 2012). Populations experienced a continued increase in longevity, most countries in the world witness demographic aging where longevity is increased. Generally, mortality declined at all ages, with varying intensities, as a result of heterogeneous factors affecting human lifespan. Over the last two centuries, most countries in the world have seen significant improvements in longevity (Atance et al., 2024). While countries differ in their trajectories and improvements in mortality levels, many similarities have been found, such as a shift from high infant mortality to patterns where older ages are more important. During the mortality transition process, longevity increases as life expectancy at birth is affected by the development of mortality in younger and middle age and it is therefore essential to assess the effect of cohort effects on mortality rates (Zafeiris et al., 2020). Hence, accordingly, the mortality rate could be regulated by three determinants: age-related changes in individuals, the environment in which individuals live, and qualitative differences between individuals (Zafeiris et al., 2020). Cause-specific mortality rates reflect numerous influences and processes ranging from medical advances, and changes in lifestyle and diet to epidemics and aging (Arnold & Glushko, 2021). Thus, despite the evident differences between the past experiences of different countries, it is still reasonable to happen that some of these processes are just as likely to be present in all countries as a result of their universal character, for example, aging (Arnold & Glushko, 2021). The crude death rate is a function of both the age-specific rates and the proportional distribution of the population across ages (Sankoh et al., 2014). Therefore, in a population, it is clear that the crude death rate depends on the age patterns of both mortality and the population (Kostaki, 1992; Liang et al., 2023). Data statisticians and demographers describe and estimate the mortality pattern of a population for mortality analysis as well as for the presentation of population projections (Karlis & Kostaki, 2002).

This study explored crude death rates across the countries of the former Yugoslavia for the period 1990-2021, using data from the UN World Population Prospects (UN, 2022) to assess differences between crude death rates. The six countries differ in population size, geographical location, histories and lifestyle and their mortality peaks appear differently in all six countries. This research work aimed to describe a novel application of the advanced econometric method to 1) explore the extent of differences in crude death rates across ex-Yugoslav countries, and 2) determine differences in crude death rates associated with differences in demographic aging across the countries in former Yugoslavia. The contribution of this research work to demographic literature is providing an interesting comparison of different demographic regimes by analyzing the evolution of mortality rates in former Yugoslav countries during the last three decades. Therefore, a useful perspective was given on the crude death rate in former Yugoslav countries in terms of different demographic regimes over three decades. Therefore, the study aims to determine the regimes that the crude death rate exhibits, to determine the time spent in these regimes and the probability of switching from one regime to another with the Markov regime-switching model. In this study, it has been determined that the crude death rate (CDR) shows two regimes: high-death rate regime and low-medium-death rate regime. The paper is organized as follows: Section 2 briefly presents the country's background regarding crude death rates. Section 3 presents data that are used in the study, and then continues with the method used. The application of Markov switching means VAR to the data is presented in Section 4, providing the main results and discussion. Section 5 concludes the paper.

2. Brief Country's Background

Mortality rates in former Yugoslavia experienced a shift toward increasing after 1990 with pronounced regional differences in mortality patterns (Josipovič, 2016). With a crude death rate of 14.2 per 1000, Serbia is among the most vulnerable countries in Europe (Miladinov, 2024). Serbia is currently experiencing several significant population challenges resulting in depopulation and an aging population (Rašević & Galjak, 2024). Thus, since the beginning of the twenty-first century, the population of Serbia has been aging at an increasing rate. It is very certain that shortly, Serbia's population will continue to age (Rašević & Galjak, 2024) so the proportion of elderly people in the total population of Serbia is expected to reach 27% by 2050. A comparison of crude death rate for 2019 between some ex-Yugoslav countries shows that Serbia is the leader (14.1 per 1000), followed by Bosnia and Herzegovina (12.3 per 1000), Montenegro (10.8 per 1000), and Macedonia (9.3 per 1000)

(Miladinov 2024; UN, 2022). Changes in mortality had a double effect on demographic aging in the former Yugoslavia: the process was slowed by the decline in youth mortality and, at the same time, accelerated by the increase in the life expectancy of the old (Penev, 2023). Overall, the decline in mortality in the former Yugoslavia until the 1990s caused a slowdown in the aging of the population (Penev, 2023). After the dissolution of Yugoslavia and the war in Croatia (1991–1995), crude death rates rose to 11.2 in Croatia and remained low in Slovenia (9.8), so that over the last 25 years the crude death rate in Croatia rose to 11.9, and stagnated in Slovenia (9.5), (Graovac-Matasi & Josipović, 2023).

The aftermath of the Civil War in Bosnia and Herzegovina from 1993 to 1995 had enormous but transient effects on the population of Bosnia and Herzegovina, which quickly returned to pre-war levels of life expectancy (Zafeiris & Skiadas, 2024). This war period affected all features of the mortality regime in Bosnia and Herzegovina, thus affecting mortality, especially among men, the survival of the population, as well as the modal age at death. The Bosnian civil war hit people aged 30-44 the hardest, while outcomes for younger age groups were more moderate. Shortly after the end of the Civil War, mortality was higher among older women (65+). After these terrible events, the mortality transition continued, and the average life expectancy increased in Bosnia and Herzegovina. Therefore, in Bosnia and Herzegovina, a gradual decrease in the probability of death occurred over time despite the huge increase in these probabilities during the period of civil war (Zafeiris & Skiadas, 2024). Mortality was higher in the late 1980s and early 1990s in Bosnia and Herzegovina in all age groups. After the war until 2009, life expectancy was higher in Bosnia than in Montenegro because, with few exceptions, mortality was lower in all age groups (Zafeiris & Skiadas, 2024). After 2009, this situation is reversed due to excess mortality among the oldest population (65+) in Bosnia and Herzegovina. The mortality transition continued in Bosnia and Herzegovina and Montenegro, even in recent years this trend slowed.

3. Data and Methods

The data for this study were obtained through a UN database, which consists of the crude mortality rate series containing the log difference of yearly crude mortality rate in the six countries of ex-Yugoslavia for 1990–2021 (https://population.un.org/wpp/), (UN, 2022).

