



The Correlation between Economic Convergence and Health Indices in Developed Countries

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(Received 11 Aug 2023; accepted 15 Oct 2023)

Abstract

Background: Economic convergence signifies diminishing income disparities among global or regional economies and their eventual disappearance. It is also linked to economic growth and key health indicators. We aimed to assess the association between economic convergence and key health indicators in developed countries called G7 (USA, UK, Germany, France, Italy, Japan, and Canada).

Methods: We examined G7 health and economic indicators from 2000 to 2021 using panel data analysis. We compared balanced and unbalanced panel datasets to address missing data and applied suitable methods to handle missing health indicators.

Results: Little's MCAR test ($X^2 = 3.2872$, $P - value = 0.3494$) confirmed random missing data in the unbalanced panel, enabling us to impute missing values as missing observations were below 5%. Unit root tests on balanced and unbalanced panel data validated the health convergence hypothesis, showing no unit roots in economic growth rate, current health expenditure, and female and male population indicators ($P < 0.05$). Interestingly, the hypothesis for hospital bed counts in the unbalanced panel, differing from the balanced panel, offers new insights into addressing incomplete health data.

Conclusion: While G7 have economic similarities, their health indicators diverge (excluding hospital bed counts). Variations in health indicators stem from healthcare system structures, funding mechanisms, resource allocation, and health investments, even among economies of similar size. Therefore, G7 member states should develop tailored national health policies based on their specific circumstances and priorities, utilizing economic convergence data for effective health resource planning.

Keywords: Economic convergence; Health key indicators; Panel unit root

Introduction

Economic convergence suggests that income differences between global or regional economies decrease over time and eventually disappear (1). This concept is tied to market structure similarity, openness, technology transfer, innovation, policy harmonization, and economic mergers. The cen-

tralization of health policies among countries, the rapid rise in health expenditures, and, consequently, the convergence of health outcomes is crucial for global health (2).

According to the convergence hypothesis, economic growth in high-income countries slows



down over time, and low-income countries grow faster and converge with them. A study conducted on the G7 and Emerging Seven (EM7) countries found that they responded similarly to global economic crises. However, post-crisis, the GDP growth rates of EM7 accelerated faster than those of the G7 (3). Health expenditures of countries with similar development levels may converge over time (4). Therefore, convergence in economic performance and living standards can lead to convergence in health expenditures (5).

There is a positive relationship between health expenditures and economic growth, and health expenditure convergence significantly contributes to convergence in growth (6). Economic convergence is closely linked to economic development. This study raises questions about whether the G7, representing the world's seven most advanced economies and accounting for 44.1% of global economic growth (7), are converging in terms of diverse economic and health indicators.

The G7 commits substantial resources to international health organizations and initiatives. The G7 Global Fund, a financing mechanism for AIDS, tuberculosis, and malaria prevention, treatment, and care programs, achieved an 83% commitment fulfillment on average from 2001 to 2020 (8). Every country possesses a distinct healthcare system shaped by its society's social, cultural, and traditional norms, lifestyles, and political structures.

The full convergence hypothesis is important in economic growth and development research, and the health convergence hypothesis is used in developing health policies and services. While studies on country groups such as the Organization for Economic Co-operation and Development (OECD), European Union (EU) or developing countries are common in the literature on economic convergence, studies on G7 are rare (9-

11). There are positive and long-term relationships between economic growth and health expenditures (12). This situation has given rise to the motivation to test the economic convergence of countries with similar development levels using health performance indicators.

This study aims to determine to what extent the basic health indicator outputs of the G7, which has different health systems that affect the global economy and health, are related to economic convergence. In line with the findings, a perspective is presented so that decision-makers can approach the process multidimensionally and evaluate the situation from an economic perspective when evaluating the performance of health systems and structuring the system. In our study, unlike the literature, micro and macro data were used together. Our study provides an original evaluation because it contains arguments different from the analysis methods, sample size and data set available in the literature.

