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Implementing Bayesian Learning in Assessing Performances of Healthcare System and Population Health in Three Transitory European Countries

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Abstract

This paper analyses the effect of key healthcare system indicators on the population health measured with the proxy variable, life expectancy at age 65, within three transitory European countries. The analysis is implemented in terms of the Bayesian TVCVAR model. The data sources are mainly from WHO, World Bank and United Nations. This study is based on the period from 1991 to 2020. The model results for Croatia correspond to the notion that the LE65+ and NM, CHEGDP, PH move in the same direction while the LE 65+and HB move in the opposite direction. The findings for Hungary reflect that NM, HB, CHEGDP and the LE65+ move in the same direction except LE65+ and PH which move in the opposing direction. The results for Romania reveal that CHEGDP, PH and LE65+ move in the same direction and that direction of NM, HB and LE65+ is time-varying. The BTVCVAR output found time-varying effect on LE65+ only for Romania. In Croatia and Hungary there was found a time-invariant effect on LE65+ by the parameters in the model. These results confirm the presence of strong relationship between population health and the key healthcare indicators that are representing the healthcare system performances within these three European countries.

Keywords: healthcare system, population health, BTVCVAR, Romania, Croatia, Hungary

1. Introduction

Since the 1970s in Europe, average life expectancy at age 65 has increased by over 3 years, and at age 80 by more than two years. The increase has been steady, except for a slight decrease in 2003 due to unusually hot weather in Western and Southern Europe whereby the gains from these increases have reflected an acceleration of the mortality decline at advanced ages. In some eastern European and former Yugoslavian countries, life expectancy at age 65 is the shortest: around 13-14 years for men and 16-17 years for women, values that Northern and Western Europe had already exceeded by 1980 (Avdeev et al., 2011). Elsewhere in Europe, the gaps stabilized or widened slightly (Slovenia, Croatia) but only in the three Baltic countries and certain eastern European countries including Hungary and Romania the life expectancy of women at age 65 continued to increase much faster than that of men (Avdeev et al., 2011).

Since the population ageing is having and will continue to have different impacts across

countries in Europe and since the higher percentage of the elder population is growing old in poor health in many of the European countries demand for long-term care will be increased. The latest global economic crisis has affected the budgets of public organizations, together with those of public hospitals and national healthcare systems in general (Orsini et al., 2021). Besides, within the developing social and economic circumstances, budget restrictions have caused a search for new ways of monitoring and controlling finances focusing on the efficient and effective use of public resources. Observing the performance of healthcare systems and hospitals is a relevant matter, given their effect of importance[1] on population health and the economy as well (Orsini et al., 2021). Thus, for healthcare systems, and hospitals within these systems, organizational readiness and capacity planning is essential (Deschepper et al., 2021). In addition, healthcare systems need data, information and human capital, but also good information management and social networks as well as collaboration (Tokalić et al., 2021). Strong political commitment is needed to assure that each person has access to reasonably priced and quality healthcare (Thapa et al., 2019). Therefore, it is required that the political actors be informed about issues related to ability to be afforded and other quality issues related to health care services and to have the political will to solve these issues as well. It is simple; people in each country must be allowed to demand health services that are accessible to their health needs. Thus, the governments should enable people some kind of platform to express their health needs by including citizens during policymaking, budgeting, and planning processes of governments (Thapa et al., 2019).

The primary objective of this study is to investigate the relationship between health system performances and life expectancy at age 65 as a proxy for the population health in three transitory European countries. Why study these three countries? Croatia, Romania and Hungary are especially interesting case study because during the last half century they experienced a process of rapid political and social change, transitioning from a socialist-communist regime (1945-1989) to a democracy-based market economy, i.e., socialist health care with universal coverage to free market model. While our approach to measuring demographic and health system indicators is, for the most part, standard; the innovation of our methodology lies in using the Bayesian TVCVAR model to explore their relationship, as explained in Section 4. This paper contributes to the literature as being among the few studies analyzing the relationship between life expectancy and health system performances in the selected transitory European countries using an innovative and advanced econometric approach. The basic contribution of this study is to provide reliable suggestions for the policymakers to initiate health policies in these selected countries as well as other concerned countries by analyzing the relationship between the indicators used in this study. Population health status is affected by an individual's social background, an idea which is well rooted in the literature (Institute of Medicine, 2002; Mechanic 2007; Hu et al., 2021; Shi et al., 2009). Our idea is to consider the role of health system performances among the determinants of population health. Therefore, our original research question would be: How the performance of the health system is related to the health of the population? The remainder of this paper is structured as follows. In the Section 2 and 3, the theoretical review and some important outlines on the national health systems which are relevant for our research are described. This is followed by a Section 5 on data, measures and methods employed. The empirical findings with the results and discussion Section are presented in section 5 and 6. Section 7 concludes.

2. Theoretical Review

One major channel through which life expectancy has affected economic growth is investment in human capital. Since *human capital theory* predicts that a longer life expectancy reinforces the motivation to make investment in skills, and since human capital is key for the growth, many economists have modeled a causal effect of life expectancy through a channel of investment in human capital (Oster et al., 2013). Some economists who have contributed to the *endogenous growth theory* have discussed on the theoretical level the relationship between health expenditures, life expectancy and economic growth (Gedikli & Kırca, 2019). As one of the sub-branches of the endogenous growth theory, human capital models bring attention to the importance of human capital in the economic growth process. Accordingly, human capital is the most important resource of productivity and

technological progress and in addition to this point of view it is implied a rejection of the view of the diminishing returns of capital, a postulate that was suggested by *neoclassical growth theories*. Thus, the endogenous growth theories accept the view of increasing returns of the capital, but including human capital as well. Investigations on the relationship between life expectancy and health expenditures are a meaningful source of data for policy makers when determining health policies (Gedikli & Kırca 2019). The reciprocal relationship between health and economic growth is evident (Can et al., 2020). Thereby, on one side, health is a significant factor of economic development, and on the other side, economic growth has an important and positive impact on population health, impacting the general welfare level as well as economic development of a country. The *economic literature* acknowledges the benefits of good health and certifies a direct connection between the health status and the development of a country (Onofrei et al., 2021). Therefore, it is crucial for all countries to properly invest in their health sector in order to realize the relationship between longevity and benefits of the economy. Research literature reveals different outcomes related to government spending on health. Thus, Onofrei et al. (2021) discussed that there are two familiar approaches that are used to determine the implication of government spending on public health outcomes. The first approach considers health as a capital good that could be affected over time and that depends on some endogenous and exogenous variables. The second approach considers health as an output of the entire health care system, which is affected by the connected inputs and for example examines the link between health care expenditure (inputs) and health outcomes (outputs).

A growing body of literature points to a clear linkage between health expenditures and health outcomes (Zarulli et al., 2021). In the research literature, the relationship between life expectancy and health expenditures could be examined using the data of a single country, as well as using a group of countries or a sample country (Gedikli & Kırca, 2019). Using regression analysis and factor analysis, Onofrei et al. (2021) explored the link between public health expenditure and health outcomes among EU less developed countries. In this specific sample, Onofrei et al. (2021) found a strong positive relationship between public health expenditure and longevity, using life expectancy at birth as a proxy. Their research results show that an increase in the overall public health spending makes the overall mortality level of a population. Furthermore, as a result of the regression analysis performed for the period of 15 years for Turkey by Can et al. (2020) it has been found out that the variance in life expectancy at birth is a consequence by the variables of GDP, number of hospital beds per 1000 inhabitants, the number of physicians and nurses per 1 000 population. Also, Zarulli et al. (2021) applied Data Envelopment Analysis (DEA) to estimate the potential increase of life expectancy for 140 countries from the UNDP. Their results show that the potential improvement in life expectancy was on average, 5.47 years, but also that the least efficient countries could gain 11.78 years, while the most efficient countries could only gain 0.83 years. It is important to stress that the relation between health care expenditure and life expectancy was not straightforward and for that reason Zarulli et al. (2021) revealed that the contextual factors could intervene between the input (health care expenditure) and the output (life expectancy at birth). Furthermore, the regression analysis showed that contextual factors such as income inequality and unemployment in the case of countries with middle or lower education index indeed influenced this relationship by increasing the magnitude of difference.