This paper considers switching regression estimation for six ex-Yugoslavian countries with the specification of a time-varying transition probability model of crude death rate. A two-state Markov switching means VAR estimates is used in which the mean growth rate of crude death rate is subject to regime switching, and where the errors follow a constant transition probability. A time series variable can be modeled with a p -order Markov regime-switching model with regime shifts in mean and variance (Ustaoğlu, 2022). A short description for switching VAR models with the standard k-dimensional VAR (p) process is shown in eq. (1), (IHS, 2020).

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + \mu_t + \epsilon_t \qquad (1)$$

where

$y_t = (y_{1t}, y_{2t}, \ldots, y_{kt})'$ is a $k \times 1$ vector of endogenous variables,

$A_1, \ldots, A_p$ are $k \times k$ matrices of lag coefficients that should be estimated,

μ_t is a $k \times 1$vector of intercepts,

$\epsilon_t = (\epsilon_{1t}, \epsilon_{2t}, \ldots, \epsilon_{kt})'$ is a $k \times 1$ white noise innovation process.

Innovation vectors are simultaneously correlated with the full rank matrix Σ_ϵ, but uncorrelated with their innovation lags and assumed to be uncorrelated with all right-hand side variables. Furthermore, eq. (1) is modified to allow for regime switching, so that it follows a VAR process that depends on the value of an unobserved discrete state variable s_t (Krolzig, 1997; IHS, 2020). It is assumed that there are $m = 1, \ldots, M$ possible regimes and when being in a regime m in period t, then $s_t = m$. The VAR regime model in our research study takes the form of switching mean as shown in eq. (2).

$$y_t - \mu_t(s_t) = \sum_{j=1}^{p} A_j(s_t)\left(y_{t-j} - \mu_{t-j}(s_{t-j})\right) + \epsilon_t \qquad (2)$$

It is assumed that the errors are distributed as $\epsilon_t \sim N(0, \Sigma_\epsilon(s_t))$ for $s_t = 1, \ldots, M,$ with density function presented in eq. (3).

$$f(\epsilon \mid \Sigma) = \frac{1}{(2\pi)^{k/2}|\Sigma|^{1/2}} \exp\left(-\frac{1}{2}\epsilon'\Sigma^{-1}\epsilon\right) \qquad (3)$$

Usually, the parameters in the VAR specification are divided into three groups: the intercept parameters μ, the endogenous variables parameters A, and the error variance parameters Σ. The notion that the error term depends on an unobserved state variable is the key to the analysis of a switching VAR model. Using the eq. (2) can be obtained a form (eq. 4) for the error in terms of the observed data and current and past observed states.

$$\epsilon_t(S_t) = y_t - \mu_t(s_t) - \sum_{j=1}^{p} A_j\,(s_t)\,\left(y_{t-j} - (s_{t-j})\right) \quad (4)$$

Where $S_t = (s_t, s_{t-1}, \dots, s_{t-p})$ is a $p+1$ dimensional state vector presenting the current and p previous regimes, where $M^*(\text{possible states}) = M^{p+1}$. In switching mean specifications $S_t = m$, it is interpreted as for S_t being equal to m-th possible realization of the $p+1$ dimensional vector, as presented in eq. (5).

$$S_t = (a_0(m), a_{-1}(m), \dots, a_{-p}(m)) \quad (5)$$

Where $a_k(m)$ is the value of k-th lagged state in the m-th possible realization, for $m = 1, \dots, M^*$.

The first-order Markov assumption requires that the probability of being in a regime depends only on the previous state, so the regime probability function will be specified as in eq. (6).

$$P(S_t = j | S_{t-1} = i, S_{t-2} = k \dots) = P(S_t = j | S_{t-1} = i) = p_{ij}(t) \quad (6)$$

Usually, it is assumed these transition probabilities be time-invariant where $p_{ij}(t) = p_{ij}$ for all t but however, there is no strong requirement of this restriction. The transition probabilities can be presented in a transition matrix as well, eq. (7).

$$p(t) = \begin{bmatrix} p_{11}(t) & \dots & p_{1M}(t) \\ . & \dots & . \\ p_{M1}(t) & \dots & p_{MM}(t) \end{bmatrix} \quad (7)$$

Where the ij-th element presents the probability of transition from regime i in period $t-1$ to regime j in period t. The process where the predicted $P(S_t = m \mid \mathfrak{J}_{t-1})$ probability estimates are upgraded to the form $P(S_t = m \mid \mathfrak{J}_t)$ is usually termed filtering. The repeated procedure may be divided into three steps (Krolzig, 1997; Hamilton, 1990). Thus, each step of the procedure starts with initial filtered estimates of the regime probabilities, $P(S_0 = m \mid \mathfrak{J}_0)$ for the previous period, or alternately, the initial one-step ahead regime probabilities, $P(S_1 = m \mid \mathfrak{J}_0)$. First, the one-step-ahead predictions of the regime probabilities are formed using the basic rules of probability and the Markov transition matrix. Next, these one-step-ahead probabilities are used to form the one-step-ahead joint densities of the data and regimes in period t. The likelihood contribution for period t is obtained by summing the joint probabilities across unobserved states to obtain the marginal distribution of the observed data. The final step is to filter the probabilities by using the results of one-step-ahead probabilities to update one-step-ahead predictions of the probabilities.

