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Green Hydrogen Production and Public Health Expenditure in Hydrogen-Exporting Countries

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ABSTRACT

Energy resources play a significant role as a production input in many economic sectors, such as production of goods and transportation. Moreover, increased energy usage may result in increased air pollution, resulting in negative societal health effects. This paper aims to examine how the production of green hydrogen energy, as proxied by low-carbon energy production, and per capita public health spending are related. This study employs various techniques that are specific to panel data, such as panel cointegration tests, second-generation stationarity tests, and panel long-run estimates. The research has been conducted on a sample of 67 hydrogen exporting nations during the period from 2000 to 2021. The study revealed that hydrogen energy production causes a rise in per capita public health spending. Policymakers should encourage the usage and production of hydrogen energy to decrease the negative consequences of using energy that emits CO_2. Reduction of carbon dioxide emissions helps nations to increase the proportion of government spending on public health per person. Furthermore, in hydrogen-exporting countries, an increase in the production of hydrogen leads to accumulate more funds from exporting hydrogen that will be used to increase spending on public health.

Keywords: Green Hydrogen, Public Health Expenditure, Hydrogen Exporting Countries, Low Carbon Energy, Panel ARDL
JEL Classifications: H51, Q20, Q28, E620

1. INTRODUCTION

The transition from an agricultural to an industrial society has been accelerating for decades. As a result, countries witnessed an increase in the usage of energy, higher rates of urbanization, and more advanced technology. These changes were beneficial, but they also contributed to the primary sources of environmental degradation. Environmental degradation may have first received less attention due to the complacency brought on by the greater quality of life made possible by technological advancements, but it has since become one of the most significant contemporary issues (Karaaslan and Çamkaya, 2022).

The development of an industrial sector and a public health system are crucial to the sustained expansion of any economy. High energy consumption in productive activities such as R and D is generally associated with industrialization. In many nations, healthcare expenditures account for a significant percentage of GDP. Good health is also recognized as a component of human capital and a motivator of economic progress. Healthier employees have greater mental and physical stamina, are more efficient, and get higher payments (Kumar et al., 2020).

Policymakers are working hard to create sustainable economies that value environmental considerations. This is one of the most pressing problems, with potential negative effects on people's standard of living. The main reason for environmental deterioration is increased CO_2 emissions and global warming which present a major danger to the global climate system. Incorporating clean energy sources, such as renewable energy and hydrogen energy, is one approach that helps to eliminate this risk.

Hydrogen is one of the most promising solutions to current climate change concerns because it can be easily converted into energy without CO_2 emissions. It is an abundant, low-impact energy source that can support long-term energy security (Brandon and Kurban, 2017; Yu et al., 2021) Because of its dual role as an energy transporter and a feedstock, it is an essential component of the energy transition required to meet the goal of mitigating climate change (El-emam and Ozcan, 2019). Hydrogen has piqued the interest of academics and politicians because it has the potential to be a clean energy carrier in the shift to an environmentally friendly energy future.

Costs and emissions of carbon dioxide from producing hydrogen from various renewable and nonrenewable sources may vary greatly. Hydrogen is now generated in most of the globe by the combustion of fossil fuels. (Yu et al., 2021) Using fossil fuels to produce hydrogen results in significant emissions of carbon dioxide which are detrimental to the environment as well as the climate.(Schmidt et al., 2018) The growing global agreement suggests that carbon-free hydrogen will be a crucial component in the world's transition to a more environmentally friendly energy source. Researchers in the field of energy are starting to pay more attention to carbon-free hydrogen. Hydrogen derived from fossil fuels is still less expensive than hydrogen produced using low-carbon technology. The extraction of hydrogen from renewable sources is a costly option due to the high price of the production and end-use technologies required. (Yu et al., 2021) Ultimately, the goal should be to generate low- or zero-carbon hydrogen supply using a cost-effective and affordable manner. (Ball and Weeda, 2015).

For the aforementioned reasons, it is worthwhile to investigate the relationship between hydrogen energy production, as proxied by low-carbon energy production, and public health expenditures. The purpose of this research is to examine the link between hydrogen energy production and per capita public Medicare expenditure using panel data from 67 hydrogen exporting countries from 2000 to 2021. The remainder of this paper will proceed as follows; Section 2 illustrates a detailed description of hydrogen types and production. The findings of relevant previous studies are exhaustively summarized in Section 3. Data and methods are included in Section 4. The major findings of this research are outlined in Section 5. The conclusion and the policy recommendations for the current study are provided in Section 6.