Materials & Methods

We investigated the health convergence hypothesis through micro and macro health indicators. The problem of missing observations in health data sets has been rarely addressed in empirical studies. Missing data methodologies are infrequently applied in panel data studies assessing the validity of the health convergence hypothesis. The study's aim gains significance by evaluating the efficacy of the econometric technique employed.

Data Collection and Sample Selection

Table 1 discusses the unbalanced panel data set containing the descriptive statistics of the G7 for the years 2000-2021 by using the World Bank data (13).

Table 1: Descriptive statistics of the unbalanced panel data set prepared within the scope of G7 countries (2000-2021)

<i>Variable</i>	<i>Shortening*</i>	<i>Mean</i>	<i>Standard Deviation</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Observation</i>
Mortality rate, infant (per 1,000 live births)	<i>Infant</i>	4.043506	1.276122	1.7	7.1	154
Mortality rate, under-5 (per 1,000 live births)	<i>Under-5</i>	4.887013	1.386664	2.3	8.4	154
GDP growth (annual %)	<i>GDP</i>	1.26246	2.627622	-11.03086	7.52491	154
Population growth (annual %)	<i>Population</i>	.4526488	.4846741	-1.853715	1.436137	154
Population, female (% of total population)	<i>Female</i>	51.04637	.4341832	50.30795	51.65887	154
Population, male (% of total population)	<i>Male</i>	48.95363	.434183	48.34113	49.69205	154
Mortality from CVD, cancer, diabetes or CRD between exact ages 30 and 70 (%)	<i>Diseases</i>	12.25071	2.167334	8.3	18.1	140
Out-of-pocket expenditure (% of current health expenditure)	<i>Pocket</i>	14.77168	4.033477	7.137969	26.46448	140
Domestic private health expenditure (% of current health expenditure)	<i>Domestic</i>	27.71784	10.74507	15.73909	55.60621	140
Current health expenditure (% of GDP)	<i>Current</i>	10.51143	2.374579	7.034562	16.84432	140
Hospital beds (per 1,000 people)	<i>Beds</i>	5.949398	3.759359	2.46	14.69	133
Nurses and midwives (per 1,000 people)	<i>Nurses</i>	9.294127	2.302103	5.2102	15.685	126
Physicians (per 1,000 people)	<i>Physicians</i>	3.093667	.7020035	1.8871	4.4348	120

Source: World Bank (2023)

Note: * it refers to the short name of the variables used in the study.

It is seen that the number of observations for the variables examined varies due to missing data.

Analytic Methods

Panel data sets may contain the same observations at different time points or different observations at the same time points and are, therefore, unbalanced. To solve the problem of missing data, missing observations in your panel data set can be filled with appropriate techniques or models suitable for cutting data can be used. Missing data are unobserved values that would be

meaningful to the analysis if observed; a missing value hides a significant discount. The most commonly used missing data identification system in the literature: Missing data types are examined in three groups: completely random missing data (MCAR), random missing data (MAR) and non-random missing data (MNAR). MCAR test is a test used for data gap analysis. This test helps determine whether the missing data is random or

systematic. MCAR refers to a scenario where missing data is random, meaning missing values occur randomly, independent of other variables or data points. The MCAR test is used to assess whether missing data is random and uses a variety of statistical methods to examine whether there is a relationship between missing data and other variables.

Missing data in the unbalanced panel was examined using Little's MCAR (Missing completely at Random) test, and it was determined to have an MCAR mechanism. Missing value imputation can be performed due to random missingness and the missing observations remaining below 5%. It was determined that the imputation process would not pose a problem regarding the reliability and consistency of the results (14). The imputation process was performed on variables with missing data using the mean imputation method to create a balanced panel data set. When the missing data rate in a data set exceeds 5%, more advanced techniques and models should be used for data imputation (15).