4. Results and Discussion

The switching VAR estimation was considered using yearly CDR data for a set of the six former Yugoslav countries obtained from the UN database (https://population.un.org/wpp/). Therefore, a Markov switching mean model with regime-specific intercepts and lagged endogenous was estimated for this study. Thus, a two-state Markov switching mean VAR(2) with switching mean regressor C, switching VAR lag coefficients, and common error variance (MSMA-VAR(2)) was estimated. Initially, the stationarity characteristics of the series were investigated. Therefore, Augmented Dickey-Fuller (ADF) test statistics and Automatic SIC (Schwarz info criterion) tests were used for the crude death rate series. It was determined that the crude death rate (CDR) series for all six countries contained a unit root in line with both ADF unit root test results and SIC, i.e., the series were not stationary. The first difference of the variable of crude death rate was taken and then all the series were stationary at the 1% significance level based on both ADF and SIC unit root test results. Related unit root test results are presented in the Appendix. As the stationary was established, it was resolved that the most suitable Markov regime-switching model for the crude death rate series based on the information criteria is the MSMA-VAR(2) model with two regimes with the constant term (C) and common error variance. Table 1 presents results for the regime varying results; for regime 1 and regime 2:

Table 1. Markov Switching Means VAR Estimates

Markov Switching Means VAR estimates

Sample (adjusted): 1993-2021. Included observations: 29 after adjustments.						
Number of states: 2. Initial probabilities obtained from ergodic solution						
Standard errors & covariance computed using observed Hessian						
Random search: 25 starting values with 10 iterations using 1 standard deviation (rng=kn, seed=1159345209)						
Convergence achieved after 41 iterations (Bosnia); 46 iterations (Croatia); 16 iterations (Macedonia & Slovenia); 26 iterations (Montenegro) and 31 iterations (Serbia). Coefficients, Standard errors in ( ) & z statistic in [ ]						
	D(Bosnia)	DLOG(Croatia)	D(Macedonia)	D(Montenegro)	D(Serbia)	D(Slovenia)
	Regime 1	Regime 1	Regime 1	Regime 1	Regime 1	Regime 1
D(CDR(-1))	0.0367 (0.0468) [0.7857]	-1.1202 (0.2285) [-4.9036]	-0.4195 (0.1789) [-2.3450]	-0.5589 (0.4416) [-1.2657]	0.2665 (0.3437) [0.7753]	-1.8771 (0.2557) [-7.3399]
D(CDR(-2))	0.1197 (0.0379) [3.1599]	-3.1504 (0.6009) [-5.2430]	-0.1359 (0.1827) [-0.7439]	-0.2006 (0.6302) [-0.3183]	0.6961 (0.3398) [2.0483]	-1.6048 (0.5681) [-2.8251]
C	0.0750 (0.1056) [0.7102]	0.0431 (0.0053) [8.0790]	0.0520 (0.0216) [2.4083]	-0.2725 (0.0986) [-2.7648]	2.4807 (0.1862) [13.322]	0.5520 (0.0536) [10.288]
	Regime 2	Regime 2	Regime 2	Regime 2	Regime 2	Regime 2
D(CDR(-1))	0.2075 (0.0443) [4.6796]	-0.0983 (0.1680) [-0.5854]	1.1800 (0.1396) [8.4519]	-0.2606 (0.2051) [-1.2707)	-0.2734 (0.0940) [-2.9072]	-0.2904 (0.1805) [-1.6085]
D(CDR(-2))	-0.9429 (0.0387) [-24.339]	0.1369 (0.1182) [1.1583]	-5.5423 (0.5624) [-9.8542]	0.3929 (0.1970) [1.9942]	-0.1306 (0.0714) [-1.8295]	0.1915 (0.1827) [1.0481)
C	1.5992 (0.2262) [7.0699]	0.0039 (0.0028) [1.3975]	0.0484 (0.0630) [0.7683]	0.3668 (0.0587) [6.2447]	0.0760 (0.0355) [2.1432]	-0.0001 (0.0356) [-0.0003]
	Common					
SIGMA-D(CDR)	0.1384 (0.0389) [3.5537]	0.0004 (0.0001) [3.1306]	0.0389 (0.0106) [3.6619]	0.0523 (0.0215) [2.4351]	0.0493 (0.0130) [3.7823]	0.0396 (0.0104) [3.7910]
	Transition Matrix Parameters					
Variable	D(Bosnia)	DLOG(Croatia)	D(Macedonia)	D(Montenegro)	D(Serbia)	D(Slovenia)
P11-C	1.9147	0.2360	3.2348	-1.3771	2.7204	1.5932

	(0.6430) [2.9777] *p*=0.0029	(0.9450) [0.2497] *p*=0.8028	(1.2061) [2.6821] *p*=0.0073	(0.8452) [-1.6293] *p*=0.1032	(1.2102) [2.2479] *p*=0.0246	(2.1513) [0.7406] *p*=0.4589
P21-C	-0.0875 (0.9455) [-0.0925] *p*=0.9263	-1.9168 (0.6848) [-2.7988] *p*=0.0051	-1.7333 (2.0127) [-0.8612] *p*=0.3892	-0.2498 (0.6055) [-0.4125] *p*=0.6800	-2.6098 (0.8118) [-3.2149] *p*=0.0013	-3.3070 (1.1061) [-2.9898] *p*=0.0028
Deter res cov	4.3182	0.0024	0.3009	0.1477	0.2393	0.1272
Log likelihood	-24.136	61.461	2.0885	-12.883	-5.5218	1.0793
Akaike info crit	2.2852	-3.6180	0.4766	1.5092	1.0015	0.5462
Schwarc crit	2.7096	-3.1937	0.9010	1.9335	1.4258	0.9706
Nb of coeff.	9	9	9	9	9	9

Source: Author's calculations.

The estimation results from Table 1 show that the crude death rate (CDR) has two different regimes. According to these findings, the first regime can be expressed as the high regime in which a high crude death rate occurs, and the second regime is the low-medium regime in which a low-medium death rate occurs. Furthermore, the results show that the estimates of coefficients on the intercept in the mean equation both differ from zero in Bosnia and Herzegovina, Serbia, Montenegro, and Slovenia (only for one equation) and are with opposite and statistically significant signs only for Montenegro and Slovenia. For Croatia and Macedonia, these coefficients are not different from zero.

As to the transition matrix parameters (Table 1), it can be seen that only for Bosnia and Herzegovina and Macedonia, and partially in Montenegro, increases in the log difference crude death rate are associated with higher probabilities of being in the high crude death rate regime, lowering the transition probability out of regime 1 and increasing the transition probability from regime 2 into regime 1. The transition probabilities are examined directly in Table 2.