A reviewing of the literature in this field done by Jabaa et al. (2014) demonstrated that the major part of these studies analyzed panel data for developed countries, such as the US, Canada or the OECD countries, even though some current papers have been focused on developing and less developed countries. It was found that health expenditures have had a significantly great positive impact on life expectancy and a considerable negative impact on mortality rate. The influence of health expenditures on health outcomes, specifically on life expectancy at birth, for a group of 175 countries in the world, in each year during the period 1995-2010, was estimated by a fixed effects model (Jabaa et al., 2014). This specific regression model explains the variation in life expectancy, the dependent variable, as a function of only one determinant factor, i.e., health expenditures. The results of the panel data analysis revealed that inequalities in health care expenditures explain the different outcomes

of health care systems, by groups of countries defined by their income level and geographic region (Jabaa et al., 2014). Their research confirmed the earlier findings on the relation between health status and health expenditures. It was found that for developed countries, health expenditures per capita increased remarkably along with an increase in longevity. The results of this research showed that the difference of health expenditures per capita was also more considerable among the developed and less developed countries, and this difference was growing through the time.

In their panel dataset analysis of OECD countries, Hosseini-Jebeli et al. (2019) have found that life expectancy has a positive correlation with the number of physicians. In addition, these scholars have revealed that life expectancy also has a negative correlation with inpatient rates and number of beds. Accordingly, it was obvious that severe patients were more likely to be hospitalized and surgeries and risky procedures to be undertaken on them, but this finding can also show the negative impact of hospitalization on health which can raise the risk of death and shorten the life expectancy. The results of the study of Czarkowska-Pączeket et al. (2021) are in line with the need to provide evidence of the role of nurses and midwives in the healthcare system. These scholars revealed that life expectancy is impacted by the number of nurses and midwives per 1000 population and is higher in the countries where this number is high. Although, there have been countries where this proportion was not sustained.

3. Outlines of the Health Systems in the Three EU Countries

There is substantial variation in how health systems are organized and funded. These variations are reflections of broader economic and societal values of a country and they vary across the world (Zarulli et al., 2021). A health care system is one of the many interconnected social welfare systems in a particular country, therefore given that health care systems are not separated from the broader social context; it is very difficult to determine the specific bounds of a given system (Medarević & Vuković, 2021). Health systems have three principal objectives: the population health status, the responsiveness, and equity (Gómez Gallego et al., 2021). The degree of accomplishment of these goals is connected to the effectiveness and efficiency of the system as a whole. In addition, measurement of performances reveals whether a given health system is achieving its goals (Gómez Gallego et al., 2021). The health system in Europe has undergone various challenges, which have led governmental representatives to enforce reforms in order to rationalize the use and providing of hospital care, improving quality of being suitable and reducing costs (European Hospital and Healthcare Federation, 2018). How many beds are needed for optimum efficiency has been the ultimate goal of the healthcare sector for many years (Jones, 2021a). According to Jones (2021a) there are proposed ways for the current models to be modified[2], but there is also an additional need for heaving capacity in the case of a major catastrophe or pandemic as COVID-19. In addition, through the years, there has been a decline in the number of hospital amenities and beds. It means fewer acute care beds and shorter stays, as well as a better occupancy rate of acute care beds. It was found that a high number of beds per person are one of the prime causes of hospital inefficiency because it increases running costs (Orsini et al., 2021).

Since hospitals are relatively expensive, often there is a political pressure to reduce hospital capacities. As a consequence, there was substantial interest in how countries that have reduced hospital beds and capacities have done so, and what the impact such changes have had on different stakeholders (McKee, 2004). A usual feature in all European countries is the massive prevalence of public funding in inpatient health-giving care: even though a part of the total health expenditure has always been funded by private insurance and out-of-pocket payments, nearly the entire amount of inpatient health expenditure has been publicly financed (European Hospital and Healthcare Federation, 2018). In the recent years, according to the European Hospital and Healthcare Federation (2018) many countries have seen an increasing share of health spending going to hospitals while at the same time there has been an inclination to change medical services from inpatient to day-care residences.

Even though the health condition of *Romanians* has improved, life expectancy at birth remains among the lowest in the EU. At age 65, life expectancy is the second lowest in the EU, and all remaining years of life are not spent in good health. Despite the fact that people are living longer, health coverage is not universal and socioeconomic inequalities in health persist.

Health system reforms have been occurring continuously but very often ineffective; in part as a result of a high level of political instability (OECD and EOHSP, 2017). Some of the recent reforms had a focus on bringing cost-saving measures as well as improving access and efficiency. The share of GDP allocated to health is the lowest and remarkably below the EU average of 9.9%. Health spending as a portion of GDP has been becoming smaller steadily since 2010, first as a result of the unsteady political situation and secondly as a result of spending cuts to come into fiscal deficit targets. Also, the numbers of physicians and nurses are relatively low compared to EU averages: 2.8 doctors on 1 000 people in comparison to 3.5 in the EU, and 6.4 nurses on 1 000 people compared to 8.4 in the EU (OECD and EOHSP, 2017). According to the report of OECD and European Observatory on Health Systems and Policies in 2017, two factors are relevant for these low point numbers: the great rates of health care staff who have emigrated during the past period (and especially after EU accession in 2007) and the drop in public sector salaries as a response to the economic crisis. In accordance with the government's commitment to give strength to the role of primary care, the total number of hospital beds has decreased, with considerable decreases in acute bed numbers during the recent decades. Even though, the number of hospital beds in Romania have varied from 2005, in 2015 its number were well above the EU average, thus, Romania had more hospital beds than the EU average in 2010 (6.3 beds compared to 5.3 beds on 1000 population (OECD and EOHSP, 2017; Scîntee, 2018). The reductions of beds in 1992, 2003 and 2010 were not satisfactorily occurred with developing alternative services; but instead, during the same period the current outpatient services provided by polyclinics were also reduced and some closures and merging of hospitals has been done (Scîntee, 2018). Overall, the Romanian health system has been characterized by an absence of integration between the different sectors (primary, hospital and public health) and by the lack of care continuity. Therefore, a key government target is improving the health workforce and specialist physician's retention rates since Romania has had relatively low numbers of physicians and nurses when compared to other EU countries (OECD and EOHSP, 2017). As a part of the plan of the Romanian government for hospital related financing policy some changes occurred during the past decade, including: Since 2005 almost 10%, i.e., approximately 15 000 bed reduction from the oversized hospital infrastructure inherited from the communist period, a gradual cutting of the hospital expenditure from 51% of the total public health expenses in 2005 to 37% in 2014, shifting the responsibility for a hospital management from the Ministry of Health to local authorities; as well as the introduction of hospital accreditation and performance management agreements (Duran et al., 2019).

After the war in 1990s, *Croatia* encountered challenges alike to other Central and Eastern European countries that changed from socialist to democratic systems (Tokalić et al., 2021). These challenges included remaining steady the development of different healthcare services while taking into account expenditure and securing of effectiveness and quality of healthcare as well as reducing direct and indirect cost from the war. Life expectancy in Croatia has been improving but with less progress in regard to the EU average. In addition, social inequalities in life expectancy appear to be less expressed in Croatia compared to many other EU countries. In 2017, the remaining life of Croatians aged 65 on average was about 17.4 years, and it was two years more compared to 2000. Nevertheless, it is important to be stressed that more than 12 years of their remaining life of this period has been spent with some kind of dysfunctions (OECD and EOHSP, 2019a). Croatian allocation of its GDP to health recently is about 6.8% vs the EU average of 9.8 % but it was higher than eight other EU countries. The number of hospital beds has decreased recently in 2017 to 5.5 per 1000 people, down from 6.0 in 2000 (OECD and EOHSP, 2019a). During the same period, hospital beds in the EU generally declined from 6.3 to 5.0. With reference to past events, in Croatia the numbers of doctors and nurses was greater than many other EU countries, but this came to the point where in 2016 there were only 6.6 nurses on 1000 people vs the EU average of 8.5 and 3.4 doctors, compared to the EU average of 3.6. In spite of concerns about the effects of EU accession of Croatia in 2013 and the prospective outmigration of health care staff, in fact the ratio of doctors and nurses to population has increased between 2013 and 2017. Human resource planning is still restricted, Croatia

facing a lack of doctors and nurses in some parts of the country. Additional concerns are the prospective outmigration of health care staff since Croatia's accession to the EU in 2013 as well as the low salaries. The governmental Strategic Plan for Human Resources in Health Care for 2015–2020, adopted in 2015 has had aims to establish a human resources management system (OECD and EOHSP, 2019a). However, further reforms are needed within the Croatian hospital sector and especially the hospital payment system needs further reform.

