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Human Resources for Health and Health Outcomes: Panel Data Analysis*

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Abstract:
This study aims to evaluate the effects of selected key factors on health outcomes. Unfortunately, statistical reporting in this field is not harmonized, and in some countries it is completely absent. For this reason, valuable information for health determinant analysis may be lacking or overlooked. Using two different databases, we obtained data from 61 countries for the period 2000–2015. To analyse panel data with over 660 observations, a linear mixed model was applied. This paper contributes to the health economics debate by statistically testing the relationship between health outcomes and variables such as healthcare personnel, healthcare expenditure and infrastructure. The results confirm the importance of healthcare expenditure and healthcare infrastructure. However, the size and direction of the effect vary among countries with different income levels. In regard to human resources, the number of doctors proved to have a significant effect only in lower-income countries.

Keywords: human resources for health, mortality rate, econometric model, panel data

JEL Classification: H51, H75, O15, I18, B23

1. Introduction

Health outcomes are a very important indicator of the development of society and its sustainability. Monitoring the situation in healthcare is now more urgent than ever in regard to the global health crisis in the context of mass poverty, uneven economic growth, accelerating

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labour migration causing a loss of nurses and doctors (brain drain), political instability, major complications caused by the COVID-19 pandemic, and others.

Many factors affect health outcomes, and they do so in different ways. One of the most important factors that contributes to the health status of a population is healthcare resources, specifically healthcare professionals (Qin and Hsieh, 2014; Jebeli et al., 2019). As evidenced by many research studies, expenditure on healthcare plays an important role in health outcomes. Globally, healthcare expenditure is highly unequal, and it is even more unequally distributed than the national income of countries (Deaton, 2013). Therefore, some studies focus on the relationship of health outcomes solely in regard to healthcare expenditure (e.g., Fujii, 2018; Ray and Linden, 2019).

Recent empirical studies often present health outcomes focusing on life expectancy or infant mortality. In our study, we comprehensively capture the factors affecting mortality rates by including three dimensions of the healthcare system. For this reason, the study aims to evaluate the effects of key determinants such as healthcare personnel, healthcare expenditure and infrastructure on health outcomes.

The study is structured as follows. First, a theoretical basis linked to the presented topic is provided, in which emphasis is placed primarily on studies in which authors focus on indicators similar to those presented in this study. Subsequently, the methodological approaches used to complete the analytical section of the study are established; in this section, methods for data selection and an econometric model are proposed. In the section with results and discussion, the completed primary analysis is introduced and discussed. A summary of acquired findings and recommendations for health policy are provided in the conclusion to the study.

2. Theoretical Background

The World Health Organization (2017) points out that the following determinants of health are fundamental: the place where people live, the state of their environment, genetics, income and level of education, relationships with friends and family, social relationships and healthcare services. Similarly, the U.S. Department of Health and Human Services (2020) states that the range of personal, social, economic and environmental factors that influence health status are understood as determinants of health.

Health services are a very important part of the healthcare system, and the quality of healthcare services is related to the sufficient capacity and quality of healthcare staff (World Health Organization, 2016a; Vallejo-Torres and Morris, 2018). Developed healthcare systems have to secure healthcare professionals in both sufficient numbers and quality (World Health

Organization, 2016b; Chopra et al., 2008). The issue of human resources for health (HRH) needs to be included in policies, as health workforce costs account for the largest share of healthcare expenditure, especially public, in most developed countries (Correia et al., 2015).

According to the World Health Organization (2015, 2016a), HRH are the heart of people-centred healthcare systems, resilient economies and sustainable development. Some research studies by the World Health Organization (2017), Or et al. (2005), Robinson and Wharrad (2000) and Speybroeck et al. (2006) have demonstrated that the populations of countries with higher levels of HRH tend to have better health. Chen et al. (2004) also confirmed that human force drives health system performance and provides evidence that higher worker density and better work quality together with other social determinants of health such as education, gender equality and higher income improve population-based health and human survival. Although some other studies such as Anand and Bärnighausen (2004), Robinson and Wharrad (2000) and Speybroeck et al. (2006) have shown that countries with a greater physician density typically have better population health, the fact that increasing physician density leads to improved population health has not been clearly proven. According to Farahani et al. (2009), the problem with this evidence is the cross-sectional design; the authors applied a dynamic regression model based on panel data to obtain estimates of the short-term and long-term effects of changes in physicians per capita on infant mortality. Their results confirmed that HRH is the strongest predictor of health outcomes. Authors have also pointed to the importance of technical progress in healthcare, including Jamison et al. (2016), who showed that the rate of technical progress reduces mortality of children under five years of age. Although their research was focused mainly on developing countries, these results can be taken into account for developed countries as well.