Table 2. The transition probability summary

Transition summary: Constant Markov transition probabilities and expected durations		
Sample (adjusted): 1993 2021		
Included observations: 29 after adjustments		
Constant transition probabilities		
Bosnia	1 Regime	2 Regime
1 Regime	0.8715	0.1284
2 Regime	0.4781	0.5218
Croatia	1 Regime	2 Regime
1 Regime	0.5587	0.4413

2 Regime	0.1282	0.8718
Macedonia	1 Regime	2 Regime
1 Regime	0.9621	0.0379
2 Regime	0.1502	0.8498
Montenegro	1 Regime	2 Regime
1 Regime	0.2015	0.7985
2 Regime	0.4379	0.5621
Serbia	1 Regime	2 Regime
1 Regime	0.9382	0.0618
2 Regime	0.0685	0.9315
Slovenia	1 Regime	2 Regime
1 Regime	0.8311	0.1689
2 Regime	0.0353	0.9647
Constant expected durations		
Bosnia	1 Regime	2 Regime
	7.7849	2.0914
Croatia	1 Regime	2 Regime
	2.2661	7.7989
Macedonia	1 Regime	2 Regime
	26.401	6.6592
Montenegro	1 Regime	2 Regime
	1.2523	2.2837
Serbia	1 Regime	2 Regime
	16.186	14.596
Slovenia	1 Regime	2 Regime
	5.9197	28.305

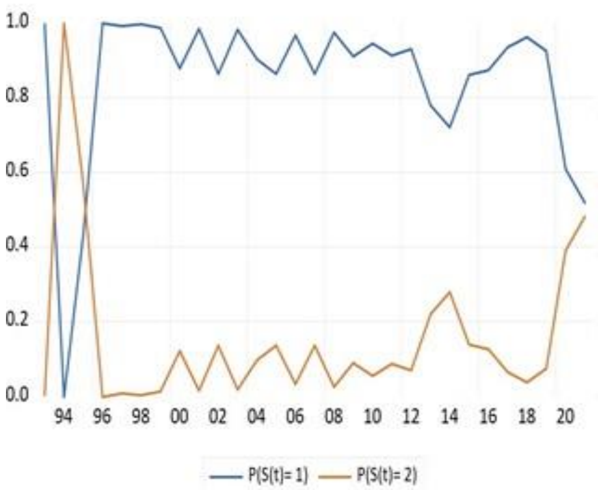
Note: Constant transition probabilities: P(i, k)= P(s(t)=k|s(t-1)=i) (row=i/column=k).

Source: Author's calculations.

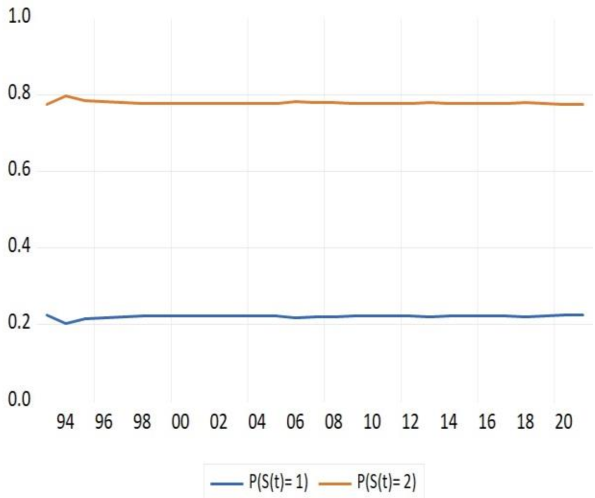
The transition probability summaries show a higher probability of remaining in the high output state for Macedonia, Serbia, and Bosnia and Herzegovina (0.96, 0.94, and 0.87, respectively). The higher probability of remaining in the low output state was found in Slovenia, Croatia, and Montenegro (0.96, 0.87, and 0.56, respectively). The probability of switching from the first high regime to the *t* period to the second low-medium regime is only 3.8% and 6.02 % for Macedonia and Serbia, respectively, 12.8% and 17% for Bosnia and Herzegovina and Slovenia, 44.1% for Croatia, and even 79.8% for Montenegro. The probability of switching from the second low-medium regime to the *t* period to the first high regime is lowest for Slovenia and Serbia, 3.5% and 6.8%, respectively; then 12.8% and 15% for Croatia and Macedonia, 43.8% for Montenegro and highest probability is calculated for Bosnia and Herzegovina, about 47.8%. As it can be seen, for all of the countries observed, while the probability of the Crude death rate (CDR) switching from one regime to another is low, the probability of remaining in the same regime is high.

The appropriate expected durations in the first regime are approximately 26.41, 16.19, and 7.78 years for Macedonia, Serbia, and Bosnia and Herzegovina, respectively and 28.30, 7.80, and 2.28 years were the corresponding expected durations in the second regime for Slovenia, Croatia, and Montenegro, respectively. Also, as it can be seen, for most of the countries observed, the Crude death rate (CDR) is more persistent in the first high regime, while the persistence is a little less in the second low medium regime.

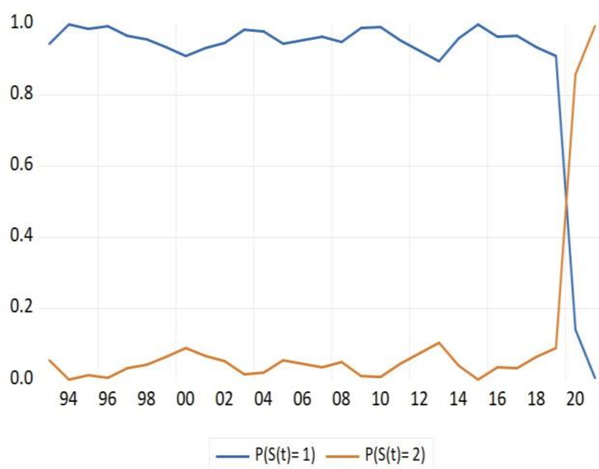
The filtered probabilities of being in the two regimes are presented in Figure 1, for each country, respectively.