The life expectancy of the *Hungarian population* has increased in the past period but still remains nearly 5 years below the EU average (OECD and EOHSP, 2019b). There are noticed inequalities in life expectancy by gender and socio-economic status. A lot of years of life after 65 are lived with some disabilities. Thus, about two-thirds of Hungarians aged 65 and over reported to have at least one chronic disease and it is 12 percentage points higher than the EU average. In addition, one in six reported some kind of limitation in basic activities of everyday living. The health sector remains persistently with insufficient funding, thus health spending amounted for 6.9 % of GDP in 2017, which is well below the EU average (OECD and EOHSP, 2019b). Namely, the public portion accounts for only two thirds of health expenditure, resulting in high levels of out-of-pocket spending (27 %) vs the EU average (16%). In general, primary care does not yet play a dominant role in Hungary; health care providing remains still highly hospitalized, i.e., at central level. There are not sufficient numbers of health professionals in Hungary and they are not allocated in equal numbers across the country. In addition, the number of health professionals in Hungary is less than the EU average. Thus, the central region of the country has almost twice as many doctors per capita than the north part, and scarcities in each region are located in rural areas. According to the report of OECD and European Observatory of Health systems and policies for Hungary from 2019, the progressive retirement of a considerable part of Hungary's practicing doctors would worsen regional disparities unless a large enough number of new doctors replace them. Also, according to the same report, the hospital sector in Hungary remains very predominant and healthcare focus could be changed more towards primary care. In addition, more leaning on the day-surgery could increase efficiency of hospital spending. Between 2004 and 2007, major reforms and initiatives focused on reforming supervision and organization in the Hungarian health care system. The Hungarian government published a policy agenda in May 2010 defining some of its plans for the health system, including increasing public expenditure on health, particularly for the public health program; enhancing the role of outpatient services; instituting a new system of capacity regulation based on healthcare needs assessment (Gaál et al., 2011).

4. Data, Measures, and Methods

4.1 Data

The analysis exploits country data over the period 1991–2019. Data on life expectancy at age 65 (years) are retrieved from United Nations World Population Prospects 2022 (https://population.un.org/wpp), (United Nations, 2022a). Data on total health expenditure as % of GDP are extracted from the World Health Organization (https://apps.who.int/nha/database/ViewData/Indicators/en), (World Health Organization, 2022a) and from WHO database via European Health information gateway website (http://gateway.euro.who.int/en/datasets/european-health-for-all-database/), (World Health Organization, 2022b). Additionally, for Croatia during 1995-1999 the data were obtained from the United Nations (http://data.un.org/Search.aspx?q=health+expenditure), (United Nations, 2022b). Data on physicians (per 1000 people), the number of nurses and midwives as well as for hospital beds per 1 000 people are taken from the World Bank database (http://data.worldbank.org/indicator?tab=all), (World Bank, 2022). In addition, only for Hungary for 2019-2020 for physicians per 1000 people, for 2020 about nurses and midwives per 1000 people and for 2019-2020 as well as for 1991-1994 regarding hospital beds per 1000 people the data were obtained through Global Economy website (https://www.theglobaleconomy.com/Hungary/), (Global Economy, 2022). In order to verify the accuracy and validity of the data additionally some other different sources, links, publications as well as official data from the national statistics estimates and international publications have been also consulted for information (Croatian institute of public health, 2021; European Observatory on Health Care

Systems, 2000; Statista, 2021; Trading Economics, 2021; Eurostat, 2022 (http://ec.europa.eu/eurostat/data/database), and WHO, 2022 via European Health information gateway (http://gateway.euro.who.int/en/datasets/european-health-for-all-database/).

4.2 Measures

There are several indicators by which could be measured the resources of healthcare systems: health expenditures (total expenditures on health per capita, health expenditure as % of GDP, and % of public expenditure in total health expenditure), number of hospital beds, number of physicians, the number of computed tomography scanners, emergency centers or clinics (Jabaa et al., 2014; Nakamura et al., 2012; Hosokawa et al., 2020; Hosseini-Jebeli et al., 2019). Within our research the following indicators were used as proxies for the performance of the healthcare system: health expenditure as % of GDP, number of physicians per 1000 inhabitants, number of hospital beds per 1000 people and the number of nurses and midwives on 1 000 people.

The output of the health systems is expressed either by longevity indicators: life expectancy (life expectancy at birth, life expectancy at 65 years, healthy life expectancy or HALE) for total population or by gender, or by mortality indicators: mortality rate, infant mortality rate, potential years of lost life. These indicators are considered as good proxies for measuring the population health status (Jabaa et al., 2014). Life expectancy and healthy life expectancy (HALE) are the most used population health outputs (Zarulli et al., 2021; Hosokawa et al., 2020; Hosseini-Jebeli et al., 2019). Needless to say that the greater the life expectancy in one country, the healthier its population is. In our research work, *life expectancy at 65 years* has been considered for assessing the population health status. Life expectancy at fixed age represents the average number of years still to be lived by a person who has reached a particular exact age, if liable to throughout the rest of his or her life to the current mortality conditions, e.g., age-specific probabilities of dying (Jabaa et al., 2014; Gómez Gallego et al., 2021). As mentioned by Czarkowska-Pączek et al. (2021), life expectancy is the result of many factors, among others including healthcare system resources and management, the socio-economic conditions, education, access to safe water, the urbanization status, or the mortality rates of infants, children and adults.

Health indicators are straight through related to the health systems and development of countries (Can et al., 2020). One of our indicators used to measure the performance of the health system is the *total health expenditure*. The total health expenditure is defined by Jabaa et al. (2014) as a sum of general government and private expenditures on health in a given year. Broader definition of health expenditure is provided by Gómez Gallego et al. (2021): "It measures the final consumption of health care goods and services including personal health care (curative care, rehabilitative care, long-term care, ancillary services, and medical goods) and collective services (prevention and public health services as well as health)." During the last decades, the increase of the health expenditure has become a great concern for most governments all over the world due to its effects on the economy (Pérez-Cárceles, 2018; Gómez Gallego et al., 2021). In this regard, Gedikli and Kırca (2019) emphasize the direct and indirect effect of health expenditures on economic growth and economic development. Thus, health expenditures contribute directly to growing output by improving the productivity of labor and consequently to increasing the working life span of individuals. In addition, the qualitative and quantitative improvements in health expenditures affect health outputs in a positive way. The basic indicators of positive health outputs are the decline in maternal and infant mortality rates and the increase in life expectancy (Gedikli & Kırca, 2019). Also, any improvement in life expectancy leads to a boost in economic growth. In the opinion of Zarulli et al. (2021), with increasing health expenditure there might be provided gains in life expectancy but also countries could improve their life expectancy when use more efficiently the resources they have even without increased health expenditure[3]. Health expenditures reflect the value a society places on health care, the resources accessible for health care and how these resources are used (Zarulli et al., 2021). The way these resources are used point to health care system efficiency. Through the years, health care system efficiency has become incorrectly synonymous with health expenditure. In other words, maintaining effective staff, purchase of equipment on time, and well-organized use of health care resources and capacities amounts to

more than just health expenditure (Zarulli et al., 2021).