The combination of immunizations and skilled birth attendants also plays an important role in better health (WHO, 2004). In particular, the density of HRH positively correlates with the percentage of deliveries assisted by skilled birth attendants and the percentage of children fully immunized against measles (Anand and Bärnighausen, 2004; Speybroeck et al., 2006), and negatively correlates with maternal, infant and under-five mortality (Anand & Bärnighausen, 2004). The issue of HRH is also important in terms of specific medical disciplines. For example, Gupta et al. (2011) demonstrated that low-income and middle-income countries tended to report lower availability of skilled health personnel, although the strength of the supply-demand relationship varied across geographical and economic country groupings.

Dempsey et al. (2014) pointed to the important role of nurses in the healthcare system and healthcare staff. Poor nurse staffing is also associated with reports of insufficient nursing care in hospitals (Griffiths et al., 2018). Evidence for supporting the importance of nursing staff in healthcare outcomes can be found in many other studies (Needleman and Hassmiller, 2009; Lankshear et al., 2005; Wilson, et al., 2011; Donald et al., 2013; Traczynski and Udalova, 2018; Butler et al., 2019; Cho et al., 2020).

One of the key roles in the performance of health systems and health outcomes is the expenditure on healthcare, as evidenced by many research studies. Fujii (2018), Ray and Linden (2019), Martín et al. (2011), Bedir (2016), Nixon and Ulmann (2006) or Steinmann et al. (2007) can be cited in this context.

The statistical assessment of relationships between income, education, technical progress and mortality is also presented in studies by Preston (1975, 2007). Preston (1975) shows that economic growth contributes to a longer lifespan. Another interesting approach utilizes the historical perspective. For example, Easterlin (1996, 1999) found little correlation between the timing of periods of economic growth and mortality decline and concluded that income growth in the 19th century probably had an admittedly modest but real impact on reducing mortality through its influence on food availability and environmental conditions. Powles (2001) determined the relationship between technical change, economic improvements and mortality reduction.

Hejduková and Kureková (2016, 2017) focused on the evaluation of the performance of health systems. Their studies compared the performance of healthcare systems using health outcomes such as life expectancy at birth, potential years of life lost and disability-adjusted life expectancy. They evaluated the following performance indicators: numbers of doctors and nurses, healthcare expenditure, prevalence of examination technology (e.g., magnetic resonance imaging machines), etc.

Some studies have focused on other aspects, such as geographical variables in the context of health outcomes (Bloom et al., 1999). Concerning the current epidemiological situation, much attention in various research studies has also been devoted to healthcare expenditure and healthcare staff related to the COVID-19 pandemic (see, e.g., Chaudhry et al., 2020; Trougakos et al., 2020; Coccia, 2021; Glied and Levy, 2020; Karabulut et al., 2021; Elgin et al., 2020; Cepparulo and Giuriato, 2021).

3. Methodology

This study aims to evaluate the effects of selected key factors on health outcomes in the context of the Millennium Development Goals (MDGs), namely MDG 4 a MDG 5. The MDGs were eight international development goals by 2015 that had been established following the Millennium Summit of the United Nations in 2000, following the adoption of the United Nations Millennium Declaration (World Health Organization, 2018).

Key factors were selected according to theoretical research, and they namely include health personnel, healthcare expenditure and infrastructure. Therefore, we verify the following three hypotheses:

H1: Increasing HRH improves health outcomes.

H2: Increasing healthcare expenditure improves health outcomes.

H3: Increasing healthcare infrastructure improves health outcomes.

An econometric analysis of publicly available country-level data since 2000 was used to examine the relationship between selected key factors and health outcomes.

3.1 Database and initial selection of variables

Health outcomes were represented by the three following MDG indicators: maternal mortality (*Y1*), infant mortality (*Y2*) and child under-five mortality (*Y3*). Similar variables representing health outcomes have been used, for example, by Anand and Bärnighausen (2004). Within the formulated hypotheses, better health outcomes should be understood as lower mortality. Data on mortality rates were obtained from the database of the World Health Organization (2021). For the variable *Y1*, data were available for 183 countries until 2017; for the variables *Y2* and *Y3*, data were available for 194 countries, with the most recent data available for 2018. The shared time period from 2000 to 2017 was thus chosen for the analysis.