The independence of units, meaning that all units are affected to the same extent in response to a shock occurring in any of the units, was examined using Pesaran's (2021) CD_{LM} test, which is based on the sum of correlation coefficients between cross-sectional residuals (16).

$$CD = \sqrt{\frac{2T}{N(N-1)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\rho}_{ij}} \quad (N > T)$$

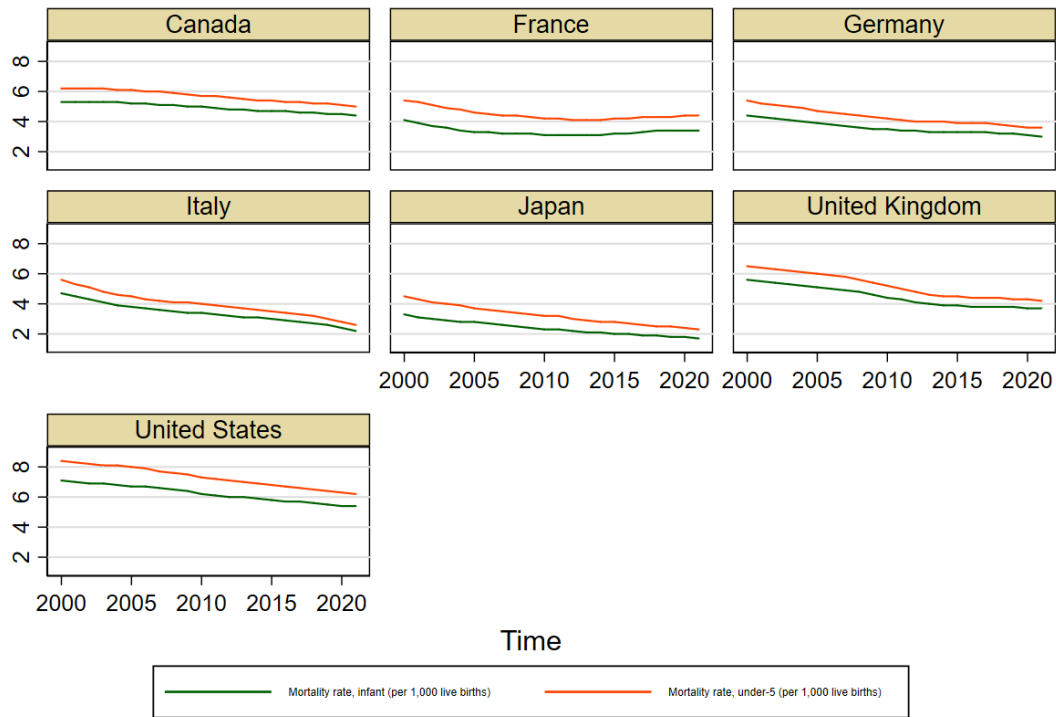
[1]

Under the null hypothesis H_0 indicating the absence of relationships between cross-sections, this test statistic follows a standard normal distribution ($CD \sim N(0,1)$) (16). Depending on whether the null hypothesis is rejected or not, first-generation unit root tests (17, 18) are used in the former case, while second-generation unit

root tests that consider cross-sectional dependence are used in the latter case (19). In second-generation panel unit root tests, it is assumed that the units in the series are affected differently by a shock occurring in one of the series, and equally in the first-generation. The LLC (Levin-Lin-Chu) test requires balanced panel data, while IPS (Im, Pesaran & Shin), Fisher ADF (Augmented Dickey-Fuller), and Pesaran unit root tests can be used for unbalanced panels (20-22). However, if the analysis continues with an unbalanced panel, it is not possible to benefit from most unit root tests and the tests for cross-sectional independence. Missing observations were completed using the mean imputation method, and the results were compared accordingly. The mechanism of missing data should be tested using Little's MCAR test. In this case, unobserved situations in the variables are completely random, and the results are unbiased due to the absence of a relationship between missing data in one variable and other variables (23). For the series with cross-sectional dependence in the unbalanced panel dataset, second-generation unit root analyses have been conducted using the Pesaran (2007) (19) Covariate Augmented Dickey-Fuller (CADF) test, while first-generation unit root tests, specifically the Fisher ADF test, have been applied to the series without cross-sectional dependence. Data analysis of the study was implemented in the Stata 15 package program.

Results

Figures 1-4 shows the time graphs for the variables in the unbalanced panel data set. In the G7, infant and under-5 mortality rates show a similar decreasing trend, but the highest rates are observed in the United States.