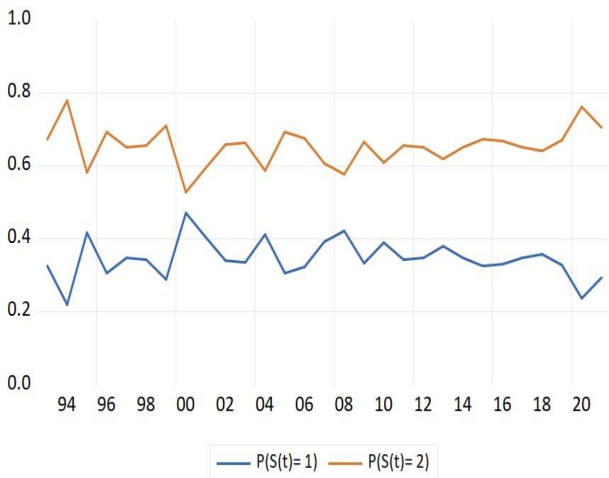
Bosnia and Herzegovina



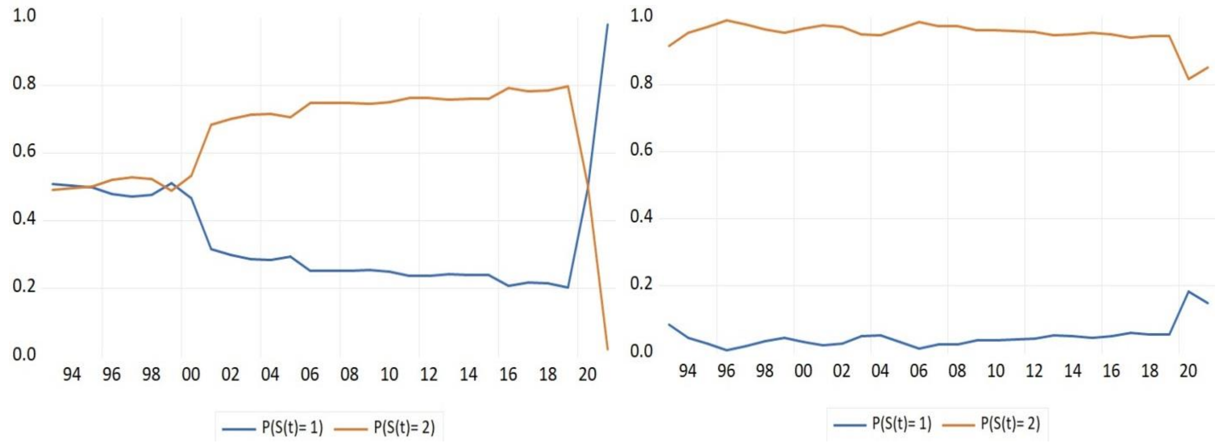
Croatia



Macedonia



Montenegro



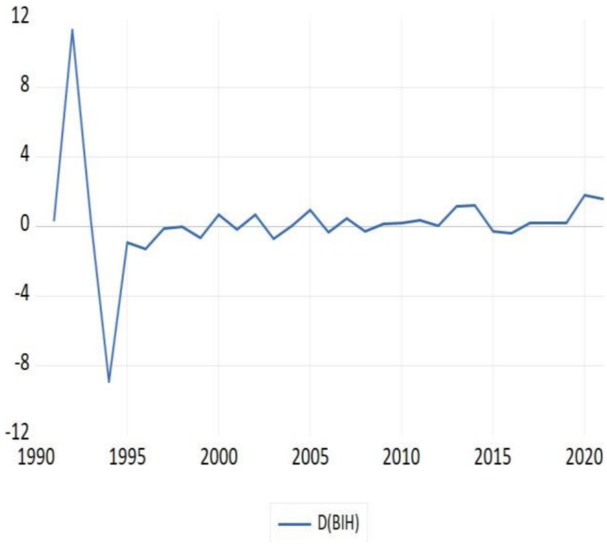
Serbia Slovenia

Figure 1. Markov switching filtered regimes probabilities

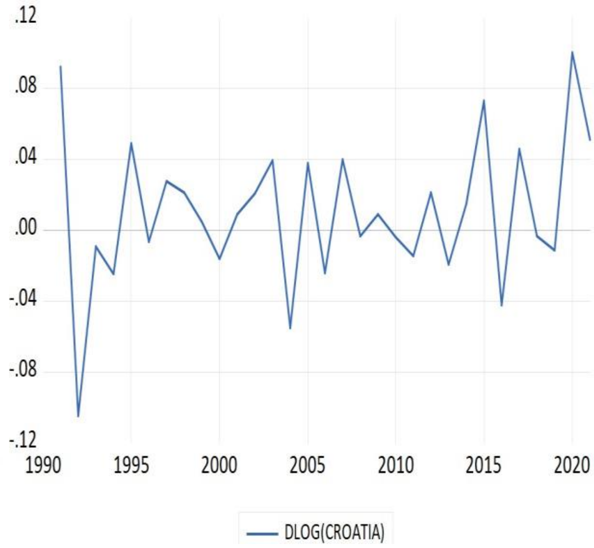
It can be seen that the predicted probabilities of being in the high and low-medium output state generally coincide with the different demographic transition processes and striking regional differences in the countries of former Yugoslavia (Josipovič, 2016; Zafeiris & Skiadas, 2024). When Figure 1 is examined, the probability of the crude death rate (CDR) remaining in the second regime for the entire period is highest for Slovenia and Croatia. The graph for Bosnia and Herzegovina and Serbia indicates the highest probability switching of the regimes of crude death rate (CDR) during the 1990s. This period coincides with the war conflicts in former Yugoslavia during the 1990s, especially in Bosnia and Herzegovina and Serbia with the very difficult political and economic situation during that period. The probability of the crude death rate (CDR) switching from low-medium to high regime was very high for Macedonia in 2020 and 2021 and it coincides with the first case period of COVID-19 in Macedonia and other European countries. In addition, for Montenegro, it was observed slightly higher probability of the crude death rate (CDR) remaining in the second high regime for the whole observed period.

