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Article

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The Link between Economic Growth, Air Pollution and Health Expenditure in the G7 Countries

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ABSTRACT

The objective of this paper is to study the effect of economic growth and pollution on health expenditure in G7 countries, during the 1990-2020. In order to obtain a reliable estimate, we adopt the partial least squares (PLS) regression method, which focuses on three explanatory indicators (GDP, CO_2, MR) and health expenditure (HE), as a dependent variable. The obtained empirical results reveal several important elements. First, all the models are significant, with the exception of Canada. Then, all countries have verified the economic theory that GDP positively affects HE. Then, we observe negative effects of CO_2 emissions on HE, except in Japan. Finally, France, Italy, the United States and the United Kingdom have negative effects of MR on HE.

Keywords: Economic Growth, Health Expenditure, CO_2 Emissions, Partial Least Squares
JEL Classifications: O41, I15, Q53, C10

1. INTRODUCTION

Several factors, such as the level of income, pollution linked to the level of industrialization, the quality of the environment, etc., influence both the health of the population and health expenditure. One of the most important goals of governments is to provide quality health services, as they can lead to an improved life expectancy, labor productivity, and social as well as economic well-being (Bayar et al., 2021).

In recent years, life expectancy has been increased in different countries due to the development in health services, the use of advanced technologies and improved living standards. The needs of the population in terms of health care are therefore currently increasing, and we have observed that in some countries (EU countries, OECD countries, and G7 countries) a faster growth in health expenditure compared to income (Hitiris, 1999). As a kind of human capital, health plays an important role in the development process of any country, and the access to health services is a basic human right. Therefore, healthcare financing is becoming important for improving population health in both developing and industrialized countries (Sirag et al., 2017).

The deterioration of the environment has a negative effect on public health; as a result, an increase in the health budget is required. This situation is valid for a country like Australia, which is in the case of the decline of Kuznet; indeed, the level of income per capita, which is considered as a key determinant of health expenditure, is related to environmental degradation, as shown by the Kuznets environmental curve (Moosa, 2019).

Jacobson (2008) establishes a link between health expenditure and carbon dioxide emissions. He has pointed out that the main culprit of air pollution is carbon dioxide. The latter increases harmful substances and other substances that consequently increase the ozone surface, which negatively affects human health, and thus increases the number of hospitalizations and deaths. He added that the increase of hospitalization and death rates have severely affected industrial production, labor productivity, and economic growth, which have also been demonstrated (Borhan et al., 2018).

According to WHO (2016), direct health expenditures related to environmental diseases can be estimated using environmental disease burden and health expenditure data. Direct health care due to environmental degradation represents a substantial cost; that is up to 0.5% of the global GDP. Furthermore, the share of health expenditure in GDP and the share of pollution-related disease burden differ considerably from one country to another Egorov et al. (2016).

In terms of determinants of health expenditure, the problem chosen in this study raises several questions of interest, such as the environmental problems due to carbon dioxide emissions, deaths related to air pollution and real GDP per capita that have an impact on health expenditure at the European level especially in the context of the current pandemic. For governments, the increase in health expenditure should be considered as a major source of concern, so understanding its determinants can assist policymakers in formulating appropriate policies.

This study explores the effects of the environment, the real GDP per capita and the air pollution-related mortality on health expenditures in a group of seven member countries (G7) over the period 1990-2020 using regression by partial least squares (PLS). In our study, we have adopted the following work plan: The first section is an introduction and the second one presents a literature review on the chosen topic. The data and the empirical methodology used are presented in the third section; the fourth section explains the major results of the study. Finally, we will discuss the results of the study before concluding.

2. LITERATURE REVIEW

In recent years, the link between health, environmental pollution and economic growth has begun to be examined by several authors and with various methodologies.

Using a two-step sequential regression model, Jerrett et al. (2003) conducted a study of cross-sectional data from 49 counties in Ontario, Canada, to determine the relationship between the environmental quality measured by total pollutant emissions and the health expenditures. They have found that there is a significant correlation between the two variables and that in countries with higher pollutant emissions, health expenditure is higher per capita; a similar result is found for the OECD cantries in Lago-Peñas et al. (2007).

Wang et al. (2012) used PLS regression to find the main influencing factors of CO_2 emissions in Beijing, India. They showed that the economic level and the proportion of industry have a positive influence on CO_2 emissions. Moreover, with the growth of GDP per capita, the increase in CO_2 emissions does not respect the model of the environmental Kuznets curve. Similarly, Yang et al. (2013) estimated that fine particles (PM2.5 and PM10) have greater impact on atmospheric visibility and public health than traditional coarse particle pollutants. In the same context, Yang and Wang (2013) examined the negative influence of rapid industrialization and urbanization to air pollution as well as the regional and the global climates on human health. These researchers have also proposed to the Chinese government to abandon forced urbanization and over-industrialization to improve both the air quality and the living environment.

Regarding OECD countries, Uçak et al. (2014) examined the relationship between carbon dioxide (CO_2) emissions and gross domestic product (GDP) for 20 high-income countries over the period 1961-2004. Their results have shown that there is a positive relationship between GDP and CO_2, except for Norway.

Chaabouni et al. (2016) examined the causal relationship between CO_2 emissions, health expenditures and GDP growth, using the Simultaneous Equation Model and the Generalized Method of Moments (GMM). They showed that there is a bidirectional relationship between CO_2 emissions and GDP per capita and between health expenditure and unidirectional causality of CO_2 emissions and health expenditure. Thus, health plays an important role in economic growth. However, health expenditure has a limited impact if levels of environmental degradation increase. Similarly, Abdullah et al. (2016) used the ARDL method based on the Malaysian data from the period 1970-2014. They carried out a cointegration analysis using the variables of health expenditure and greenhouse gas emissions. Between these two, they have also found a long-run negative relationship, in contrast to a short-run positive relationship.

Murthy and Okunade (2016) have found a positive bidirectional relationship between economic growth and health care spending in the United States. This is consistent with the studies of Piabuo and Tieguhong (2017), Zaidi and Saidi (2018) and Erçelik (2018). They used the Autoregressive Distributed Lag (ARDL) model as an empirical methodology over the period 1995-2015.

In fact, several researchers have confirmed and found positive effects of carbon emissions on healthcare spending, including Apergis et al. (2018) time series from the United States, and Chaabouni et al. (2016) for developing countries classified by low, middle and high-income levels. However, the authors Zaidi and Saidi (2018) found that these emissions had a negative impact on health spending in African countries.

Wei et al. (2018) attempted to identify the main sectors contributing to the emission of air pollutants and tested the regional heterogeneity characteristics of air pollution in China. They demonstrated that in non-key regions, air pollution comes mainly from coal consumption, coke production and electricity generation. In urbanized areas, the main air pollutants are mainly sulfur oxides (SOX), nitrogen oxides (NOx), volatile organic compounds (VOCs) and fine particles (PM). Under some weather conditions, these air pollutants are transformed into PM2.5 after a complex chemical reaction process. This further aggravates pollution and human health.