The key HRH factor was represented by two variables from the World Health Organization (2021) database, namely the number of doctors (*DOC*) and the number of nurses (*NURSE*). Considering that *Y1* and *Y2* are related to mortality rates at birth, it would undoubtedly be helpful to include indicators directly recording the number of birth attendants and paediatricians/children's nurses, which are unfortunately not available. Nonetheless, it can still be assumed that growing numbers of healthcare personnel (*DOC* and *NURSE*) will lead to decreasing mortality rates. However, the effect would not be as significant as it would be for the variable birth attendants and paediatricians/children's nurses.

From the world development indicators available in the World Bank (2021) database, the number of beds (*HBED*) was selected as a variable characterizing health infrastructure. Values for healthcare expenditure (*HEXP*) from the same database were used. Unfortunately, it was not possible to obtain statistics recording finances and the number of beds directly intended for postnatal care. The additional inclusion of a variable characterizing the quality of prenatal care in the form of the relative representation of pregnant women receiving prenatal care was considered. Unfortunately, this variable contained a fairly large number of missing observations, and therefore we eventually decided not to use it.

Table 1: Overview of considered variables with their expected direction (ED) on mortality rates

Variable	Indicator	Model	Source	ED
Y1	Maternal mortality ratio (per 100,000 live births)	Dependent variable	WHO	
Y2	Infant mortality rate (per 1,000 live births)		WHO	
Y3	Under-five mortality rate (per 1,000 live births)		WHO	
DOC	Medical doctors (per 10,000 population)	Key explanatory variables	WHO	(–)
NURSE	Nursing and midwifery personnel (per 10,000 population)		WHO	(–)
HEXP	Current healthcare expenditure per capita, PPP (current international $)		WB	(–)
HBED	Hospital beds (per 1,000 people)		WB	(–)
POVERTY	Poverty headcount ratio at national poverty lines (% of population)	Control numerical variables	WB	(+)
LITERACY	Literacy rate, adult female (% of females aged 15 and above)		WB	(–)
GDP	GDP per capita (constant 2010 USD)		WB	(–)
POPDEN	Population density (people per km2 of land area)		WB	(+/–)
POPGRW	Population growth (annual %)		WB	(+/–)
REGION	Europe, Eastern Mediterranean, Africa, Americas, Western Pacific, South-East Asia	Control categorical variables	WHO	
INCOME	Low income, lower middle income, upper middle income, high income		WB	

Source: Own work based on World Health Organization (2021) and World Bank (2021)

To maximize the explanatory power of the econometric model, control variables were considered. Their selection was based on theoretical research and available statistical indicators, which include poverty, literacy, GDP, level of income, population density and population growth. All these indicators come from the World Bank (2021) database. Relatively richer countries might reach lower mortality rates, as they have higher-quality and more available healthcare. In terms of population density, the mortality rate can be expected to be higher for more densely populated countries; on the other hand, smaller countries with high population densities belong to the group of high-income states. An unclear influence can also be expected in terms of population growth – a growing population will probably lead to an increase in deaths and thus a higher mortality rate; on the other hand, however, some states have high population growth and a large population, and therefore mortality rates may seem relatively low.

Due to missing values, in place of the income variable expressed as adjusted net national income per capita, the categorical variable of the World Bank income groups (low income, lower middle income, upper middle income, high income) was chosen. Furthermore, a geographic division of countries according to World Health Organization regions was applied (Europe, Eastern Mediterranean, Africa, Americas, Western Pacific and South-East Asia).

An overview of variables is listed in Table 1, which also presents the expected direction (−/+) of the influence of individual variables on health. However, observations were not always available for all the countries and for the same time period. Therefore, considerable attention was paid to data preparation, which is described in detail below.

3.2 Data preparation and final selection of variables

Unfortunately, the first glimpse at the obtained data confirmed that some of the variables had a high number of missing values. Therefore, a three-stage procedure to prepare a final dataset was proposed.

In the first stage, the occurrence of missing values was used to judge whether to include the given indicator in the econometric estimate. Based on missing values, two control variables were excluded: literacy and poverty. In terms of literacy, only 18 out of the 158 countries had available data for a time period longer than nine years. In terms of poverty, the situation was somewhat more favourable, as 49 out of the 153 countries had a time series longer than nine years. However, a strong correlation with GDP per capita can be expected for this variable.

In the second stage, the frequency of observations for a given unit (country) was evaluated. In cases in which at least three consecutive observations in all the variables occurred for the given unit, these units (countries) were left in the dataset. In cases in which time series were interrupted, the longest uninterrupted time series was included. After this step, 68 countries remained in the research sample.