The often use ratio for international comparisons of whether a country has an adequate number of hospital beds is the indicator number of *hospital beds per 1000 people* (Jones, 2018). Accordingly, this ratio varies from 0.2 beds per 1000 population in Madagascar, the Republic of Niger and the Republic of Senegal up to 13.8 in Monaco and Japan. In Jones (2018) a hospital bed is defined as: "Hospital beds include inpatient beds available in public, private, general, and specialized hospitals and rehabilitation centers. In most cases beds for both acute and chronic care are included." In addition, hospital beds provide information on the maximum number of patients who can be treated by hospitals. Thus, total hospital beds are all hospital beds which are regularly maintained and staffed and instantly are able to be used for the care of admitted patients; thereby both occupied and unoccupied beds are covered (Gómez Gallego et al., 2021). According to McKee (2004) bed numbers are very substandard measures of health system capacity, since a bed only provides health care if it is assisted by an appropriate combination of staff and equipment.

Over the last few decades, there has been an increasing interest in investigating the relationship between availability of human resources for health and health outcomes. Thus, Nguyen et al. (2016) emphasize that outcomes of the population health are a product of compound and interdependent interventions; therefore, a disentangling and burdening this relation could be helpful for providing information for policy reforms. Preferably, healthcare access should be balanced over a given region. Generally, developed communities have a tendency to attract more physicians than their less developed communities. As stated by Gómez Gallego et al. (2021) physicians can be enumerated according to different concepts, e.g., "practicing", "professionally active" or "licensed to practice". Practicing physicians are those who provide services directly to patients. In Gómez Gallego et al. (2021): "Physicians are those who put in application preventive and curative measures, improve or develop theories, concepts, as well as operational methods and carry out research in the area of medicine and health care." For the healthcare system, it is not important only *the number of physicians* accessible in a particular area in any given year, but also any increase or decrease in their number during that year (Nakamura et al., 2012). The so-called "medical brain drain" also shapes a fundamental part of the present, global, health workforce crisis (Elmer et al., 2022). Thus, an equitable relationship between the increase or decrease in healthcare access and the lifespan of the population in a particular region is a primary matter for healthcare planners. It is a fact that the nursing profession owns much strength that highlights their importance in multidisciplinary teams as well as their basic role in improving the healthcare system. The outcomes of the scientific papers clearly indicate that nurses and midwives play an important role. Thus, the appropriate and optimal number of *nurses and midwives on 1 000 people* is a crucial factor (Czarkowska-Pączek et al., 2021). Accordingly, a lot of evidence also shows that the proper number of nurse workers and patient-to-nurse ratios in healthcare amenities are connected with lower mortality rates. As pointed out by You and Donnelly (2022), nurses and midwives are crucial to the reaching of general health coverage not only through providing health contributions to disease prevention, and education of patients, but also providing healthcare in health emergencies. The quality of healthcare service provided by the nurses and midwives has been considered a major indicator of population health level, and more and more studies have related nursing workforce with the extension of life expectancy at birth (You & Donnelly, 2022).

4.3 Methods

One of the popular VAR assumptions is that model parameters are constant through the time. Two favored modeling approaches that removed this assumption are the switching VAR and the time-varying coefficients VAR (TVCVAR), (IHS, 2022). The switching VAR handles with irregularly discrete changes (for instance, structural breaks), in contrast with the TVCVAR grasps constant and coefficients that change smoothly over time. The Bayesian TVCVAR or BTVCVAR is a nonlinear VAR model that uses a Bayesian framework which combines the TVCVAR model with a prior distribution. The BTVCVAR is in demand even among those who do not recognize it as Bayesian for the reason that the prior provides a suitable way to instigate shrinkage in a model that has a need of. The TVCVAR includes two equations, an

observation equation and a process equation (IHS, 2022). The observation equation is a VAR equation with period-specific coefficients, and the process equation defines a law of motion for the coefficients. Consequently, the BTVCVAR integrates the TVCVAR with a prior distribution on the state occurring at the beginning of the coefficient process and parameters of the model. Firstly, starting under the basic VAR model will be provided the way two equations form the TVCVAR. Thus, the basic VAR equation is given in eq. (1), which y_t represents the N-vector of endogenous variables observed for the period t, where t = 1, 2….., T.

$$y_t' = x_t' B + e_t' \tag{1}$$

Further, the covariate vector x_t is given in eq. (2):

$$x_t = \left(y_{t-1'}, y_{t-2'}, \cdots, y_{t-p'}, w_t'\right)' \tag{2}$$

where p represents the lags of y_t and w_t is the vector of the exogenous variables. The coefficient matrix B is constant over time. The assumption of constant parameters can be removed by adding a time index on B and then the observation equation is produced, (eq. 3):

$$y_t' = x_t' B_t + e_t' \tag{3}$$

When the both sides of eq. (3) will be transformed into vectors then the new form of observation equation is presented in eq. (4):

$$y_t = X_t B_t + e_t \tag{4}$$

where $X_t = I_N \otimes x_t'$ and $b_t = \mathrm{vec}(B_t)$. The error vector e_t can be presented as $e_t|S \sim N(0,S)$ where S represents the observation covariance matrix. Thus, the original problem is solved by making coefficients period-specific, but a new one arises: as a result of just taking an observation equation, one can obtain a model that is over-parameterized for any sample size. This issue can be moderated by designating the law of motion for the coefficients. Usually, the law of motion has the form of a random walk process, (eq. 5), and this is the process equation:

$$b_t = b_{t-1} + u_t \tag{5}$$

The process error is presented as $u_t|Q \sim N(0,Q)$ where Q represents the process covariance matrix. The state occurring at the beginning of this process b_0 is defined as part of the prior. The process equation is definitely useful, but cannot entirely remove the problems that are connected with over-parameterization. The common solution is to "shrink" the model towards a simpler form. Therefore, the BTVCVAR combines the TVCVAR with a prior distribution. Bayesians form priors based on information they possess on the subject under study prior to looking at the data. For many of those non-Bayesians, the prior is simply a means for reaching shrinkage. One case of shrinkage is when the TVCVAR can be constructed to shrink towards the basic form of VAR. Shrinking towards the basic VAR to some degree is useful because it produces coefficient estimates that change more smoothly over time. The prior distribution on the state occurring at the beginning of the coefficient vector b_0 and the covariance matrices S and Q is shown is eq. (6). In practice, it is more usual to work with a diagonal Q covariance matrix.

$$\pi(b_0, S, Q) = \pi(b_0)\pi(S)\pi(Q) \tag{6}$$

Where

$$\begin{aligned} b_0 &\sim N\left(\underline{b}_0, \underline{B}_0\right) \\ S &\sim IW\left(\underline{S}, \underline{s}\right) \\ Q &\sim IW\left(\underline{Q}, q\right) \end{aligned} \tag{7}$$

Moreover, the prior distribution brings together parts with the likelihood function to create the posterior distribution, which enhances the argument for inference and predictions. Thus, a Bayesian estimate results commonly consist of just the mean or median of the posterior distribution (Lubik & Matthes, 2015; IHS, 2022). The posterior distribution can be presented as follows in eq. (8):

$$\pi(b, S, Q|y) \propto \pi(b_0, S, Q) \prod_{t=1}^{T} f\left(y_t|b_t, S\right) f(b_t|b_{t-1}, Q) \tag{8}$$

where the first, second and third expressions on the right side of the proportionality symbol $\propto$ accordingly coincide with the prior distribution, the observation equation as well as the process equation. In addition, the collection of all observed data is indicated by y and with b is

indicated the set of all coefficients which include b_0 .The unknown parameters of the model with the posterior distribution are $b, S,$ and Q, respectively.