In order to provide a comprehensive overview of the existing relationship between CO_2 emissions and economic growth associated with other indicators, Mardani et al. (2019) proposed a qualitative systematic meta-analysis method called PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). They showed that the link between CO_2 emissions and economic growth justifies the policy options that are used to reduce emissions by imposing limiting factors on economic growth as well. Thus, there is a two-way causality as economic growth increases or decreases.

In order to assess the efficiency of healthcare spending, Jakovljevic et al. (2020) applied the two-way fixed effects model (country effects and year effects) on a selected group of Asian countries for the years 1996 and 2017. They demonstrated that carbon dioxide emissions per capita increase infant mortality, and that there is a strong negative association between GDP per capita and infant mortality in the sample.

Using the STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model and the partial least squares (PLS) regression and from 1996 to 2015, Li et al. (2020), examined the demographic factors that drive carbon emissions in Shanghai. Their results showed that the effects of GDP per capita on carbon emissions are positive, with an elastic coefficient of 0.004.

Bayar et al. (2021) examined the effects of the environment the real GDP per capita and life expectancy on health expenditure in 27 EU member countries during the period 2000-2018. These results showed that there is a significant unidirectional causality between the studied variables. Indeed, real GDP per capita, greenhouse gas emissions and life expectancy exert a statistically significant effect on short-run health expenditure. While the cointegration coefficients reveal that life expectancy and real GDP per capita have a moderate positive impact on health spending in most panel countries (the same findings for the study by Oladosu et al., 2022), the environment admits a small positive or negative impact on health expenditure in a limited number of countries (Similar results for Sirag et al., [2017] and Akbar et al., 2021).

3. DATA AND METHODS

3.1. Data

To investigate the links between economic growth and health expenditures, the annual data was collected from 1990 to 2020 of seven countries of the G7. The source of this data is from The Organization for Economic Cooperation and Developement (OECD), the World Bank, and the International Energy Agency (IEA). The next paragraphs explain our data and Table 1 summarizes it.

3.1.1. Health expenditure

According to the OECD, health expenditure measures the final consumption of health goods and services, including personal health care (curative care, long-run care, rehabilitation care, ancillary services and medical goods) and community services (public health and preventive services as well as health administration) without taking into account capital expenditure (Figure 1).

Table 1: The Studied variables

	Description	Source of data
HE	Total health expenditure per capita expressed in USD.	The Organization for Economic Cooperation and Developement (OECD)
GDP	Gross domestic product per capita expressed in constant 2015 USD	World Bank
CO_2	Global carbon oxide emissions expressed in metric tonnes per capita	International Energy Agency (IEA)
MR	Number of deaths per 1,000,000 inhabitants due to pollution	The Organization for Economic Cooperation and Developement (OECD)

3.1.2. Gross domestic product

According to the World Bank, GDP is the sum of the gross value added by all resident producers in the economy, plus taxes on products and minus any subsidies not included in the value of products. Data is calculated without making deductions for depreciation of manufactured assets or for depletion and degradation of natural resources. All data is in constant 2015 US dollars (Figure 2).

3.1.3. Carbon dioxide emission

We have chosen carbon dioxide emissions (metric tons per capita) as the environmental indicator. Carbon dioxide (CO_2) is a natural gas fixed by photosynthesis in organic matter. It is the main anthropogenic greenhouse gas that affects the Earth's radiative balance. According to the World Bank (2020), carbon dioxide (CO_2) is a natural gas incorporated into organic matter through photosynthesis. It is emitted as a by-product of burning fossil fuels and biomass, but also from land-use change and other industrial processes. Carbon dioxide pollution is the main driver of global climate change. CO_2 data refer to gross direct emissions from energy combustion only and are from the International Energy Agency (Figure 3).

3.1.4. Mortality due to air pollution

The number of deaths due to air pollution (MR) is 1,000,000. Indeed, fine particles can cause serious health problems including respiratory and cardiovascular diseases; the most serious effects of which are seen in children and the elderly. Cost estimates represent only premature deaths. They are determined from estimates of the values of a statistical life and the number of premature deaths attributable to ambient air pollution by particulate matter (Figure 4).

3.2. Methods

As part of our work, we have studied the relationship between economic growth, pollution and health expenditure in the group of G7 countries. Our study uses the partial least squares (PLS) model. The latter was chosen because of the existence of a multicollinearity problem (see annexes) between the explanatory

Figure 1: Evolution of health expenditure from 1970 to 2020 for the G7 (in years). Illustrates the evolution of health expenditure, measuring the final consumption of health goods and services, during the period 1970-2020, for the group of G7 countries (Canada, United States, United-Kingdom, Japan, Italy, Germany, France). The *Source of the data is* the *oecd data, with are available at https://data.oecd.org/healthres/health-spending.htm*

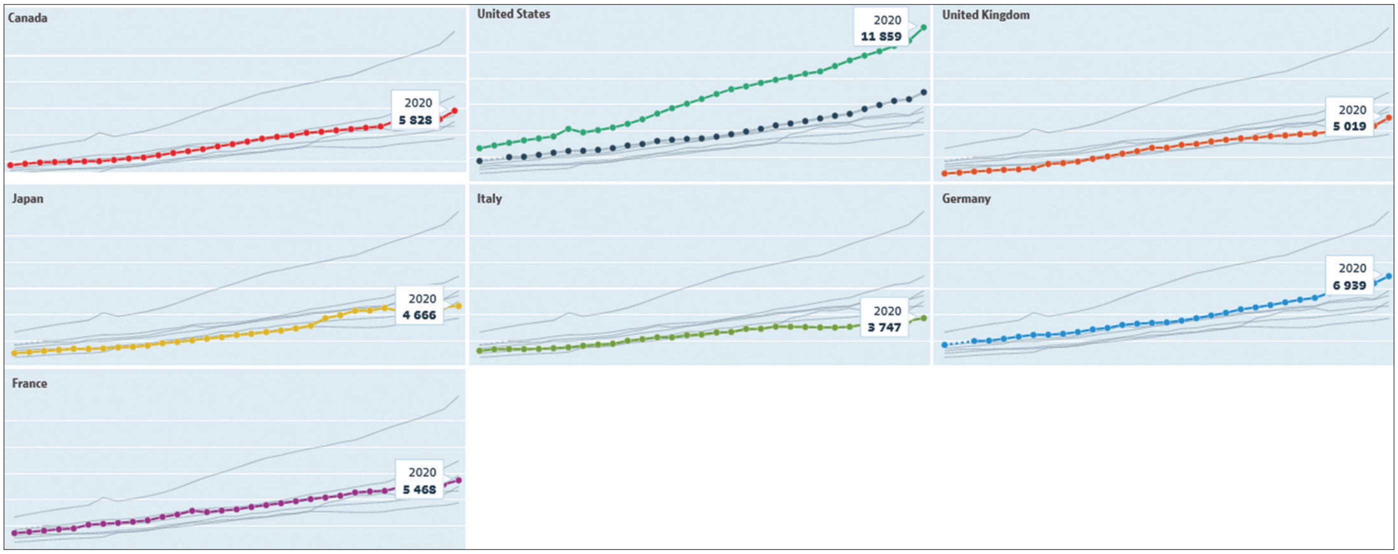
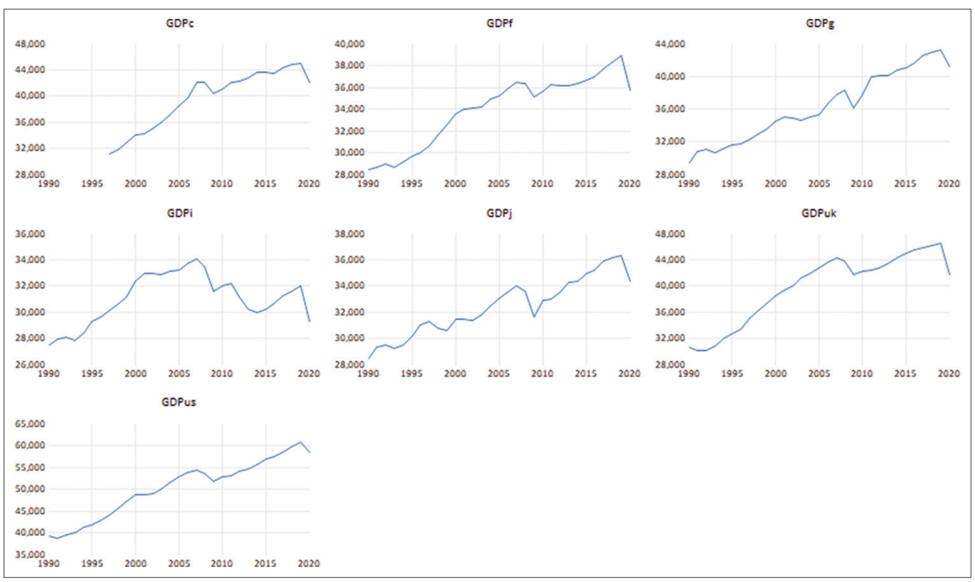