Figure 2 presents the graphs corresponding to an endogenous variable (CDR). From all graphs for each of the countries, it can be easily seen that during the observed period the crude death rate (CDR) corresponds to more fast and positive and somewhere with slow and negative growth rates.

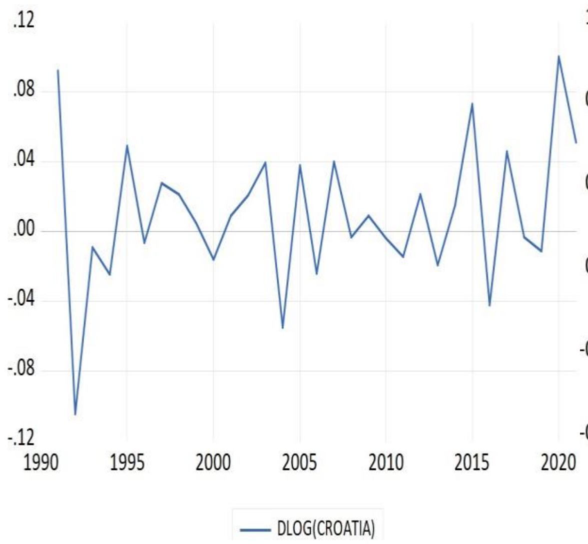
Therefore, the gain results from the Markov switching mean VAR (2) model point out that there are dissimilarities in terms of regime-switching of mortality rate among ex-Yugoslavian countries. These findings support the studies of Yin and Bennett (2012) and Cameron (2023). Population aging will continue to be an important feature of many nations in the coming decades (Yin & Bennett, 2012). Thus, the findings of this research show that demographic aging will be more rapid and dramatic in the coming period for Bosnia and Herzegovina and Macedonia, and partially for Montenegro as a result of the advanced process of population aging and an older population that will determine the average value of crude death rate (Zafeiris & Skiadas, 2024; Penev, 2023). On the other hand, as a result of some progress in reducing mortality, the degree of aging will be decelerated in the coming period for Croatia, Serbia and Slovenia (Penev, 2023). As time goes on, improvements in mortality tend to be concentrated at older ages, as evidenced by the additional years of life someone can expect to live given that they have already survived, e.g., age 60 (Yin & Bennett, 2012). To target resource allocations appropriately, policymakers and planners must know how and where population aging is likely to be felt most acutely by careful measurement of population aging at both the national and subnational levels (Cameron, 2023).



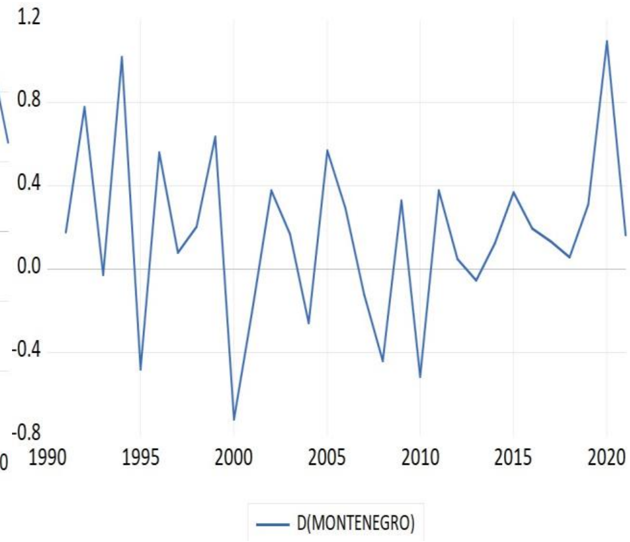
Bosnia and Herzegovina



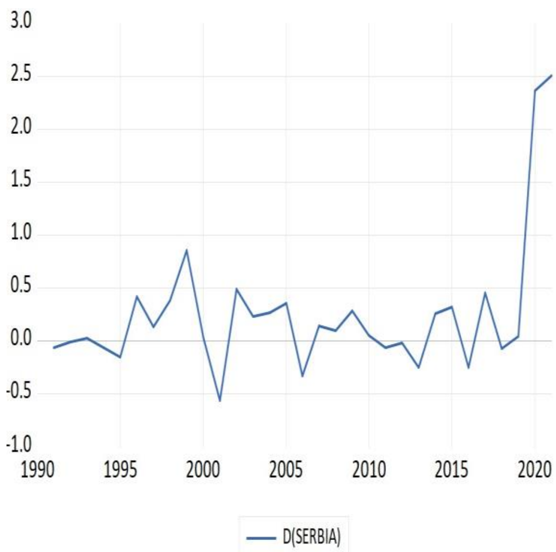
Croatia



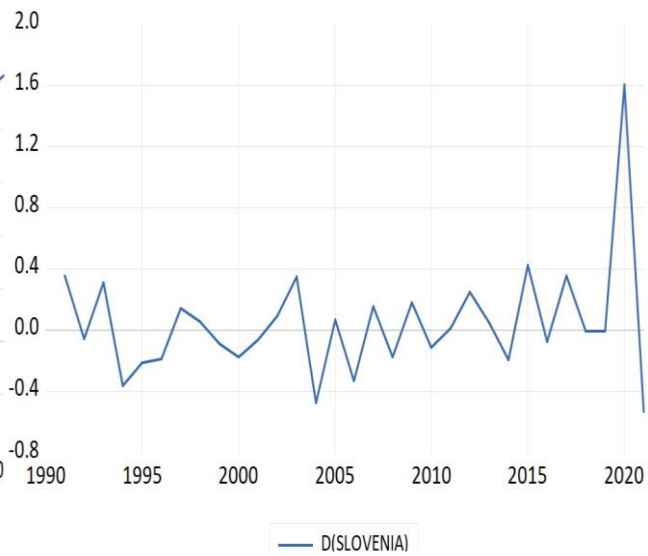
Macedonia



Montenegro



Serbia



Slovenia

Figure 2. Endogenous variables

5. Conclusion

This study aims to determine the regimes' structure, the regime transition probabilities, and the duration of the regimes by investigating whether there is regime-switching of the crude death rate (CDR) with the Markov regime-switching model. For this purpose, crude death rate (CDR) between 1990 and 2021 was used in the study. It was determined that the crude death rate (CDR) series for all six countries was not stationary. The first difference of the variable of crude death rate was taken and then all the series were stationary at the 1% significance level based on both ADF unit root test results and SIC. To model the crude death rate (CDR) with Markov regime-switching models, it was determined that the most suitable model is the two-regime MSMA-VAR(2) model, with switching VAR lag coefficients and with the constant term (C) and common error variance. In our study, it was determined that the crude death rate (CDR) series showed two different regimes. These regimes are the first regime in which a high crude death rate occurs, and the second regime in which low-medium crude death occurs.