The third stage dealt with the exclusion of countries based on outliers. Based on the occurrence of a larger number of outliers in the boxplot, the following seven countries were excluded: Afghanistan (AFG), Bosnia and Herzegovina (BIH), Switzerland (CHE), Luxembourg (LUX), Nicaragua (NIC), Pakistan (PAK) and Tajikistan (TJK).

The selection method shows that the harmonization of statistical reporting does not take place in all countries, and therefore valuable information for analysis of health determinants may be overlooked. Therefore, from the original data for 194 countries, only 61 countries were finally analysed.

Table 2 gives an overview of basic statistics of variables in the final dataset. Basic descriptive statistics for the whole dataset are listed at the top of the table. In addition, a more detailed overview for *Y1–Y3* by income group is available at the bottom of the table. According to expectations, high-income countries reach the lowest average values of *Y1–Y3*. Unfortunately, less developed countries might expect to reach higher values of *Y1–Y3*, which is likely a result of low public healthcare expenditure combined with low household incomes. This makes it difficult for people living in these countries to afford high expenditures on preventive care, thus causing high mortality rates.

Table 2: Descriptive statistics of variables before their transformation

Variable		Mean	Std. dev.	Min	Max
Y1		18.60	17.66	2.00	88.00
Y2		10.71	10.74	1.82	61.06
Y3		12.60	12.55	2.31	74.60
DOC		29.02	8.72	6.65	75.67
NURSE		67.14	33.59	1.00	172.12
HEXP		1,692.02	1,267.75	72.24	6,012.88
HBED		5.24	2.35	1.10	12.60
GDP		22,180.24	19,337.84	654.31	91,565.73
PDEN		166.88	540.54	2.82	6,913.42
PGRW		0.81	1.91	-9.08	15.18
Lower middle income	**Obs.**	**Mean**	**Std. dev.**	**Min**	**Max**
Y1	73	42.55	19.07	21.00	85.00
Y2	73	23.34	11.15	8.77	51.82
Y3	73	27.06	13.12	10.22	62.04
Upper middle income	**Obs.**	**Mean**	**Std. dev.**	**Min**	**Max**
Y1	171	30.26	16.72	3.00	80.00
Y2	171	19.26	12.68	3.40	61.06
Y3	171	22.56	15.02	4.50	74.60
High income	**Obs.**	**Mean**	**Std. dev.**	**Min**	**Max**
Y1	420	9.70	9.09	2.00	88.00
Y2	420	5.04	2.45	1.82	19.93
Y3	420	6.04	2.86	2.31	23.48

Source: Own work based on data from World Health Organization (2021) and World Bank (2021)

When compiling the econometric model, it was necessary to transform some of the variables. Specifically, a logarithmic transformation of the dependent variables *Y1–Y3* was used. Units were also adjusted for three of the quantitative explanatory variables (*HEXP°* = *HEXP* / 100; *GDP°* = *GDP* / 1000; *PDEN°* = *PDEN* / 10). The categorical explanatory variables *REGION* and *INCOME* enter the model through dummy variables.

3.3 Econometric model

With respect to panel data, the dependence of individual health outcomes on selected explanatory variables was investigated based on a linear mixed model with normally distributed random intercepts and slopes (Pinheiro and Bates, 2006). Fixed effects, including interactions between key variables (*DOC, NURSE, HEXP°, HBED*) and control categorical variables (*INCOME, REGION*), were considered. The interaction with *INCOME* turned out to be significant. The parameterization of the model was chosen to allow a direct estimate of the effects of key variables within individual income groups $g = 1, 2, 3$ representing lower middle income, upper middle income and high income. *REGION* entered the model without interaction through three dummy variables *REG2*, *REG3* and *REG4*, with Europe as the reference category. Furthermore, different residual variance appeared to be present in different income groups. To capture the apparent heteroscedasticity, the residual variance parameter depends on the income group in the model formulation:

$$
\begin{aligned}
&logY_{it} = a_i + b_i t + \sum_{g=1}^{3}\left(\alpha^g + \beta_0^g\, t + \beta_1^g DOC_{it} + \beta_2^g NURSE_{it} + \beta_3^g HEXP_{it}^{\circ} + \beta_4^g HBED_{it}\right) \\
&I\left(INCOME_i = g\right) + \ \beta_5 GDP_{it}^{\circ} + \beta_6 PDEN_{it}^{\circ} + \beta_7 PGRW_{it} + \beta_8 REG2_i + \\
&+ \beta_9 REG3_i + \beta_{10} REG4_i + \varepsilon_{it} \qquad (1)
\end{aligned}
$$