Figure 2: Evolution of gross domestic product from 1990 to 2020 for the G7 (in years). Represents the evolution of gross domestic product (GDP), during the period 1990-2020, for the group of G7 countries (Canada, United States, United kingdom, Japan, Italy, Germany, France), knowing that, the GDP is the sum of the gross value added of all resident producers in the economy, plus taxes on products and minus any subsidies not included in the value of products.The Source of the data is the world bank and Figure 2 is processed by the software eviews 12



variables, missing data in our database and the low number of observations (31 observations).

In 1966, Wold proposed the PLS method in the context of modelling structural relationships on latent variables for the analysis of multiple blocks of observed variables on the same individuals. Subsequently, Wold et al. developed this method in 1983 to apply it on chemometrics.

Indeed, Partial Least Squares (PLS) regression is a dimensionality reduction technique used when working with high-dimensional data and when there is a strong collinearity between variables. In this case, the PLS model is the most suitable because it reduces the dimension and ensures that the composite variables are not correlated. Thus, it makes it possible to distinguish a continuous binary or a nominal dependent variable with K modalities from a matrix of continuous quantitative or mixed explanatory variables. With the aim of obtaining a compromise between the maximization of the variance explained by the variables, PLS regression aims to combine the characteristics of principal component analysis (PCA) and regression.

According to Wang and Hu (2006), the term collinearity refers to the circumstance in a linear regression model in which the

Figure 3: Evolution of CO_2 emissions metric ton/capita from 1960 to 2020 for the G7 (in years). Represents the evolution of carbon dioxide emissions (metric tons per capita) (CO_2), over the period 1960-2020, for all G7 countries (Canada, United States, United Kingdom, Japan, Italy, Germany, France), knowing that (CO_2) is a natural gas incorporated into organic matter by photosynthesis. It is emitted as a by-product of the combustion of fossil fuels and biomass, but also of land-use change and other industrial processes. The source of the data is OECD, which can be found in *https://data.oecd.org/air/air-and-ghg-emissions.htm#indicator-chart*

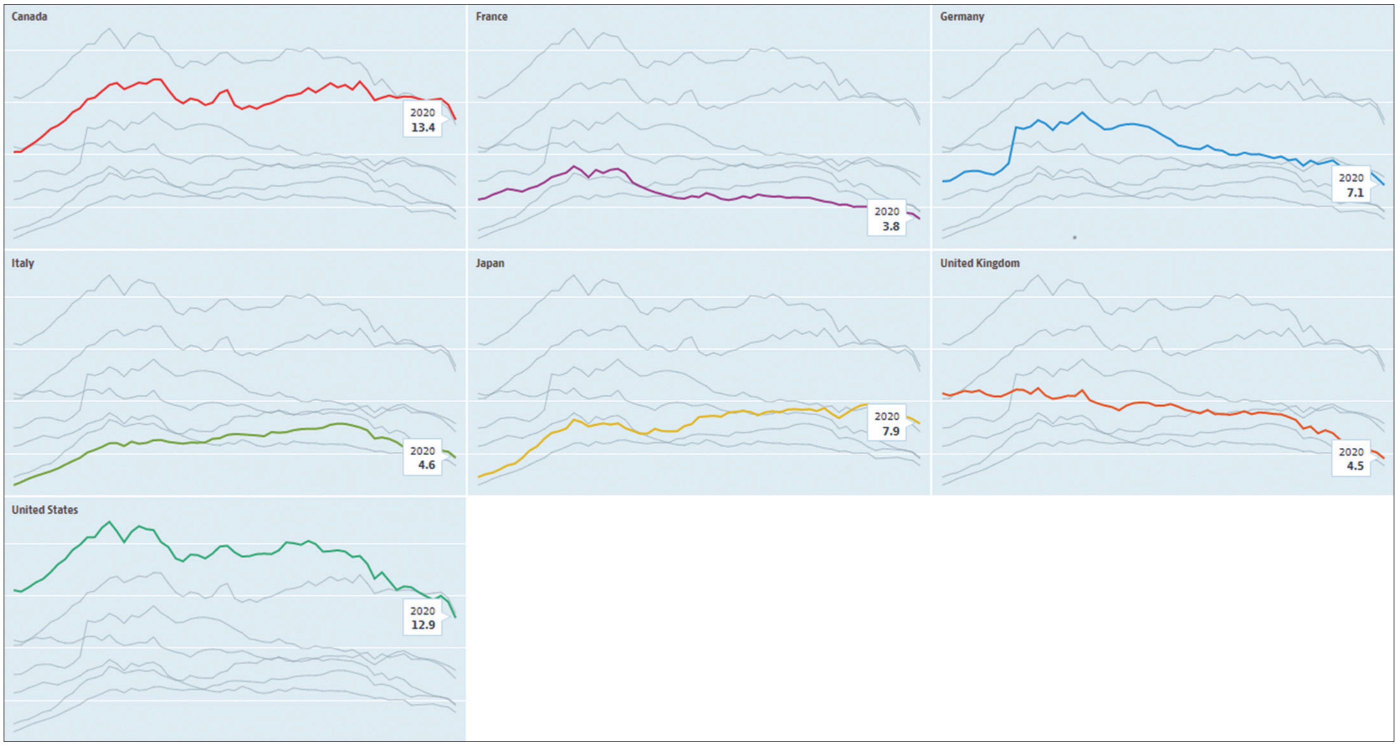
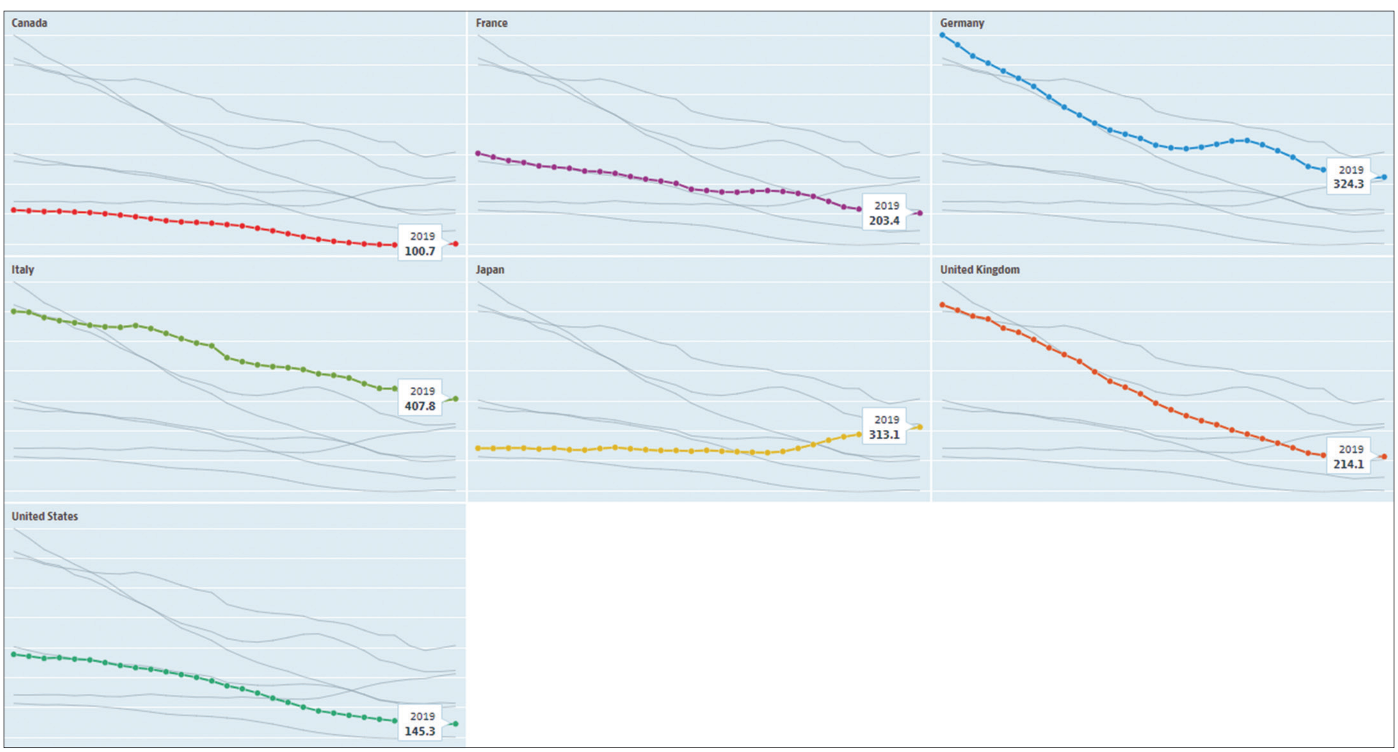