5. Empirical Findings

The estimation output for the BTVCVAR was obtained by implementing of the BTVCVAR using an accompanied code to yearly data sample from 1991-2020 containing the series of life expectancy at 65 years (LE65+), health expenditure as percentage of GDP (CHEGDP), number of hospital beds (HB), number of physicians (PH), and the number of nurses and midwives (NM). Thus, the endogenous variables, lag specification, exogenous variables, the constant term and the estimation output for the BTVCVAR for each three countries are presented in the Figures 1-3 as a spool object. Figures 1-3 display graphs showing the evolution of coefficients over time. The summary results show that BTVCVAR uses prior hyper-parameters to position six scalar quantities which include: T0, tau0, tau1, tau2, nu1, and nu2. Furthermore, these scalars were set to identify clearly a prior sample and to determine the variability of the time-varying coefficients. The Posterior sample size was used to find out how many posterior draws are utilized to implement subsequent procedures, i.e., estimation, forecasting or impulses responses examination. While doing so, the Burn-in size sampler process was applied. The burn-in option provides a significant basis for the Markov chain to have time to connect to the posterior distribution. In addition, the simulation smoother - Cholesky factor algorithm (CFA) was used.

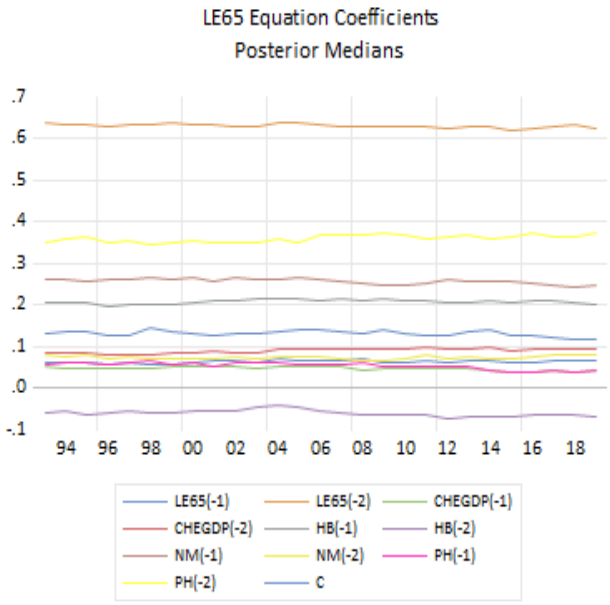

Figure 1. Bayesian TVCVAR estimates: Croatia

Source: Author's work

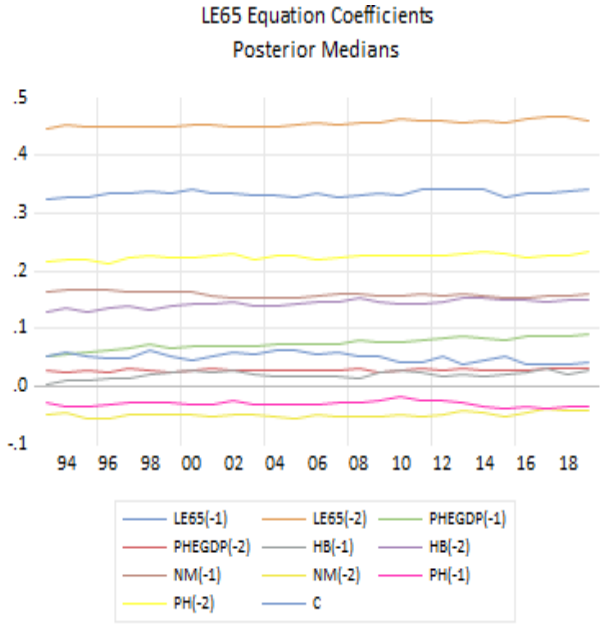

Figure 2. Bayesian TVCVAR estimates: Hungary

Source: Author's work

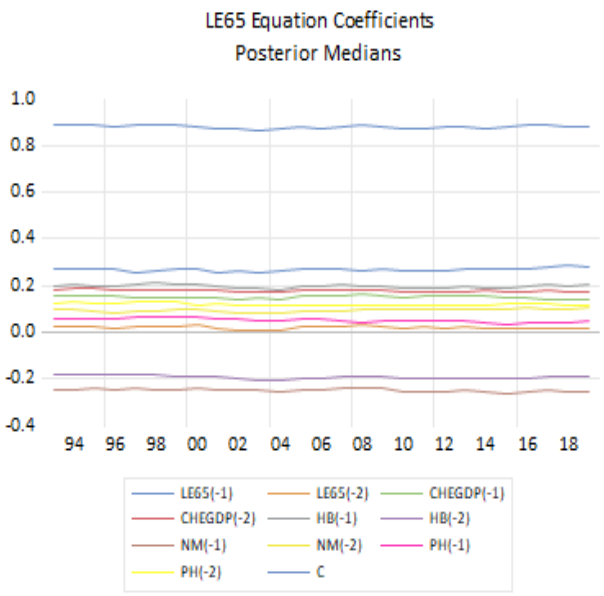

Figure 3. Bayesian TVCVAR estimates: Romania

Source: Author's work

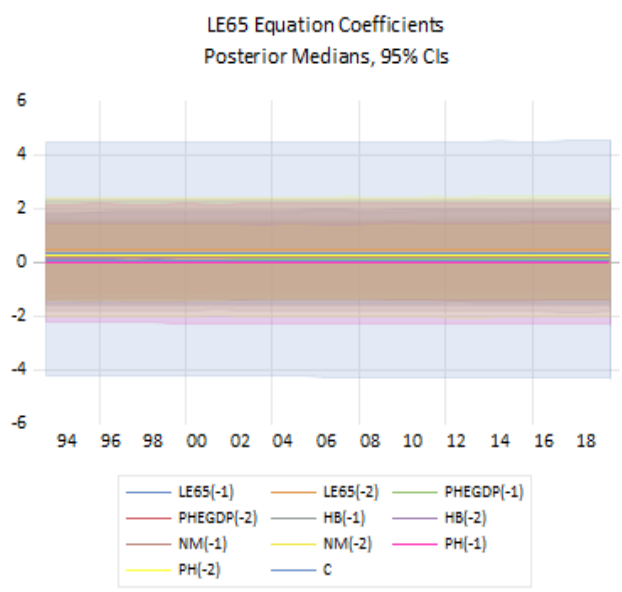

Figure 5. Bayesian TVCVAR estimates: Hungary

Source: Author's work

The estimation output in Figures 4-6 shows the shaded 95% credibility intervals for the BTVCVAR with a median of the posterior distribution for each country separately.

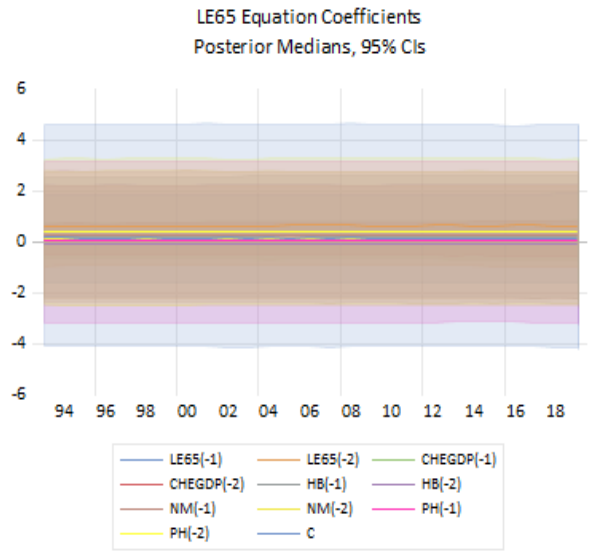

Figure 4. Bayesian TVCVAR estimates: Croatia

Source: Author's work

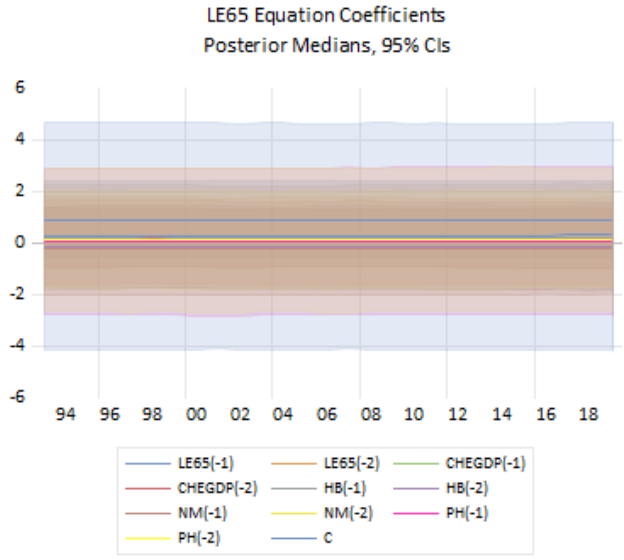

Figure 6. Bayesian TVCVAR estimates: Romania

Source: Author's work

The estimate of the error matrix in the form of a Residuals graph can be seen in the Appendix (pages 17-19). The impulse responses functions for each country separately were generated as well. Impulse responses were generated on the base of VAR coefficients at the impulse dates within the sample period (Figures 7-9).