where $(a_i,\ b_i)' \sim N((0,0)',\ \mathrm{D})$ and $\varepsilon_{it} \sim N(0,\ \sigma_g^2)$. That is, the model contains country-specific random intercept a_i and random slope b_i, which are assumed to be jointly normally distributed. Their covariance matrix D is assumed to be a general positive definite matrix, that is, the random intercept and slope are correlated and their correlation is of unknown model parameters. Furthermore, the residual variance σ_g^2 depends on the income group to model the heteroscedasticity present in data. The index i expresses the cross-section unit ($i = 1, 2, \ldots, N$), which in our case is represented by a country. The index t, which represents the period of the observed unit, takes on values of $t = 0, 1, \ldots, T$ ($T = 15$), given that the referential time period for the main analysis ranges from 2000 to 2015. There are a total of 61 countries from around the world in the acquired dataset; the index i thus takes on values from 1 to 61. The created dataset is unbalanced, and the total number of observations is 664.

For all the key variables (*DOC, NURSE, HEXP°, HBED*) in Equation (1), a negative correlation to mortality rates *Y1–Y3* can be assumed (see Table 1, column ED). In case the number of medical personnel is increasing, we can expect that, *ceteris paribus*, there will be a decrease in the mortality rate because qualified medical personnel are able to address a larger proportion of conditions that put mothers, infants or children at immediate risk of death. Furthermore, with the increase in the number of hospital beds, there will be, *ceteris paribus*, greater availability of healthcare and, thus, a reduction in the mortality rate. In the case of an increase in healthcare expenditure, *ceteris paribus*, there will be a reduction in mortality rates through investment in modern medical equipment, leading to professionalisation of healthcare. Professionalisation of healthcare can also be driven by rising expenditure on health personnel, *ceteris paribus*, through rising average real wages. Comments on the results for each explanatory variables are provided in sections 4.1 to 4.3.

As mentioned above, five control variables (*GDP°, PDEN°, PGRW, INCOME, REGION*) were included in the econometric model to reveal the true influence of other potential factors on the dependent variables *Y1–Y3*. The strength of multicollinearity was measured using the variance inflation factor (VIF; for factors and indices of the correlation matrix of explanatory variables, see, e.g., Lavery et al., 2019). As the mean VIF value was 3.14 and the maximum VIF was 7.45, all the explanatory variables could be included in the model.

4. Results and Discussion

Table 3 shows the basic results of the three linear mixed models according to Equation (1). The model parameters were estimated using the maximum likelihood method, and their significance was assessed using Wald tests. The results are broken down according to income groups of countries, where the interaction with the key variables was taken into account. The data clearly demonstrate that mortality rates are decreasing over time in all three income groups of the countries in question. For the key variables, ten statistically significant results out of 36 possible ones can be identified, with no significant effect whatsoever of the *NURSE* variable in any model.

Statistically, maternal mortality (*Y1*) is significantly dependent on two of the four key variables, namely in countries with lower middle income. The other two mortality rates (*Y2*, *Y3*) are dependent on two key variables in lower middle-income countries, while they are dependent on one key variable in upper middle-income and high-income countries.