Figure 4: Mortality per 1,000,000 inhabitants from 1990 to 2019 for the G7 (in years). Figure 4 represents the evolution of the number of deaths due to air pollution (MR), during the period 1990-2019, for all the G7 countries (Canada, United States, United Kingdom, Japan, Italy, Germany, France). Moreover, air pollution, for example fine particles, can cause serious health problems, in particular respiratory and cardiovascular diseases; the most serious effects of which are seen in children and the elderly. Cost estimates represent premature deaths only. The source of the data is the OECD, which is available at *https://data.oecd.org/air/air-pollution-effects.htm*



presence of a perfect correlation between variables can lead to data disturbance and also to misleading conclusions. Indeed, the presence of collinearity can lead to an obvious instability of the coefficients of the variables (Næs and Mevik, 2001).

In both his article "PLS Regression and Applications" and his research notebook "New PLS Regression," Tenenhaus (1998) presented the PLS model, its algorithm, its equations as well as its main components and graphical interpretations.

PLS regression is done in three steps. The first consists in calculating the orthogonal components by blocks of the explanatory variables X. The second is the regression of Y on the orthogonal PLS components most correlated to Y (see appendices of correlation matrix). The third is the expression of the regression equation as a function of X (Desbois, 2002).

According to Tenenhaus (1998), partial least squares regression is based on the following iterative algorithm:

- Step 0: We start from the initial tables X and Y.
- Step 1: We calculate the vector W_1

$$W_{1j} = \operatorname{cov}(X_j, Y) \Big/ \sqrt{\sum_{j=1}^{p} \operatorname{cov}^2(X_j, Y)} \quad (1)$$

Then, it is necessary to perform a linear combination t_1 of the explanatory variables X_j:

$$t_1 = w_{11}X_1 + \ldots + w_{1p}X_p \quad (2)$$

The regression of Y and X on t_1 are then:

$$X = tp_1' + X_1 \quad (3)$$

$$Y = t_1c_1' + Y_1 \quad (4)$$

Where X_1 and Y_1 are the vectors of the residuals.

- Step 2: We construct two new components t_2 and w_2 which represent the linear combinations of the linear combinations of the columns of X_1 and Y_1 respectively. From where:

$$t_2 = w_{21}X_{11} + \ldots + w_{2j}X_{1j} + w_{2p}X_{1p} \quad (5)$$

$$W_{2j} = \operatorname{cov}(X_{1j}, Y) \Big/ \sqrt{\sum_{j=1}^{p} \operatorname{cov}^2(X_{1j}, Y)} \quad (6)$$

We then perform the regressions of Y and X on t_1 and t_2:

$$X = t_1p_1' + t_2p_2' + x_2 \quad (7)$$

$$Y = t_1c_1' + t_2c_2' + y_2 \quad (8)$$

We repeat the same steps for the other components to finally construct the following regression:

$$Y = X\sum_{h-1}^{\alpha} w_h c_h + Y_\alpha \quad (9)$$

4. RESULTS AND DISCUSSION

4.1. Results

4.1.1. Number of components

For Germany, the coefficient of determination (R2Y=0.97) is >50%. This indicates a very good quality of fit.

$$HE_g = 2.451 + 0.695GDP_g - 0.415CO2_g + 0.144MR_g \quad (10)$$

Germany's PLS equation (10) presents the regression coefficients that measure the contribution of each explanatory variable to the construction of the dependent variable. We notice that the coefficients of all the variables have a very high contribution to health expenditure in Germany. On the one hand, the GDP and the MR have a good contribution to the HEg (0.695 and 0.144). This finding confirms previous empirical studies Yazdi et al., (2014); Wang et al., (2019). On the other hand, CO_2 emissions have a poor contribution to HEg with a very high coefficient (0.415) (Table 2).