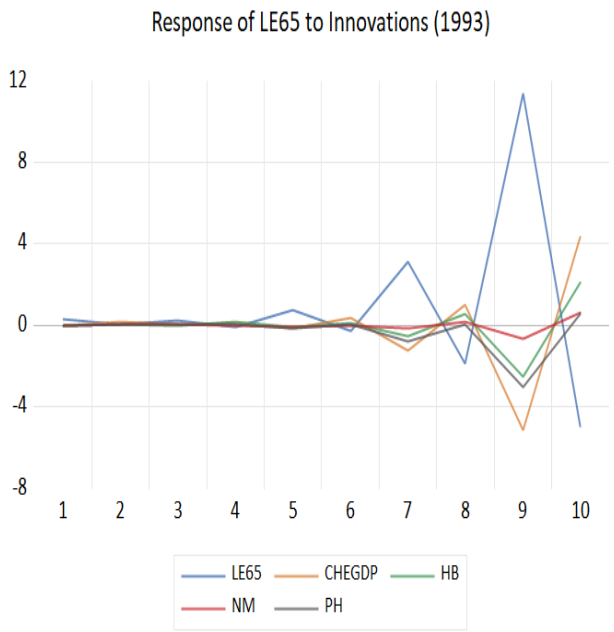

Figure 7. Bayesian TVCVAR estimates: Croatia
Source: Author's work

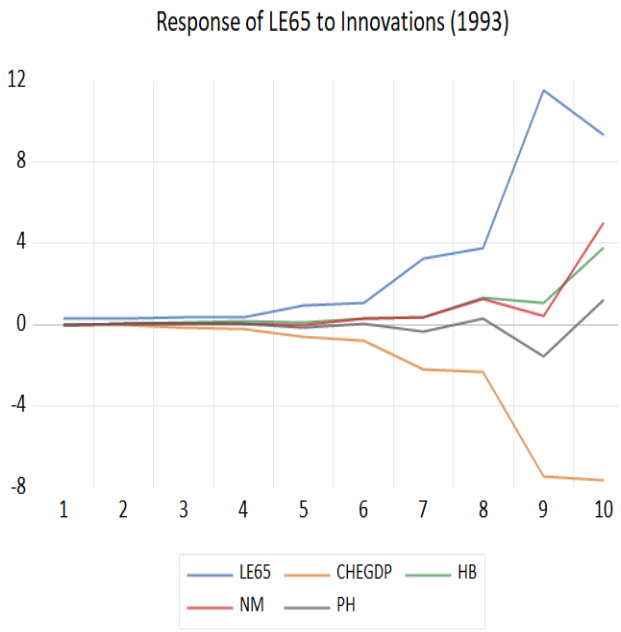

Figure 9. Bayesian TVCVAR estimates: Romania
Source: Author's work

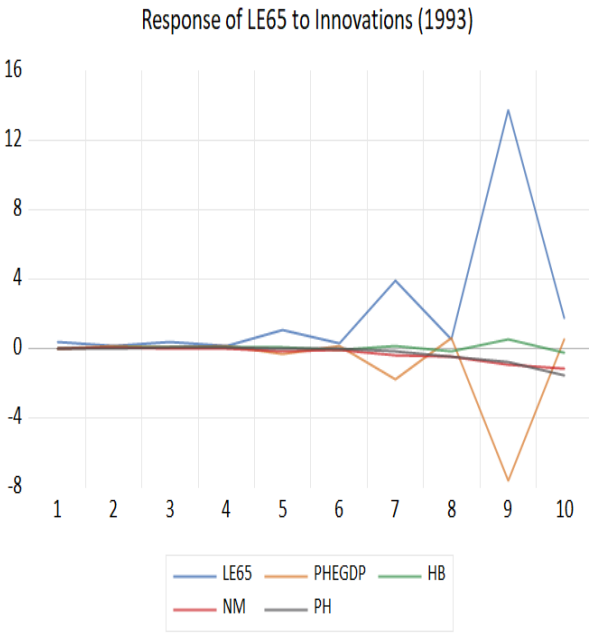

Figure 8. Bayesian TVCVAR estimates: Hungary
Source: Author's work

6. Discussion

The median coefficient estimates of Bayesian TVCVAR are equal to sampling from a posterior distribution. The posterior distribution provides a brief explanation of the main points of all information available in the data as well as and in the prior distribution. The most important impression is that there is not much time variation in the lag coefficients in all three countries. This is a common finding that takes place all over the TVCVAR literature. Figures 1-3 show that for Croatia the relationship between NM, CHEGDP, PH and LE65+ is consistently positive across the sample, while it is negative between the LE 65+ and HB. The strongest relationship was found between LE65+ and NM. This observation for Croatia corresponds to the notion that the LE65+ and NM, CHEGDP, PH move in the same direction while the LE 65+and HB move in the opposite direction. This finding for Croatia was clearly confirmed earlier pointing that Croatia is facing a lack of doctors and nurses in some parts of the country as a result of the outmigration of the healthcare workforce. The study provided evidence regarding the importance of the number of NM in terms of LE 65+ for Croatia. The results indicate that NM in Croatia are very important in the healthcare system, and their relevant contribution should be considered by policy makers, especially as their number in the

country relies on the level of financing for the healthcare system. For Hungary, the relationship between NM, HB, CHEGDP and the LE65+ is invariably positive and all times it is negative between LE65+ and PH. The findings for Hungary reflect that NM, HB, CHEGDP and the LE65+ move in the same direction except LE65+ and PH which move in the opposing direction. However, the results show the positive predominant impact of the hospital sector, including the distribution of hospital beds in Hungary on its population health. This particular impact of HB might be explained by the fact that HB has not been well-distributed in Hungary during the 1990s. For Romania, the relationship is positive on every occasion between CHEGDP, PH and LE 65+, the association between NM, HB and LE65+ is not always positive and sometimes it varies. The results for Romania reveal that CHEGDP, PH and LE65+ move in the same direction and that the direction of NM, HB and LE65+ is time-varying. Thus, the coefficients for the relationships between NM and LE65+ and HB and LE65+ for Romania reveal a time-varying effect. The positive impact of CHEGDP on LE 65+ found for Romania is not surprising since the share of GDP allocated to health in Romania is the lowest and remarkably below the EU average of 9.9%. This finding reflects the point that with the increase of the share of health expenditures in GDP in Romania there comes a more favorable positive effect on life expectancy.

Credible intervals are of great significance in Bayesian statistics. The main goal of the credible intervals is to measure and sum up the uncertainty associated with the unknown parameters around the effect estimate (Hespanhol et al., 2019). In this regard, credible intervals may seem very similar to the confidence intervals. Since the Bayesian inference puts a posterior distribution of probable effect values, the credible interval is exactly the range holding a certain percentage of possible values. Thus, the 95% credible interval is simply the median portion of the posterior distribution that holds 95% of the values. This notion is likely to have a far-reaching effect by improving the explanation of the meaning of the Bayesian interval compared to the confidence interval. Actually, under the Bayesian framework it could be claimed that "given the observed data, the effect has 95% probability of falling within this range", compared to the less straightforward, (the 95% Confidence Interval) that could be "there is a 95% probability that when computing a confidence interval from data of this sort, the effect falls within this range". The colored parts within the graph (Figure 4-6) represent the respective proportion of explained variance of each variable in the model. Comparing these estimates across the three Figures (4-6) about each country separately, shown estimation lines reveal that the effect of the same parameters has 95% probability of falling within this range. This interpretation also would indicate a statistically significant result at a significance level of 0.05 (1-0.95) or 5%, since credibility intervals do not contain zero. The Bayesian Credibility intervals interpretation is considered to be easier to interpret than the frequentist confidence interval approach since the Bayesian credibility intervals could be explained in a probabilistic way and since the Bayesian approach returns a direct estimate from the population distribution.