Table 3: Linear mixed model results for *Y1–Y3*

	Model for *Y1*			Model for *Y2*			Model for *Y3*		
	Coeff.	**SE**	**P-val.**	**Coeff.**	**SE**	**P-val.**	**Coeff.**	**SE**	**P-val.**
Lower middle income									
(Intercept)	4.7368	0.3403	**<0.001**	3.7332	0.2256	**<0.001**	3.8736	0.2284	**<0.001**
t	−0.0473	0.0135	**<0.001**	−0.0406	0.0088	**<0.001**	−0.0427	0.0090	**<0.001**
DOC	−0.0249	0.0098	**0.011**	0.0046	0.0050	0.365	0.0059	0.0052	0.262
NURSE	−0.0047	0.0037	0.205	−0.0008	0.0019	0.680	−0.0004	0.0020	0.825
HEXP°	0.0823	0.0305	**0.007**	−0.0762	0.0149	**<0.001**	−0.0793	0.0157	**<0.001**
HBED	−0.0190	0.0329	0.564	−0.0517	0.0162	**0.002**	−0.0561	0.0171	**0.001**
Upper middle income									
(Intercept)	3.3413	0.1680	**<0.001**	2.8779	0.1289	**<0.001**	3.0357	0.1277	**<0.001**
t	−0.0557	0.0078	**<0.001**	−0.0508	0.0054	**<0.001**	−0.0514	0.0054	**<0.001**
DOC	0.0013	0.0011	0.251	0.0004	0.0006	0.496	0.0004	0.0006	0.498
NURSE	−0.0005	0.0007	0.497	−0.0003	0.0004	0.466	−0.0002	0.0004	0.560
HEXP°	0.0004	0.0070	0.959	−0.0001	0.0040	0.984	−0.0003	0.0040	0.935
HBED	0.0189	0.0122	0.121	0.0144	0.0067	**0.031**	0.0135	0.0068	**0.048**
High income									
(Intercept)	2.2859	0.1489	**<0.001**	1.8791	0.0885	**<0.001**	2.0580	0.0873	**<0.001**
t	−0.0312	0.0054	**<0.001**	−0.0333	0.0033	**<0.001**	−0.0334	0.0033	**<0.001**
DOC	0.0023	0.0025	0.363	−0.0010	0.0008	0.217	−0.0010	0.0008	0.222
NURSE	0.0003	0.0005	0.450	0.0002	0.0001	0.109	0.0002	0.0001	0.106
HEXP°	0.0017	0.0025	0.491	−0.0023	0.0008	0.007	−0.0023	0.0008	**0.005**
HBED	0.0001	0.0153	0.995	−0.0052	0.0053	0.330	−0.0050	0.0053	0.345
REG2	1.2108	0.2473	**<0.001**	0.2677	0.1900	0.164	0.3008	0.1814	0.103
REG3	0.6622	0.2369	**0.007**	0.6962	0.1829	**<0.001**	0.6830	0.1745	**<0.001**
REG4	0.4618	0.2532	0.074	−0.0467	0.1918	0.809	0.0012	0.1840	0.995
GDP°	−0.0073	0.0021	**0.001**	−0.0022	0.0008	**0.005**	−0.0021	0.0008	**0.006**
PDEN°	0.0001	0.0008	0.920	−0.0002	0.0005	0.643	−0.0002	0.0005	0.632
PGRW	−0.0030	0.0030	0.315	−0.0012	0.0011	0.287	−0.0012	0.0011	0.300

Note: REG2 – Americas, REG3 – Eastern Mediterranean, REG4 – Western Pacific. Statistically significant results (p-value < 0.05) are highlighted in bold.

Source: Own estimates based on data from World Health Organization (2021) and World Bank (2021)

Concerning the explanatory variables, it is also necessary to consider the possible relationship between them. For example, increased healthcare personnel or hospital beds likely increase healthcare expenditure. Even though the strength of the multicollinearity was not found to be severe (see comments on VIF results in section 3.3), the estimation of Equation (1) was carried out without variable healthcare expenditure *HEXP°*. The results are presented in Table 4.

Table 4: Linear mixed model results for *Y1–Y3* (without healthcare expenditure *HEXP°*)

	Model for *Y1*			**Model for *Y2***			**Model for *Y3***		
	Coeff.	**SE**	**P-val.**	**Coeff.**	**SE**	**P-val.**	**Coeff.**	**SE**	**P-val.**
Lower middle income									
(Intercept)	4.8209	0.3460	**<0.001**	3.6109	0.2387	**<0.001**	3.7561	0.2420	**<0.001**
t	−0.0271	0.0113	**0.016**	−0.0597	0.0081	**<0.001**	−0.0625	0.0081	**<0.001**
DOC	−0.0225	0.0102	**0.027**	0.0035	0.0058	0.548	0.0040	0.0060	0.499
NURSE	−0.0038	0.0038	0.314	−0.0013	0.0022	0.537	−0.0008	0.0022	0.708
HBED	−0.0367	0.0339	0.280	−0.0341	0.0185	0.066	−0.0381	0.0194	**0.050**
Upper middle income									
(Intercept)	3.3439	0.1667	**<0.001**	2.8745	0.1308	**<0.001**	3.0312	0.1297	**<0.001**
t	−0.0556	0.0066	**<0.001**	−0.0508	0.0047	**<0.001**	−0.0516	0.0047	**<0.001**
DOC	0.0013	0.0011	0.251	0.0004	0.0006	0.483	0.0004	0.0006	0.481
NURSE	−0.0005	0.0007	0.490	−0.0003	0.0004	0.486	−0.0002	0.0004	0.585
HBED	0.0188	0.0119	0.115	0.0146	0.0065	0.025	0.0136	0.0066	**0.041**
High income									
(Intercept)	2.2972	0.1471	**<0.001**	1.8564	0.0894	**<0.001**	2.0343	0.0884	**<0.001**
t	−0.0293	0.0047	**<0.001**	−0.0359	0.0031	**<0.001**	−0.0361	0.0031	**<0.001**
DOC	0.0023	0.0025	0.350	−0.0010	0.0009	0.226	−0.0010	0.0008	0.232
NURSE	0.0004	0.0005	0.431	0.0002	0.0002	0.127	0.0002	0.0002	0.125
HBED	0.0003	0.0153	0.986	−0.0061	0.0054	0.255	−0.0060	0.0053	0.264
REG2	1.2066	0.2443	**<0.001**	0.2722	0.1951	0.169	0.3067	0.1870	0.107
REG3	0.6561	0.2343	**0.007**	0.7089	0.1879	**<0.001**	0.6984	0.1802	**<0.001**
REG4	0.4512	0.2508	0.077	−0.0318	0.1970	0.872	0.0190	0.1898	0.921
GDP°	−0.0069	0.0021	**0.001**	−0.0025	0.0008	**0.002**	−0.0024	0.0008	**0.002**
PDEN°	0.0001	0.0008	0.916	−0.0002	0.0005	0.643	−0.0002	0.0005	0.632
PGRW	−0.0031	0.0031	0.310	−0.0012	0.0011	0.290	−0.0012	0.0011	0.311