For France, the coefficient of determination (R2Y) is equal to 0.989. The model is globally significant with two PLS components.

$$HE_f = 2.778 + 0.386GDP_f - 0.289CO2_f - 0.364MR_f \quad (11)$$

According to the equation (11) of the PLS regression in the France case, CO_2 emissions and mortality due to air pollution contribute weakly to health expenditure as the coefficients are quite high; 0.289 for carbon dioxide and 0.364 for mortality. On the contrary, the contribution of gross domestic product to health expenditure is 38% (Table 2).

Regarding Italy, Table 2 shows that the coefficient of determination (R2Y=0.972) is >50% and therefore the model is completely significant.

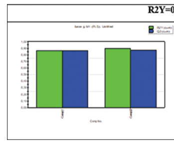
$$HE_i = 3.129 + 0.339GDP_i - 0.331CO2_i - 0.604MR_i \quad (12)$$

On the one hand, equation (12) of Italy's PLS regression shows that the contribution of economic growth in determining healthcare

Table 2: Number of components

Germany

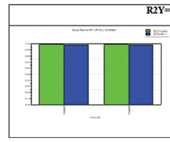
R2Y=0.97



Nombre des composantes	Q^2_{cum}	Limite
1	0.861	0.05
2	0.873	0.05
3	0.865	0.05

France

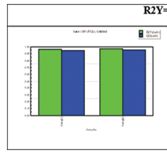
R2Y=0.989



Nombre des composantes	Q^2_{cum}	Limite
1	0.987	0.05
2	0.987	0.05

Italy

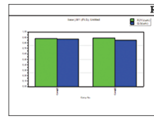
R2Y=0.972



Nombre des composantes	Q^2_{cum}	Limite
1	0.949	0.05
2	0.955	0.05

Japan

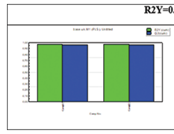
R2Y=0.89



Nombre des composantes	Q^2_{cum}	Limite
1	0.865	0.05
2	0.851	0.05

United Kingdom

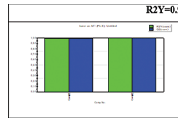
R2Y=0.977



Nombre des composantes	Q^2_{cum}	Limite
1	0.694	0.05
2	0.961	0.05

United States

R2Y=0.996



Nombre des composantes	Q^2_{cum}	Limite
1	0.992	0.05
2	0.996	0.05

spending in Italy is positive with an almost high coefficient (0.339). The contribution of CO_2 emissions and MR is negative, with high coefficients respectively, 0.331 and 0.604.

For Japan, the model is also globally significant, the coefficient of determination is >50% (R^2Y=0.89).

$$HE_j = 2.152 + 0.671GDP_j + 0.163CO2_j + 0.295MR_j \quad (13)$$

From Japan's PLS equation (13), we find that all explanatory variables have a positive contribution to the construction of health expenditures in Japan. Indeed, the contribution of GDP is good with a very high coefficient (0.67), that of CO_2 emissions with a rate of 16% and that of MR with a rate of 29% (Table 2).

For the UK, only the first two components are significant, the coefficient of determination R^2 is equal to 97%. This indicates a very good quality of fit.

$$HE_{uk} = 2.104 + 0.151GDP_{uk} - 0.418CO2_{uk} - 0.461MR_{uk} \quad (14)$$

Equation (14) shows that both CO_2 emissions and MR have negative effects on UK health expenditure with quite high coefficients (0.418 for CO_2 and 0.461 for MR). On the other hand, the economic growth indicator (GDP) positively affects the HE variable with a rate of 15% (Table 2).

For the United States, the coefficient of determination is significant with a very good goodness of fit (R^2= 0.996). Only the first two components are significant as provided by the SIMCA-P software.

$$HE_{us} = 2.474 + 0.443GDP_{us} - 0.233CO2_{us} - 0.367MR_{us} \quad (15)$$

From equation (15) of the PLS regression, we notice that the explanatory variables (GDP, CO_2 and MR) have a significant contribution to the construction of the dependent variable (HE). In particular, a poor contribution of CO_2 and MR with fairly large coefficients (0.233 and 0.367) and a good contribution of GDP with a fairly large coefficient (0.443) (Table 2).

Indeed, the previous overall results have shown that there is a link between health expenditure and GDP, such as the study Gerdtham and Löthgren (2002); Baltagi and Moscone (2010); Wang et al. (2019); Kutlu and Örün (2022) and Mujtaba and Ashfaq (2022) which confirmed our results, in contrast to the study of Albulescu et al. (2017) which has found that there is no relationship between GDP and health expenditure. Similarly, environmental degradation negatively affects healthcare spending in 5 countries (Germany, Italy, France, United States, and the United Kingdom) which confirms the study by Wang et al. (2019) which is in contrast to the study by Boachie et al. (2014) and that by Moosa and Pham (2019). Regarding mortality from pollution, we have found that it had a negative effect on health care spending in France, Italy, the United States, and the United Kingdom, and vice versa for Germany and Japan, with a statistically positive effect, as shown by Aziz et al. (2021).

4.1.2. Importance of variables

As Table 3 shows, it is possible to classify countries into three groups according to the importance of the variables.

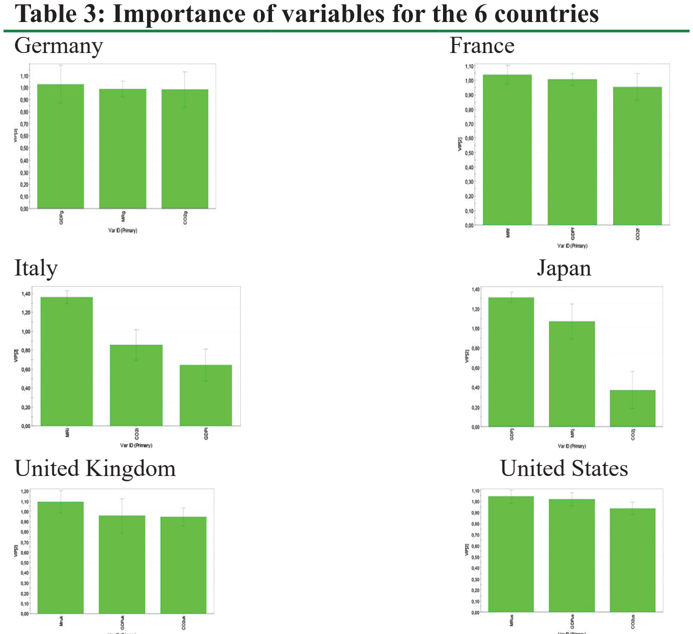
The first group contains Germany and Japan. Moreover, for Germany we notice that the gross domestic product per capita affects more health care expenditure, since its VIP value is higher than 1 (the same case for Japan). The most important variable in Japan, which affects health expenditures, after gross domestic product, is the MR variable (their VIP is >1); however CO_2 emissions in both countries have a VIP value <1. In general, the variables used in our study have a strong impact on health expenditures in both countries as reported by Mujtaba and Ashfaq (2022) in their research.

The second group consists of France, the United Kingdom and the United States, where all three variables (MR, GDP and CO_2) are very important in explaining health expenditures in these three countries. This result is confirmed by the study of Abbasian et al. 2021. Mortality due to air pollution affects health expenditures more strongly. In the one hand, for GDP, their VIP is >1 only in France and the USA. On the other hand, for CO_2 emissions, their importance is less than that of the other explanatory variables (their VIP values are <1).