According to the MSMA-VAR(2) estimation results of the crude death rate (CDR) series, while the probability of the Crude death rate (CDR) switching from one regime to another is low, the probability of remaining in the same regime is high. While the permanence of the Crude death rate (CDR) is higher in the first high regime, its permanence is less in the second low-medium regime. The transition probability summaries show a higher probability of remaining in the first high regime state for Macedonia, Serbia, and Bosnia and Herzegovina (0.96, 0.94, and 0.87, respectively). The higher probability of remaining in the second low-medium regime state was found in Slovenia, Croatia, and Montenegro (0.96, 0.87, and 0.56, respectively). The appropriate expected durations in the first regime are approximately 26.41, 16.19, and 7.78 years for Macedonia, Serbia, and Bosnia and Herzegovina, respectively and 28.30, 7.80, and 2.28 years were the corresponding expected durations in the second regime for Slovenia, Croatia, and Montenegro, respectively.

The results gained in the study are worthy of attention for policymakers and analysts. Considering that the probability of the crude death rate (CDR) moving from one regime to another is low, but the probability of remaining in the same regime is high, policymakers are advised to take appropriate policy measures by determining in which regime the crude death rate (CDR) are in the previous and current period. In addition, it is good to know that it will take a longer time for the crude death rate (CDR) to be in another regime. Therefore, depending on the country policymakers are advised to make good decisions regarding the implications of population aging during the following period. From this point of view, policymakers and analysts should follow the trajectories of population change as well as the crude death rate closely while the crude death rate (CDR) is in the first regime. It should be more than clear that a better understanding of population aging is central for policy and decision-makers.

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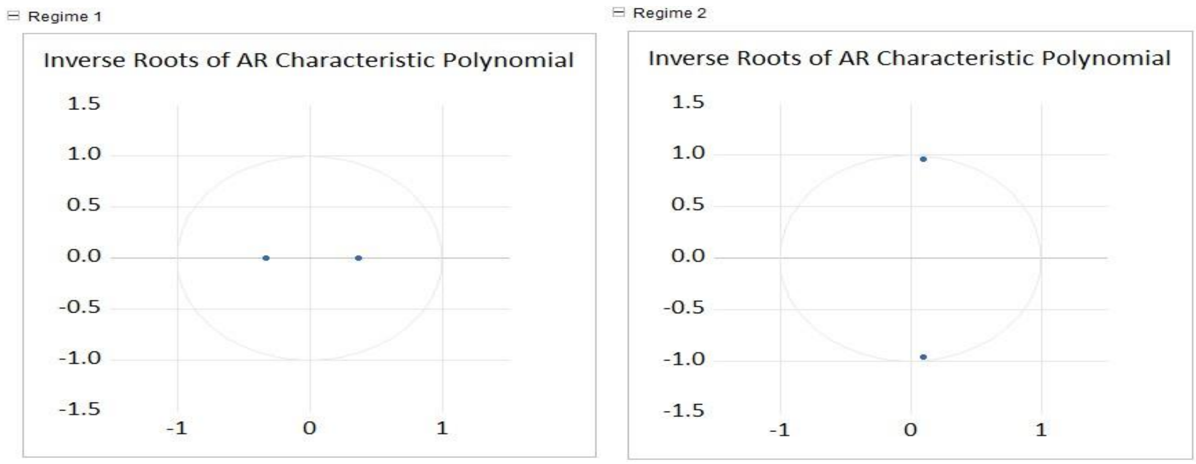
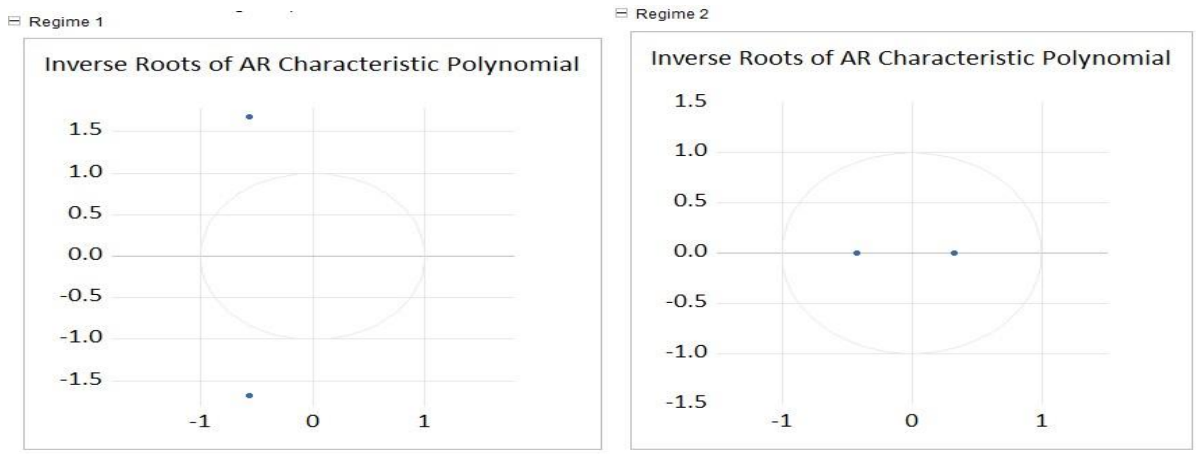
Appendix A