The results of Figures 7-9 present the impulse response functions of PH, CHEGDP, HB, NM, and LE65+. Taking into consideration the comparability of results through the time, the impulse response was computed by fixing an initial shock date at 1993 to the time-series average over the sample period, and using the simultaneous relations at each point in time. The Figure 7 for Croatia shows how the variable LE65+ reacts to a shock to the variables CHEGDP, HB, and NM. The response of a shock to LE65+ is a positive change in LE65+ in the last period and having previously an effect with negative response to all variables. Figure 8 for Hungary shows that the response of LE65+ to the shocks of PH and NM on LE65+ is negative; meaning that a negative shock to PH and NM will cause a negative shock to the LE65+ and the negative effect of CHEGDP dies out over time. The response of LE65+ to HB is a small positive change at the end of the time period. Figure 9 for Romania presents that the responses of LE65+ to shocks of HB and NM across the time are remarkably similar pointing that LE65+ rise with increasing of the HB and NM. Lastly, the LE65+ decreases as CHEGDP reduces over time and the response of LE65+ to PH shocks is slow move over time.

Finally, using the Bayesian TVCVAR approach, a comparison about population health within these three countries suggests that there exist differences in the health system according to its

performances. The differences in health care system performances are found to have an impact on the health status of the population through their life expectancy. The empirical evidence is broadly in line with the established debate; see Onofrei et al. (2021) and Gedikli and Kırca (2019) for instance. In addition, previous research suggests that healthcare indicators, including the number of hospital beds as well as the number of nurses and midwives per 1000 population could affect population health (Can et al., 2020; Jones, 2018; Jones, 2021a; Jones, 2021b; Czarkowska-Pączeket et al., 2021). Moreover, the findings from this study regarding the relationship of life expectancy with health care spending are consistent with previous studies conducted at the European level (Onofrei et al., 2021; Jabaa et al., 2014).

7. Conclusions

This is a rare study to assess the influence of the healthcare system performances on life expectancy based on objective data for three transitory European countries. Overall, this research about these three countries showed that variables NM and HB only for Romania have a time-varying effect on LE65+. In Croatia and Hungary there was found a time-invariant effect on LE65+by the parameters in the model. Furthermore, the results show that in Croatia and Hungary the level of health resources, including human and physical resources as well as health expenditures as percentage of GDP is likely to be positively related with better population health outcomes including decreased death rate and prolonged life. In whatever way, it is extremely important for policymakers to consider the optimal level of health resource in regard to the number of physicians, nurses, hospital beds and more health expenditures to achieve better population health outcomes. The present study indicates the need to promote social policies created to reduce country's disparities in terms of population health. As explained in the previous Section, some factors related to healthcare resources have been significantly related to life expectancy at 65+ such as the numbers of nurses and midwives, number of hospital beds and health expenditures as % of GDP. Our results suggest the need to consider the redistribution of healthcare resources in the given country, respectively. In addition, further studies are required to assure a more effective and balanced allocation of healthcare resources of the system in each of these three countries.

Authors' Contributions

The Author is solely responsible for conception and design of the study. The author fully and independently carried out the empirical analysis and interpreted both the theoretical and empirical results of the paper work.

JEL Codes: J14, C52, C87, I15, I18, I31, I38

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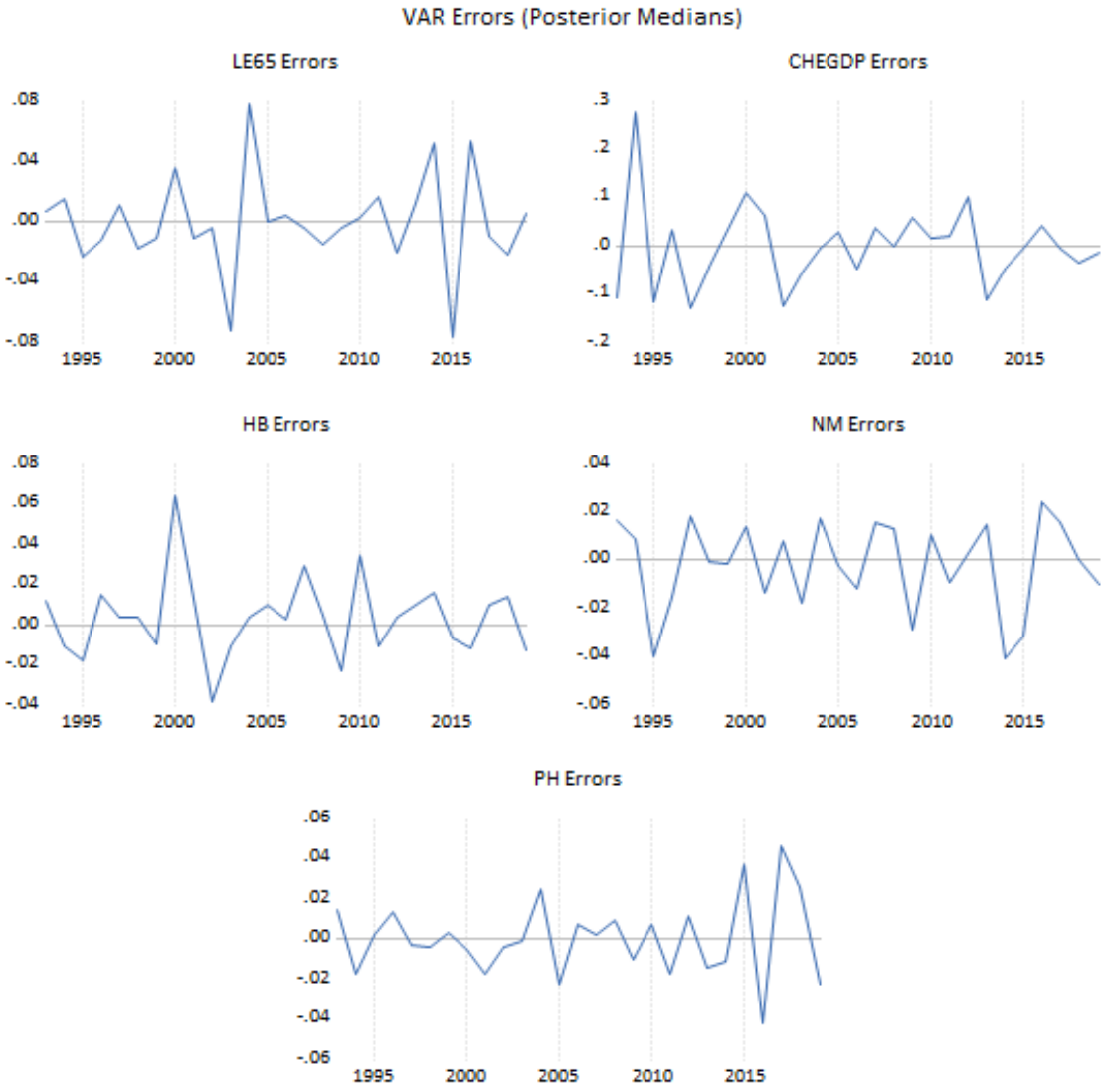
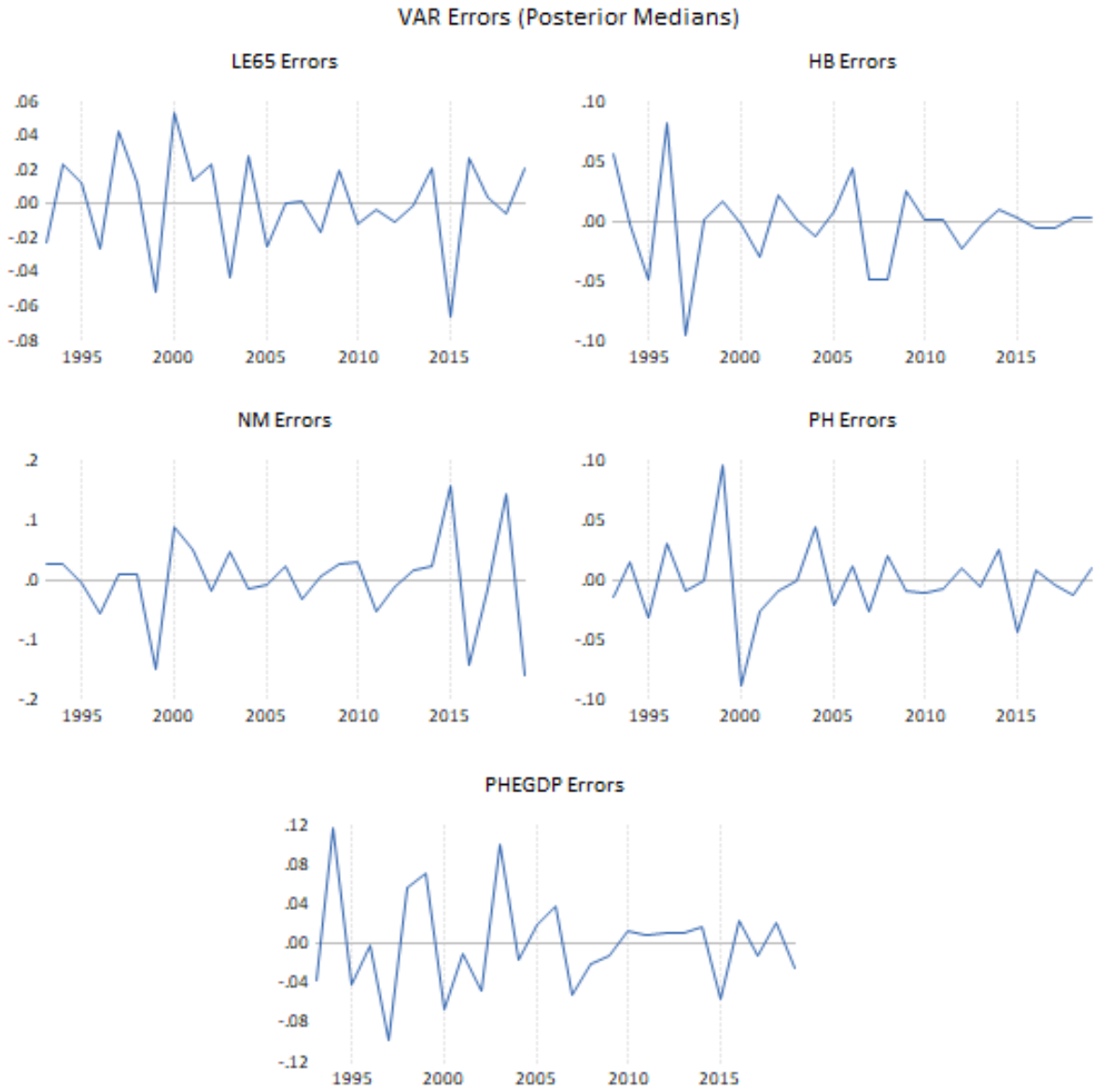
Appendix