In the third group, which contains Italy, we notice that the MR variable (their VIP is >1) is the most important in explaining health care spending in Italy, followed by CO_2 emissions and GDP being less important (their VIP is <1). This finding is fully consistent with the study of Zaidi and Saidi (2018).

Several economic and social factors justify the importance of health. In fact, several studies have focused on the determinants of health spending, including Boussalem et al. (2014); Wang et al. (2019); Coccia (2021); Elola-Somoza et al. (2021); Oladosu et al. (2022). Nevertheless, the results of these studies remain

Table 3: Importance of variables for the 6 countries



controversial. This controversy is due to the diversification of variables used, the populations studied, the periods of analysis and the methods used.

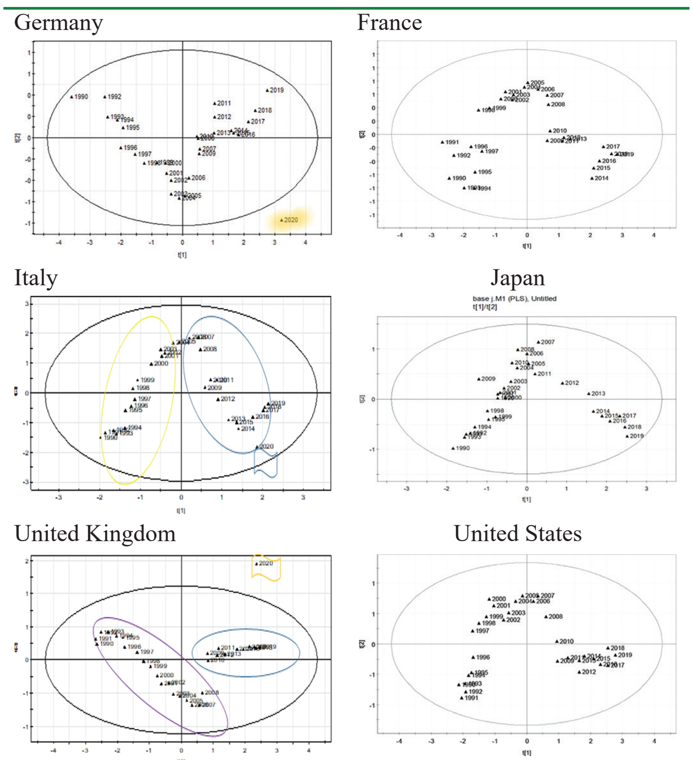
4.1.3. Chart of the observations

The results in Table 4 show that most of the observations lie inside the ellipse (are homogeneous); meaning that they have the same characteristics in all six countries, except for the year 2020, which lies outside the ellipse in Germany and the UK.

Indeed, the total lock-in, due to covid-19, has led to the shutdown of carbon- and energy-intensive economic sectors such as manufacturing and transportation in many countries. These shutdowns have helped to relieve congestion in urban centers and reduce traffic levels, resulting in lower anthropogenic emissions (Verisk, 2020). The industrial economy of Germany, like other European countries, is one of the peaks of COVID-19 as the number of infections by the pandemic has an increasing trend. Germany's situation is unique in that it has experienced a high infection rate but a very marginal mortality rate from COVID-19 (Bashir et al., 2020). Environmental pollution has decreased due to the closure of vital economic sectors such as transportation, aviation, and industries. Similarly, health systems have been significantly improved to save lives at the expense of economic deterioration (Sarkodie and Owusu, 2021).

We explain the existence of all observations inside the ellipse for France by the national lock-in over a 55-day period (March-May 2020), which has been imposed by the French government. Malliet et al. (2020) showed that the lock-in period had significant short-run negative consequences on the economic activity and that this economic downturn had an immediate mechanical impact on CO_2 emissions. For this reason, France can be considered as one of the countries that has the covid-19 crisis under control.

Table 4: Chart of the observations of the 6 countries



In Italy, Table 3 shows that the year 2020 is approaching an atypical point. We have noted that Italy has experienced an improvement on the economic and social levels between 1990 and 2005. Health care expenditure increased from 1272.1 dollars per capita in 1990-2504.1 dollars per capita in 2005. During the same period, the gross domestic product per capita increased by 21%. CO_2 emissions and deaths from air pollution have begun to decline. As for the second period (2005-2019), it experienced a slowdown in economic growth. In fact, the gross domestic product started to decline in 2007 from $3,467.9 million per capita to $3,043.9 (per capita) in 2019. Then, it dropped by 8.6% in 2020 ($29,287.1). For example, CO_2 emissions decreased from 7.69 in 2006 to 5.13 in 2019. Moreover, deaths due to air pollution decreased by 114.2 cases between 2006 and 2019. On the other hand, health expenditures increased from $2660.4 to $3653.4 per capita during the same period. We note that the year 2020 is approaching an atypical point. It is characterized by a reduction in all areas due to the global health crisis covid-19.

Japan's situation is approaching an atypical point in 2019. This is due to the increase in its per capita healthcare spending of $3606 between 1990 and 2019. During the same period, the economic growth rate increased by nearly 27.5%, only to fall by 5.5% in 2020. On the other hand, the curve of CO_2 emissions is disturbed. In this context, these emissions have increased from 8.51 metric tons in 1990 to 9.09 metric tons per capita in 1996. In 2012, they still experienced fluctuations. But, in 2013 these emissions started to decrease at a steady pace to reach 8.5 metric tons per capita in 2020. In the ranking of countries according to CO_2 emissions, Japan's emissions reached 1,061.774 megatons in 2020. Therefore, we can say that it is one of the ten most polluting countries in the world in terms of carbon dioxide emissions. In the same vein, deaths due to air pollution increased from 242.3 cases in 1990 (per 1,000,000 inhabitants) to 313.1 cases in 2019.

Over the period (1990-2008), health care expenditure in the UK increased by more than 300% (from $722.6 in 1990 to $3203.6 per capita in 2008). CO_2 emissions were reduced at a slower rate compared to the number of deaths from air pollution, which declined at an accelerated rate (401.3 deaths/1,000,000 inhabitants). Between 2009 and 2019, health expenditures have increased by $1229 per capita and gross domestic product has increased from $41742 to $46611. Then it has decreased in 2020 to reach $41811. Thus, CO_2 emissions decrease from 7.4 to 5.1 metric tons per capita for the same period. However, those of deaths due mainly to air pollution, they are reduced to 89 deaths (on 1 000 000 inhabitants). In 2020 and after the global crisis of covid-19, the United Kingdom has witnessed an increase in its health expenditure by almost 17% compared to 2019. As for the rate of economic growth; it has dropped by 11.5% from 46611 to 41811 dollars per capita.

For the United States, its health care expenditures have increased by more than 300% following a 55% increase in GDP per capita between 1990 and 2019 to a drop of 3.82% in 2020. On the other hand, CO_2 emissions have decreased by more than 24% and mortality has decreased by 61.5% over the same period.