Note: REG2 – Americas, REG3 – Eastern Mediterranean, REG4 – Western Pacific. Statistically significant results (p-value < 0.05) are highlighted in bold.

Source: Own estimates based on data from World Health Organization (2021) and World Bank (2021)

4.1 Healthcare personnel

Although the importance of healthcare personnel in health outcomes has been confirmed in a number of studies (Needleman and Hassmiller, 2009; Lankshear et al., 2005, Donald et al., 2013; Traczynski and Udalova, 2018), in this study its effect was confirmed in only one case. Specifically, the number of nurses did not have any effect on health outcomes, and the number of doctors had a significant effect only on maternal mortality rate. However, for upper middle-income and high-income countries, the significance of the number of doctors was not demonstrated. The significance of the results for healthcare personnel remains the same even in models without the explanatory variable healthcare expenditure *HEXP°*; see Table 4. In summary, Hypothesis H1 was not fully confirmed.

Similar conclusions, albeit from a different perspective, are provided by Farahani et al. (2009). They found that populations of countries with a higher level of HRH usually have better health. However, they also confirmed that the evidence that heightening HRH leads to better health of the population itself is limited. Nevertheless, the long-term effects were confirmed to be greater than initially estimated. The number of physicians per 1,000 inhabitants is seen by Anand and Bärnighausen (2004) as the strongest predictor of results in the area of health among various HRH factors.

The effect of the number of doctors may differ among countries with different income levels, as there is possibly a more significant increase in specialist doctors in countries with higher income levels. Moreover, low-income countries may also suffer from brain drain and inadequate or outdated medical equipment. There is a consensus that the effects of medical brain drain, especially in Sub-Saharan African countries, ought to be perceived as more than just a simple misfortune (Yuksekdag, 2018).

Qualified medical personnel are able to address a professional array of medical conditions that expose mothers and their infants to the immediate risk of death. Based on the results, it can therefore be expected that investment in human resources, especially in doctors, will significantly contribute to the reduction of maternal mortality in lower middle-income countries and the achievement of MDGs. OECD countries naturally deal with a shortage of staff by acquiring foreign employees with healthcare training, which is a significant characteristic of globalization. The migration of nurses is becoming a more significant problem in terms of the general migration of healthcare staff, although the migration of doctors is also crucial in studying healthcare systems. Nurses and doctors have been found to have different motivations to migrate and prefer different countries for their migration (Hejduková and Kureková, 2019; Neethu and Helan, 2021).

4.2 Healthcare expenditure and infrastructure

The results indicate that health outcomes are most closely associated with healthcare expenditure, as they have a significant effect on all three mortality rates. This result is consistent with Hypothesis H2 and many previous studies (Fujii, 2018; Ray and Linden, 2019; Martín et al., 2011; Bedir, 2016; Nixon and Ulmann, 2006; Steinmann et al., 2007). In particular, a significant *HEXP°* effect was confirmed for five of the nine situations. It is worth noting that the effect of healthcare expenditure was not manifested in the group of upper middle-income countries. To determine where healthcare spending yields the greatest value, it is necessary to compare the benefits provided by different treatments (Hall, 2020). In addition to the level of healthcare expenditure, it should also be mentioned that the institutional environment is conducive to the efficient functioning of the healthcare system and therefore helps to stabilise the labour market and hence the economy (Kadeřábková et al., 2020; Čermáková and Jašová, 2019), which may indirectly positively affect health outcomes.