Graphs by Country

Fig. 1: G7 Mortality Rates

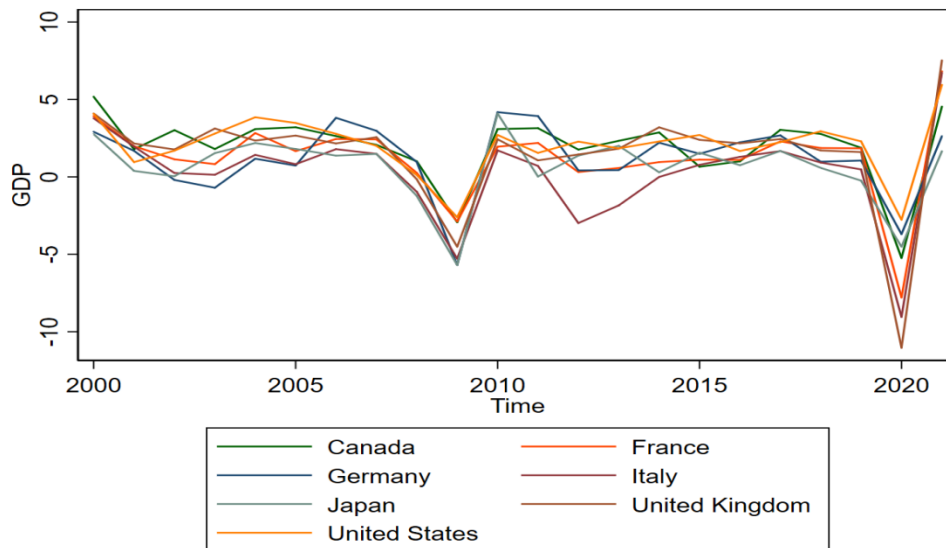
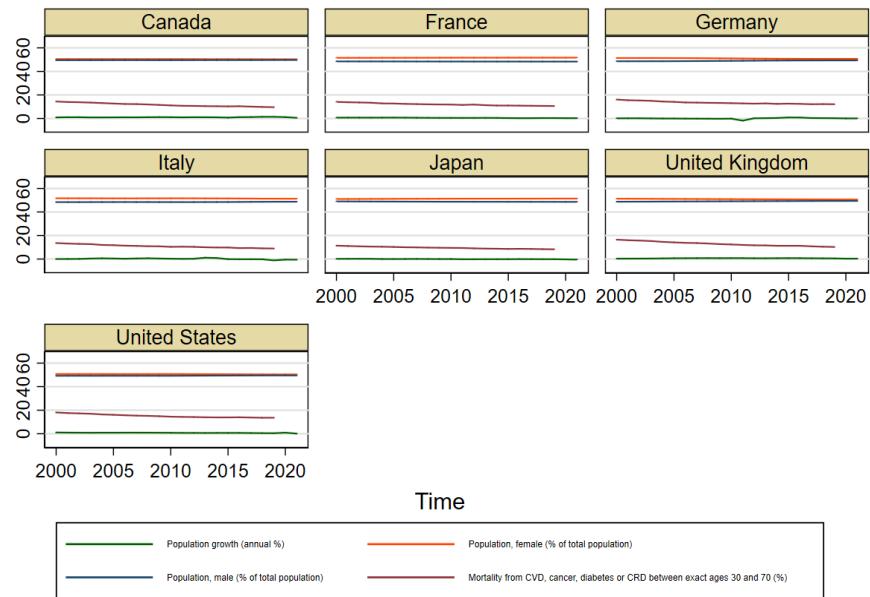


Fig. 2: G7 Economic Growth Rates

The course of economic growth in the G7 is similar, and all countries have experienced a decline in 2020. There was a decrease in all countries in

2009 and 2020. It can be said that this situation is the delayed effects of the 2008 global financial crisis and the 2019 COVID-19 pandemic.