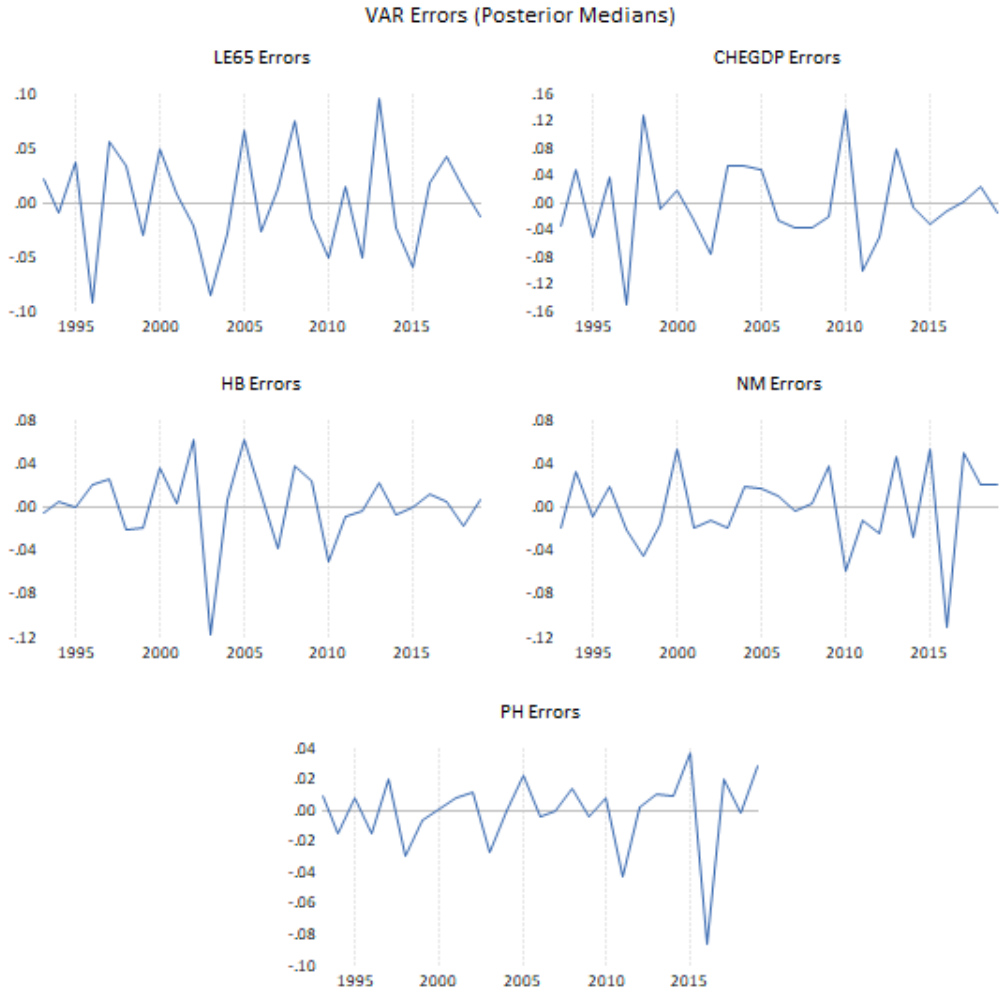
A. Residuals graph: Croatia



B. Residuals graph: Hungary



C. Residuals graph: Romania



[1] In a contemporary society, medicine has become almost all-powerful. When a person is in critical health condition, the decision to hospitalize is made more or less instantly (Ferdynus, 2021). In addition, for a lot of people, the hospital has come to be a symbol of the modern health care system (McKee, 2004).

[2] Age-based predictions of the number of hospital beds have been used for a lot of years. Age-based forecasting has its origin from age-standardization methods employed by public health institutions in order to compare mortality and morbidity rates in populations with different age structures (Jones, 2021b). There are recommendations that the use of age-based planning methods is inadequate to accurately forecast future demand for beds. Thus, one of the miscalculations regarding the perceived need for a smaller number of beds is that length of stay has been rapidly decreasing (Jones, 2021b). Since the current models for determining the size of a hospital could be manipulative, Jones (2021a) discusses a new internal and international tool for comparing bed numbers. This method relies upon the operation of the nearness to death (NTD) effect in which up to 55% of an individual's bed occupancy occurs in the last year of life and is harshly not depending on the age at death. As stated by Jones (2021a) economists have identified the NTD effect for over four decennials, but it has never been included into standard healthcare demand and capacity organization or to comprehension municipal cost volatility.

[3] The population's health is under the impact of both the health systems and of their resources. The relation between resources and outcomes is important for evaluating whether a country has a health system with good performances. A country has a health system with better performances if with the same resources it generates better health outcomes, or if it generates the same outcomes but with less resources (Jabaa et al., 2014).