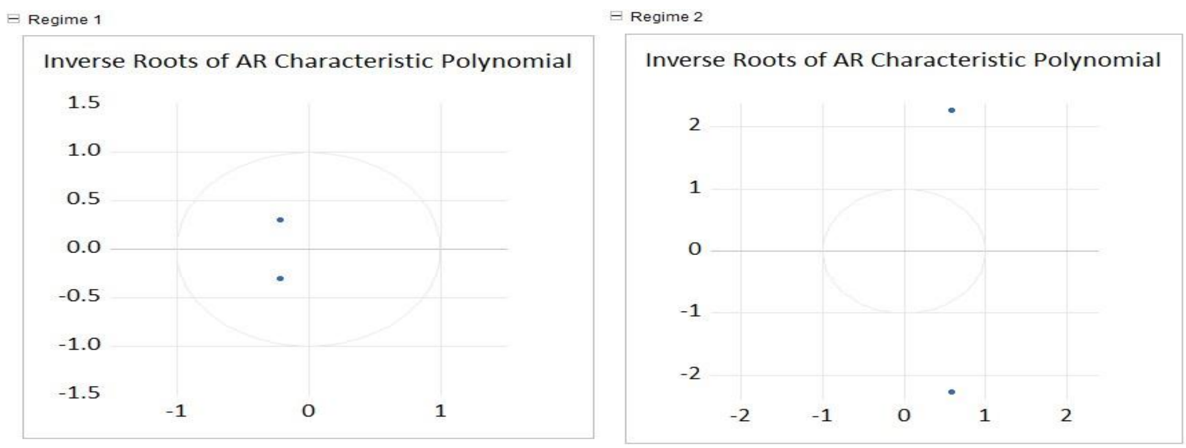
A) Inverse Roots of AR Characteristic Polynomial for Regime 1 and Regime 2 — Bosnia.



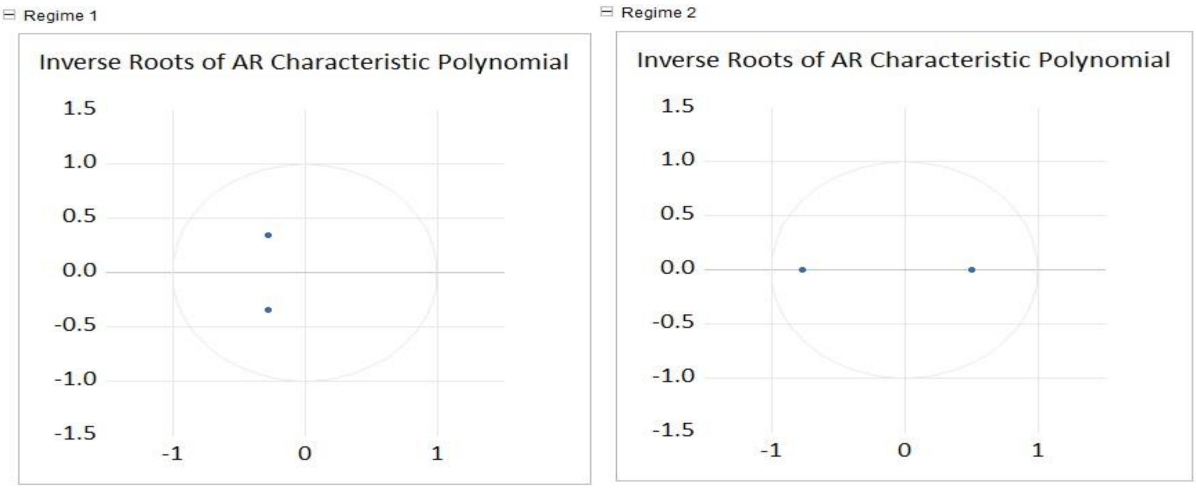
B) Inverse Roots of AR Characteristic Polynomial for Regime 1 and Regime 2 — Croatia



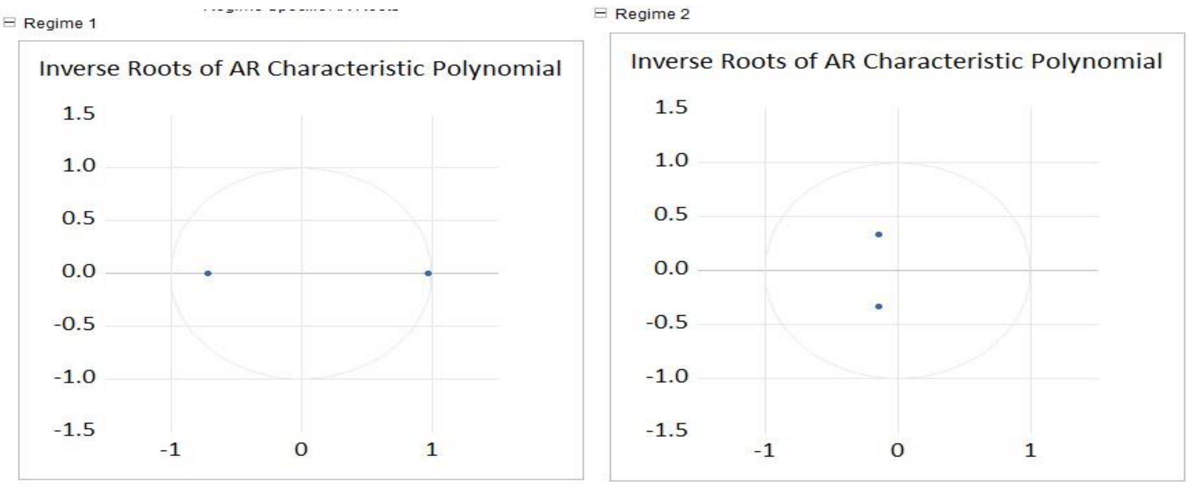
C) Inverse Roots of AR Characteristic Polynomial for Regime 1 and Regime 2 — Macedonia



D) Inverse Roots of AR Characteristic Polynomial for Regime 1 and Regime 2 — Montenegro



E) Inverse Roots of AR Characteristic Polynomial for Regime 1 and Regime 2 — Serbia



F) Inverse Roots of AR Characteristic Polynomial for Regime 1 and Regime 2 — Slovenia