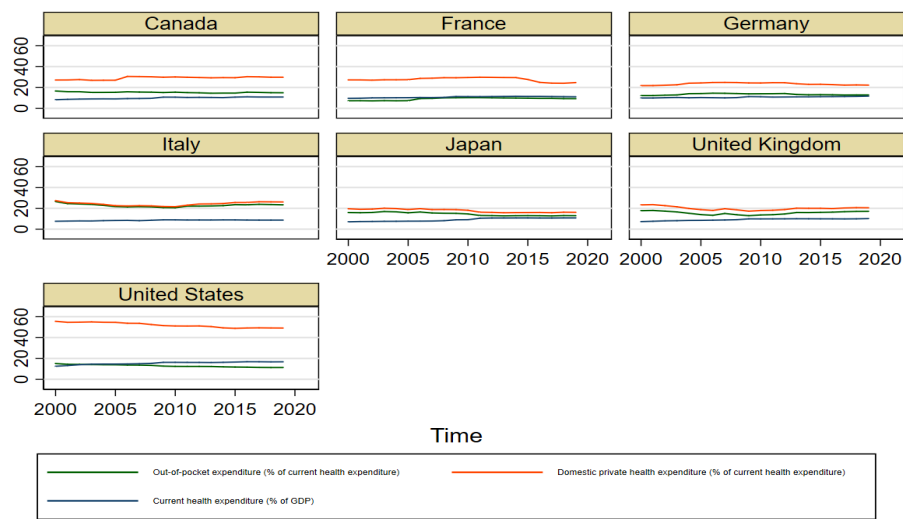


Graphs by Country

Fig. 3: G7 Population and Disease Rates

In the G7, the mortality rate from non-communicable diseases in individuals aged 30-70 years is highest in the United States and follows a similar trend in other countries. The population growth rate is also similar across the G7. This indicates that the variables are stationary on average in the years examined.

In the G7, the health expenditure rates have followed a similar trend over the years, but the highest domestic private health expenditures are observed in the United States. Findings regarding the cross-sectional dependence of the variables examined within the scope of the study are given in Table 2.



Graphs by Country

Fig. 4: G7 Health Expenditure Rates

Table 2: Cross-Sectional Dependence (CD)

Variables	CD-test	P-value	Correlation
	H_0 : No cross-sectional dependence		
Infant-Missing	18.48	0.000	0.860
Infant	21.81	0.000	0.879
Under-5-Missing	19.85	0.000	0.923
Under-5	23.17	0.000	0.933
GDP-Missing	18.00	0.000	0.837
GDP	19.00	0.000	0.766
Population-Missing	3.27	0.000	0.152
Population	4.49	0.000	0.181
Female-Missing	1.35	0.178	0.063
Female	-1.29	0.198	-0.052
Male-Missing	1.33	0.156	0.054
Male	-1.29	0.198	-0.052
Diseases-Missing	20.26	0.000	0.988
Diseases	24.44	0.000	0.985
Pocket-Missing	-0.48	0.632	-0.023
Pocket	1.40	0.161	0.057
Domestic-Missing	-1.54	0.123	-0.075
Domestic	-0.10	0.918	-0.004
Current-Missing	18.87	0.000	0.921
Current	13.89	0.000	0.560
Beds-Missing	18.86	0.000	0.956
Beds	11.64	0.000	0.469
Nurses-Missing	4.04	0.000	0.305
Nurses	6.17	0.000	0.249
Physicians-Missing	4.38	0.000	0.277
Physicians	6.41	0.000	0.258

Note: Horizontal sections are independent of each other. $CD \sim N(0,1)$. Variables in the unbalanced panel data set are expressed with "Missing".

According to the results of the Pesaran test for cross-sectional dependence at 5% significance level, no cross-sectional dependence was detected in the series of female $P > 0.05$ and male $P > 0.05$ populations, out-of-pocket health expenditures $P > 0.05$, and domestic private health expenditures $P > 0.05$ in both balanced and unbalanced panel datasets. After detecting cross-sectional dependence in the variables, stationarity was checked, and the findings were presented in Table 3 respectively.