The effect of the number of beds was shown to be significant for infant and child under-five mortality. For lower middle-income countries, the sign of the effect is negative, while for upper middle-income countries, the sign of the effect is positive. This positive effect contradicts Hypothesis H3. Ricketts and Holmes (2007) noted a similar paradox that can appear alongside a growing healthcare supply. In addition, the number of hospital beds or their location in a region does not reflect the quality of healthcare. This is related to technological progress, which has been demonstrated to help reduce the infant mortality rate (Jamison et al., 2016). It can be assumed that technological progress is one of the variables reflected in the significance of the time effect in the results presented in Table 3.

4.3 Control variables and study limitations

It is worth noting that all three mortality rates are significantly linked to GDP. However, Easterlin (1996, 1999) pointed out that there is a small correlation between periods of economic growth and mortality. The results of our study indicate that maternal mortality has the closest relationship with GDP. Differences in mortality among regions are also considerable. If we focus on significant differences compared to Europe, most of them concern maternal mortality. Furthermore, among the regions included, the Eastern Mediterranean region has the largest difference in all three mortality rates compared to Europe. The effect of population density and growth has not been demonstrated.

However, the results of the study need to be regarded with some caution, as data are fragmented and the availability of high-quality and comparable information is limited (World Health Organization, 2004). A limitation of the study is that it ultimately did not include low-income countries that lacked sufficient available data. For the same reason, the study results do not cover the Africa and South-East Asia regions. Also, the selection of suitable explanatory variables was limited by the data availability. Besides, future research should include the impact of technology and digitization on health outcomes.

5. Conclusion

The linear mixed model results suggest that investment in human resources, especially in doctors, can be expected to make a significant contribution to reducing maternal mortality and achieving MDGs only in countries with lower middle income. Therefore, in developed countries, the results indicate that it is not necessary to increase the numbers of these resources, but rather to maintain expertise and develop necessary competencies among them. Contrarily, the results do not suggest the number of nurses affecting any studied mortality rates. Possibly, the number of nurses as a statistical indicator might cause a lack of support for this effect in our results. It would be more appropriate to include indicators directly recording the number of birth attendants and paediatricians/children's nurses. Unfortunately, these indicators were not available for our analysis.

On the other hand, the results demonstrate the importance of healthcare expenditure and the infrastructure of healthcare services. However, the size and direction of the effect vary among countries with different income levels. The results show that healthcare expenditure has the most considerable effect on health outcomes in lower middle-income and high-income countries. From a health policy perspective, the obtained results are interesting. In country types analysed here, there is still room for health improvements with larger healthcare expenditure. Furthermore, with an increasing number of beds, mortality decreases in lower middle-income countries, while mortality increases in upper middle-income ones. This paradox can appear along with growing healthcare supply. In addition, the number of hospital beds or their location in a region does not reflect the quality of healthcare.

The results support the validity of the theory that economically strong countries will have a lower mortality rate. A statistically significant effect of GDP growth appeared in the decrease in maternal, infant and child mortality rates. On the other hand, population density and population growth were not statistically significant for any mortality rate. Mortality, therefore, appears relatively stable in regard to these changes in the population.

This paper contributes to the health economics debate by statistically testing the relationship between health outcomes and selected variables. It shows that statistical reporting is not harmonized, and in some countries it is completely absent. For this reason, valuable information for analysis of health determinants may be overlooked. Due to the problem of missing values, a three-stage data selection was performed to partially solve this problem. This procedure may help with the replication of the research and its possible extension in the future.

Some studies have focused on the relationship of health outcomes solely in regard to healthcare expenditure. Our study emphasized capturing the impacts on health outcomes more comprehensively by examining the relationship through three dimensions of the healthcare system. The panel data analysis provides valuable information on these three dimensions in terms of health outcomes on a global scale.

The present research can serve as a guide for health policy and can be used to make the following recommendations in this area to improve health outcomes: investments should be made into the healthcare system, and better monitoring of healthcare indicators is necessary; health crisis management must be well-prepared and systematically supplemented; further harmonization of reporting is needed in all countries for valuable analysis; the European Union needs to make efforts to modernize healthcare systems across Europe, with an emphasis on the quality of healthcare staff; the importance of the World Health Organization's role in health policy should be recognized; and poor countries must not be neglected, as they still have a greater need for healthcare but a shortage of quality personnel.

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