4.1.4. Map of variables

The structure of the correlations between the dependent variable (HE) and the explanatory variables (GDP, CO_2, MR) is presented in Table 5. Note that GDP positively affects health care expenditure in all 6 countries. This result is similar of the anterior work of Yun and Yussof (2015); Khoshnevis Yazdi and Khanalizadeh (2017); Abbasian et al. (2021) and Mujtaba and Ashfaq (2022). This variable is very close to the HE variable in Germany. Similarly, the CO_2 and MR variables have a poor influence on the dependent variable (HE) in France, Italy, the United Kingdom and the United States. This confirms the results of the PLS regression.

Indeed, the French model shows that all explanatory variables are far from the dependent variable, but the coefficients of the two variables (CO_2 and MR) are very low. For Italy, all the variables are located far from the origin. This explains the existence of a good quality representation of the scatterplot. For Japan, all explanatory variables have a significant and positive influence on health expenditure. This finding is confirmed by the study of Narayan and Narayan (2008). Besides, the PLS regression equation has shown that the two variables (CO_{2j} and MR_j) have very low coefficients and therefore have a low contribution in the construction of the dependent variable (HE_j).

4.1.5. Comparison between observed Y and predicted Y

PLS regression provides a very efficient solution and resolution. Indeed, the percentage of R^2 determination is equal to nearly 97% with 3 PLS components (Germany), 99% with two components (France), 97.5% with two components (Italy), 89% with two components (Japan), 98% with two components (United Kingdom) and 99% with two components (United States).

For the six countries, the prediction results confirm this efficiency since the predicted, and the observed values are very close (Table 6).

4.1.6. Canada

The coefficient of determination of Canada is not significant, and the efficiency is very low (R^2= 0.146). This allows us to say that the model is not significant. Furthermore, the SIMCA-P software indicates that only the first three components are weakly significant. This means that the economic growth and the environmental pollution have no effect on health expenditures in Canada. This can be explained by the strict environmental legislation that has been adopted.

Indeed, carbon pricing is a way to reduce pollution at the lowest cost to businesses and consumers. Around the world, businesses, governments and experts say that putting a price on carbon is the most effective and economical way to reduce carbon emissions. This carbon pricing has several major public health benefits.

According to Brécard et al. (2009), the history of environmental legislation in Europe began around 1990. Each year, the bee pollination generates billions of dollars in value for Canadian agricultural crops. Opportunities to enjoy nature also contribute

Table 5: Map of variables for the 6 countries

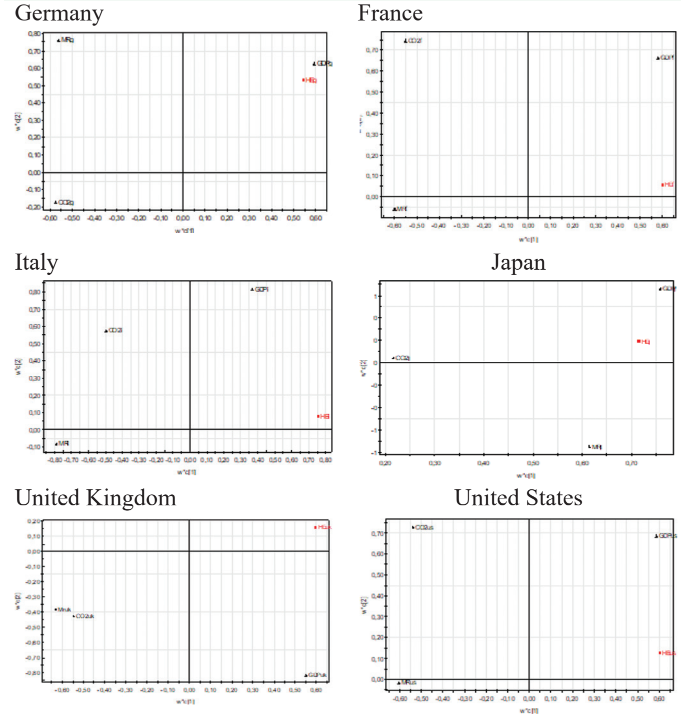
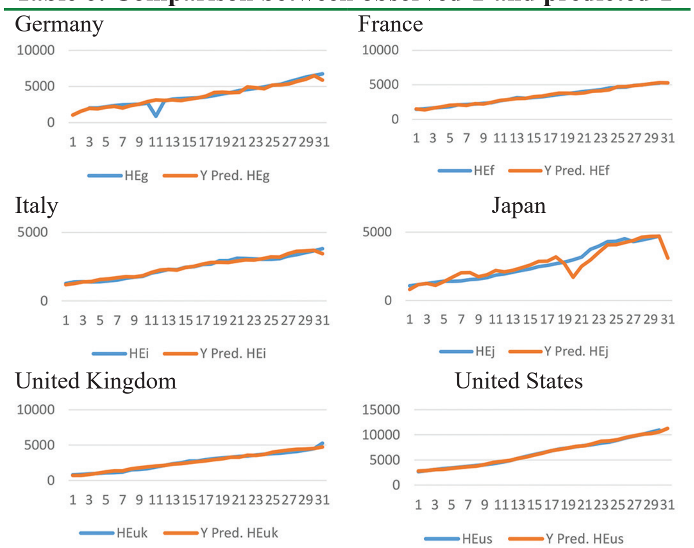


Table 6: Comparison between observed Y and predicted Y



to Canada's economy. According to the 2012 Canadian Nature Survey, Canadian adults spend more than $40 billion in 1 year on nature-related activities, such as hiking, hunting, fishing and sport fishing.

Since climate change has an obvious cost, it is impossible to pollute for free. For this reason, the Government of Canada has introduced a price on carbon pollution throughout its territory in 2019. In a bill, the Canadian government is proposing to increase the price of carbon by $15 per year, starting in 2023, to $170 per tonne of carbon pollution by 2030. This price increase will make clean options more affordable and discourage pollution-intensive investments.

Thus, the social impacts of air pollution on human health are not limited to medical care costs. The medical costs associated with hospitalization for respiratory illness are approximately $3,000. Similarly, this hospitalization can also result in a loss of wages of approximately $1,000. Thus, the social cost of hospitalization for respiratory illness is even higher than $4,000.

In Canada, the incremental social cost of illness is measured by the individuals' willingness to pay in order to avoid illness. This is done either through direct payment or by making choices in their lives that represent a trade-off of material consumption for better health. Numerous studies of environmental valuations indicate that Canadians are willing to pay to reduce the number of bad health conditions and illnesses caused by air pollution.

4.2. Discussion

Economic growth positively affects health care expenditure in all countries in our study. In the case of Germany, a 1% increase in GDP per capita generates a 0.69% increase in health expenditure. For France, a 0.38% increase in health expenditure is explained by a 1% increase in GDP. At the same time, a 1% increase in GDP increases health expenditure in Italy by 0.34%. For Japan, a 1% increase in GDP explains the 0.67% increase of its health expenditure. The effect of GDP per capita on health expenditure is very small in the UK (its coefficient is 0.15). For the United States, an increase of 0.44% per capita in health expenditure is explained by that of GDP per capita (1%). All these results coincide with several previous studies, including Akram et al. (2008), Boussalem et al. (2014), Yun and Yussof (2015), Badri and Badri (2016), Khoshnevis Yazdi and Khanalizadeh (2017) and Abbasian et al. (2021).