According to the Fisher ADF test, the fact that the male and female population series $P = 0.001$ do not contain unit roots at the 5% significance level shows that there is convergence between these variables. In the Pesaran (2007) test, it was determined that there was convergence at a 5% significance level only in the variables of GDP $P = 0.021$ and current health expenditures $P = 0.002$.

Table 3: Panel Unit Root Tests (*Unbalanced*)

Variables	Constant Term+Trend (Second-Generation)			Constant Term+Trend (First-Generation)				Result
	t-bar	Z-bar	P-value	χ^2	P-value	Z-stat	P-value	
	H_0 : There is a unit root							
Infant	-1.712	0.130	0.552					I(1)
Under-5	-1.673	0.238	0.594					I(1)
GDP	-2.503	-2.028	0.021					I(0)
Population	-1.515	0.669	0.748					I(1)
Female				94.986	0.000	-5.726	0.000	I(0)
Male				94.976	0.000	-5.724	0.000	I(0)
Diseases	-2.167	0.297	0.617					I(1)
Pocket				11.891	0.751	0.437	0.669	I(1)
Domestic				10.195	0.856	0.381	0.648	I(1)
Current	-2.872	-2.935	0.002					I(0)
Beds	-2.295	-1.451	0.073					I(1)
Nurses	-1.9280	0.377	0.973					I(1)
Physicians	-1.0491	0.502	0.694					I(1)

Table 4: Panel Unit Root Tests (*Balanced*)

Variables	LLC		IPS		Fisher ADF		Pesaran			Result
	t-stat	P-value	Z-stat	P-value	χ^2	P-value	t-bar	Z-bar	P-value	
Infant							-1.621	2.095	0.982	I(1)
Under-5							-2.205	0.318	0.625	I(1)
GDP							-3.927	-4.918	0.000	I(0)
Population							-2.141	0.512	0.696	I(1)
Female	-9.014	0.000	-2.476	0.006	94.986	0.000				I(0)
Male	-9.012	0.000	-2.474	0.006	94.976	0.000				I(0)
Diseases							-2.487	-0.538	0.295	I(1)
Pocket	-0.361	0.3587	1.573	0.942	9.426	0.894				I(1)
Domestic	-0.686	0.246	1.483	0.931	8.714	0.924				I(1)
Current							-3.080	-4.845	0.000	I(0)
Beds							-3.585	-3.878	0.000	I(0)
Nurses							-2.616	-0.931	0.176	I(1)
Physicians							-2.031	0.847	0.802	I(1)

According to Table 4, the stationarity of the series in balanced panel data is parallel to the unbalanced panel data results presented in Table 3. In the balanced panel, it was determined that there was convergence at the 5% significance level only in the hospital bed number series $P=0.001$.

Discussion

We aimed to determine to what extent economic convergence relates to basic health indicator results in the G7. Our study decided that there was no convergence trend in the mortality rates of

children under five and infants. No G7-specific analysis regarding this indicator has been found in the literature. In studies conducted with panel unit root test within the scope of G20 (24), Turkey, Middle East North Africa (MENA) (11) and OECD (25), it was determined that there was a convergence in the infant mortality rate. A different study determined that there was no convergence in the infant mortality rate (26).

In our study, the highest infant and under-five mortality rates are observed in the United States. This may be because of ethnic/racial disparities, rural-urban differences, and health inequalities (27,28). When the health expenditures of G7

were examined in our study, it was seen that the current health expenditures of the state were at similar levels over the years, and the rates of current state health expenditures of the countries converged in the examined time series. A study conducted within the EU determined a convergence in per capita health expenditures and the share of health expenditures in GDP (29). Regarding the health expenditure trends in the G7, all countries have had similar levels of governmental current health expenditures over the years, and their governmental current health expenditure rates have converged in the time series examined in the study. Some studies about the European Union (EU) and OECD countries have found convergence in their health expenditures (4,29), while others have not found such convergence (25,30). A study conducted specifically on the G7 reported that there is no convergence in per capita health expenditures (31). The results vary depending on the period examined and the groups of countries.

The highest domestic private health expenditure is also observed in the United States, and there is no convergence in out-of-pocket and private health expenditures in the G7. This result is consistent with OECD statistics and the literature (32,33). A study about the convergence of per capita health expenditures in OECD countries showed a convergence trend for almost all countries except the USA (34). The private health expenditures in the USA are higher than in other countries due to the country's health financing structure. While the healthcare financing system in the USA is based on private insurance and out-of-pocket payments (35), the healthcare systems of the UK, Italy, and Canada are based on the tax-financed Beveridge model, and the healthcare systems of Germany, France, and Japan are based on the Bismarck model, which is financed by premiums paid by employees and employers (36,37). Each country's health financing method is shaped according to the socio-economic situation and political preferences, and the society shares the financing burden through various methods.

The economic growth rates in the G7 have a similarity over the years, and there was a decline in all countries in 2020, which coincided with the beginning of the COVID-19 pandemic that has disrupted the world and national economies (38). The GDP growth rates of the G7, which experienced a similar situation discussed in our study, have converged over the years. This result is consistent with studies involving OECD and G7 countries, where economic growth rates have been observed to converge (39, 40).

Our study found that the population growth rates in the G7 have progressed similarly over the years. Economies with similar characteristics, such as population growth and technology, converge to a steady state known as absolute convergence (41). Significant relationships have been identified between the convergence of Europe's aging population and economic convergence (42). The result of our study regarding the similarity in population growth rates parallel to economic convergence in the G7 is consistent with those in the literature.

In our study, the death rate from non-communicable diseases among the 30-70 age group in the G7 has been highest in the USA over the years, while other countries have shown a similar trend. One of the Sustainable Development Goals, the "Goal 3: Good Health and Well-being," aims to promote healthy lives and well-being for all ages. In line with this goal, the G7 measures and reports the age-standardized death rates (%) due to cardiovascular diseases, cancer, diabetes, or chronic respiratory diseases among adults aged 30-70 years as a performance indicator. The results for this indicator are as follows: Italy 9.5, United Kingdom 10.9, Canada 9.8, USA 14.6, France 10.6, Germany 12.1, and Japan 8.4 (43). In this context, our results are consistent with those in the report. It is stated that countries with similar economic sizes have similar characteristics in chronic diseases (44).

The study also explored micro health infrastructure indicators, including doctor, nurse, and hospital bed counts, to assess the hypothesis across micro and macro variables. The health convergence hypothesis is not supported by the health

infrastructure indicators, except for hospital bed counts in the balanced panel data. These variables included in the health service indicators reveal the healthcare infrastructure of the countries (45). Economic similarities make similarities in the distribution of hospital beds and healthcare workers between regions (46). There is no evidence in the literature regarding these indicators for the G7. A study conducted in China determined that as the number of beds and healthcare workers converged over the years, resources were distributed more evenly (47). Health resources are distributed similarly in G7 with similar economies.

Based on the results, the validity of the health convergence hypothesis shows parallelism in terms of balanced panel and unbalanced panel data. Only the hospital bed count series was found to differentiate and remain stationary in the balanced panel data. Although the unbalanced panel data model has fewer observations, it provides unbiased estimates based on the available data. However, it should be noted that while the obtained estimation results generally show similarities, imputing missing data might lead to variations in the results.

Strengths of the study: The method of analysis used and the health indicators selected for the G7 are rarely addressed in the literature. The problem of missing data was addressed with two different alternative solutions by using panel data in the study, which offers an innovative contribution in terms of method.

Limitations of the study: Although the G7 is economically similar, their health systems differ, so that study results may vary depending on period intervals and estimation methods.

Conclusion

G7 did not differ in economic indicators and government health expenditures but did differ in health indicators (except for the number of hospital beds). There are structural differences in the provision and financing of health services among the G7. This may affect the results of health indi-

cators. It is important to develop national health policies and programs to address varying health indicators, considering each country's unique conditions and needs. In addition, it is recommended that decision-makers benefit from economic convergence findings when planning health resources. In future research, the similarity of results can be examined according to alternative missing data imputation methods, and different health systems can be discussed comparatively.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of Interest

The authors declare that there is no conflict of interests.

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