The OECD (2019) report indicates that the United States invests significantly more in health care than other countries (nearly US$11,000 per capita in 2019, adjusted for purchasing power parities), and also spends the majority as a percentage of GDP. Similarly, in Germany healthcare spending is also high. Because of the COVID-19 pandemic outbreak, early data for 2020 indicate a large increase in overall health care spending (nearly 5.1%).

In 2019, before the COVID-19 pandemic, OECD countries spent about 8.8% of their GDP on health care (a rate that has been roughly stable since 2013). The United States had the highest healthcare spending, at 16.8% of its GDP, far ahead of Germany, which was second at 11.7%. As for France, Canada, Japan and the United Kingdom, they spent more than 10% of their GDP on healthcare.

In the United Kingdom, central government systems accounted for 80% or more of national health expenditures. In Germany, Japan and France, more than 75% of spending was covered by some type of mandatory health insurance scheme. While Germany and Japan rely on a multi-risk health insurance scheme. This coverage is supplemented in France by a system of private health insurance arrangements, which became mandatory under certain employment conditions in 2016.

During the COVID-19 pandemic, healthcare spending increased sharply in several countries, particularly in Europe. Combined with the decline in economic activity, the average ratio of health spending to GDP increased from 8.8% in 2019 to 9.7% in 2020. Countries that were strongly hit by the pandemic have had an unprecedented increase in the share of GDP allocated to health. The United Kingdom, for example, estimates that its share of health spending has increased from 10.2% in 2019 to 12.8% in 2020. Given the differences in the organization of health systems, the impact on health spending per provider is significant in each country. For example, in Germany and Canada, <30% of the total health budget is spent on hospitals.

We find that environmental pollution, as measured by CO_2 emissions, has a statistically negative effect on health expenditures in all countries except Japan. Indeed, a 1% increase in CO_2 emissions leads to a decrease in health expenditures of 0.41% in Germany, 0.28% in France, 0.41% in the UK, and 0.23% in the US. This result is similar to the study by Zaidi and Saidi (2018) and the study by Abbasian et al. (2021).

In Japan, the situation is completely different, a 1% increase in CO_2 emissions leads to a 0.16% increase in health care expenditures. This result coincides with previous studies (Narayan and Narayan [2008]; Chaabouni et al., [2016] and Bayar et al. [2021]). This can be explained by the CO_2 emissions related to healthcare. Nansai et al. (2020) showed that greenhouse gas emissions were associated with health care in Japan which accounted for 4.6% in 2011 and 5.2% in 2015 of total national GHG emissions (were 62.5 Mt CO_2e in 2011 and 72.0 Mt CO_2e in 2015). To meet the Paris Agreement targets in 2030, Japan's healthcare sector must avoid these potential increases in emissions.

There is an urgent need to understand the impact of the environmental footprint of the health care sector. As investments in health care increase worldwide, the damage to health from pollution and environmental change is likely to increase significantly.

Cross-sectoral policies are needed to reduce pollution and its health effects, including partnerships with various international, national, and local stakeholders, including municipal authorities and ministries of industry, environment, transport, and agriculture. Similarly, reducing slash-and-burn agriculture and emissions from motor vehicles and industries can reduce outdoor air pollution.

Our results show that air pollution mortality affects negatively health care expenditures in France, Italy, the United Kingdom and the United States with relatively high rates of 0.36%; 0.6%; 0.46% and 0.36%, respectively. On the other hand, we find that the same indicator positively affects health expenditures in Germany and Japan with a relatively low rate (0.14% and 0.29%, respectively).

The number of deaths per 100,000 people due to selected particulate matter pollution in the air has decreased by 25% since 2000 in most OECD countries. But, mortality has increased in Japan during the same period.

On average, outdoor air pollution causes about 29 deaths/100,000 people. This digit varies from 1 to 7 times among OECD countries.

According to OECD projections, air pollution could cause 6-9 million premature deaths per year worldwide by 2060.

5. CONCLUSION

It is well known that the most industrialized countries in the world are the most polluting by, emitting large amounts of carbon dioxide. Carbon dioxide is known to be a major greenhouse gas that has been trapped in Earth's atmosphere for decades. Therefore, we need to understand its impact on human health.

The purpose of the current study was to determine the effects of economic growth and environmental deterioration on health expenditure in the G7, during the 1990-2020. We take gross domestic product as an indicator of economic growth, CO_2 emissions as an indicator of the environment and pollution-related deaths as an indicator of health. These indicators are identified and then the magnitude of the effects is estimated based on the PLS regression technique.

The results will develop the theoretical underpinnings and will provide important policy implications for reducing emissions to protect our health. The results show that economic growth affects positively health expenditure in the G7 on the one hand. On the other hand, CO_2 emissions have negative effects on all countries except Japan. Finally, MR negatively affects health expenditure per capita in France, Italy, the United Kingdom and the United States, while its effect is positive in Japan and Germany. The scenario is completely different in Canada, where the PLS regression shows no effect of economic growth and pollution on health expenditure, given the environmental legislation and pricing required for air pollution-related diseases.

The results of this study have many important implications for future policy decisions, as there is an urgent need to review health and environmental policies to ensure that GDP growth does not endanger public health or the environment. The consumption of fossil fuels in the G7 countries means that natural resources in industry and households contribute significantly to CO_2 emissions (Wang et al., 2019). It appears that policy makers should take into consideration the need to invest in promoting technology transfer to protect the environmental quality.

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APPENDICES

Appendices. Correlation matrix

		Germany		
	HEG	**GDPG**	**CO_2G**	**MRG**
HEG	1	-		-
GDPG	0.94	1	-	-
CO_2G	−0.89	−0.94	1	-
MRG	−0.84	−0.92	0.91	1
		France		
	HEF	**GDPF**	**CO_2F**	**MRF**
HEF	1	-	-	-
GDPF	0.95	1	-	-
CO_2F	−0.90	−0.76	1	-
MRF	−0.98	−0.95	0.88	1
		Italy		
	HEI	**GDPI**	**CO_2I**	**MRI**
HEI	1	-	-	-
GDPI	0.56	1	-	-
CO_2I	−0.58	0.30	1	-
MRI	−0.98	−0.46	0.66	1
		Japan		
	HEJ	**GDPJ**	**CO_2J**	**MRJ**
HEJ	1	-	-	-
GDPJ	0.93	1	-	-
CO_2J	0.26	0.27	1	-
MRJ	0.75	0.69	−0.09	1
		United Kingdom		
	HEUK	**GDPUK**	**CO_2UK**	**MRUK**
HEUK	1	-	-	-
GDPUK	0.96	1	-	-
CO_2UK	−0.88	−0.77	1	
MRUK	−0.99	−0.97	0.84	1
		United States		
	HEUS	**GDPUS**	**CO_2US**	**MRUS**
HEUS	1		-	-
GDPUS	0.96	1	-	-
CO_2US	−0.88	−0.73	1	
MRUS	−0.98	−0.94	0.88	1
		Canada		
	HEC	**GDPC**	**CO_2C**	**MRC**
HEC	1	-	-	-
GDPC	−0.17	1	-	-
CO_2C	0.29	−0.42	1	-
MRC	0.24	−0.95	0.61	1