2. IS HYDROGEN AN ENERGY TRANSPORTER OR A SOURCE OF ENERGY

Hydrogen is not an energy source, instead it is a mean of transmitting energy. This means that it could play a role similar to that of electricity. Hydrogen and electricity may be generated using a variety of energy sources and methods. Both are adaptable and may be used in a variety of contexts. There are no greenhouse emissions produced while using electricity or hydrogen. However, if hydrogen is generated from fossil fuels, it might have a high CO_2 intensity upstream. Using renewables or nuclear as the primary source of hydrogen is the only way to counteract this drawback. (IEA, 2019)

Hydrogen is an inert gas that produces no emissions when burned. It is indeed better to categorize hydrogen generation techniques according to the amount of carbon dioxide they release during the whole production process (e.g., high-carbon or low-carbon hydrogen). However, the colors are commonly used to distinguish how the hydrogen was created, and the various colors are occasionally used to represent the intensity of the hydrogen generation process's greenhouse gas emissions. (Joshi et al., 2022) Figure 1 summarizes the different sources of hydrogen production and their colors.

Recently, various colors have been utilized to represent various hydrogen production sources. Colors of grey, green, blue, turquoise, and pink predominate. Grey hydrogen is now the most abundant kind of hydrogen. Hydrogen produced during coal gasification or natural gas steam reforming is identifiable by its grey color. It is mostly employed in the petrochemical sector and the manufacturing of ammonia. The main drawback of grey hydrogen is the large carbon dioxide emissions produced during the hydrogen generation process (Ajanovic et al., 2022).

Coal is used to create black or brown hydrogen using coal gasification. The bituminous (black) and lignite (brown) coal kinds are represented by the colors black and brown, respectively. CO_2 and carbon monoxide are produced as byproducts and discharged into the environment, making it a particularly polluting process.

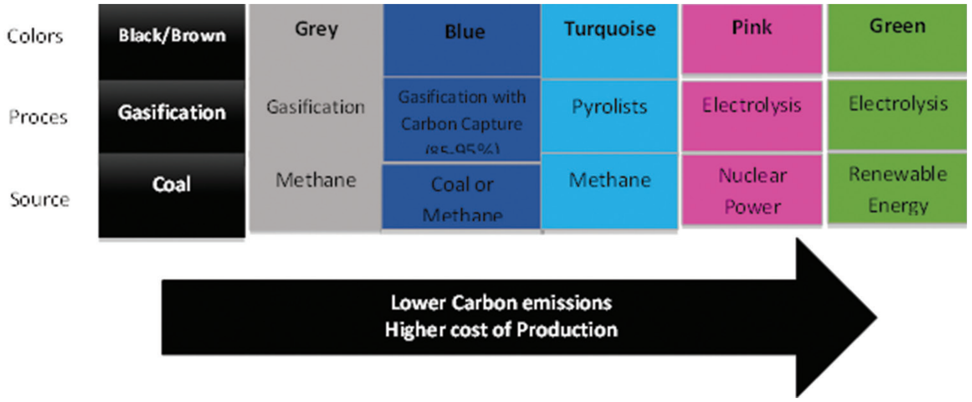
Turquoise hydrogen refers to hydrogen created by pyrolyzing a fossil fuel. The process of pyrolyzing methane, which involves a temperature increase, yields turquoise hydrogen. Though still in the testing phase, this method successfully removes carbon in a solid form rather than in a gas form (Kampouta, 2022).

Blue hydrogen is made by reforming methane steam from natural gas or biomass. Blue hydrogen is thought of as a transitional technology before a full switch to green hydrogen. Even though the technology reduces emissions, it is still a long way from being climate neutral (Dom et al., 2022).

Green hydrogen is generated through the process of electrolysis, which is fueled by a renewable energy source like wind or solar power. By avoiding the usage or burning of fossil fuels, greenhouse gas (GHG) emissions are prevented, which lowers the amount of air pollution. This kind of hydrogen has a negligible or nonexistent carbon footprint. Hydrogen and oxygen are released from water by electrolysis, creating "green hydrogen." Providing energy to split water is a costly procedure, but it is significantly less harmful to the environment than creating grey hydrogen (Yu et al., 2021).

In conclusion, hydrogen and low-carbon energy are closely connected since they both have the potential to be very important in lowering carbon emissions and addressing climate change. Green hydrogen can be produced using low-carbon energy sources such as wind and solar power. This is considered a clean and sustainable alternative to traditional hydrogen, which is often produced using fossil fuels. Green hydrogen can be used as a fuel for transportation and industrial processes and has the potential for power generation

Figure 1: Hydrogen color cartography



and grid storage. Additionally, hydrogen can also be used as a way to store excess energy from intermittent renewable sources like solar and wind. Low-carbon hydrogen could also be used as a feedstock for various chemical industries, steel production, and other sectors that are difficult to decarbonize. Low-carbon energy and hydrogen, when combined, can create a truly low-carbon energy system.

3. LITERATURE REVIEW

There is a large number of previous studies that investigates the determinants of healthcare expenditure. Nevertheless, to the best of our knowledge, there is not any study that examines the impact of green hydrogen production on public health expenditures. To clearly highlight the contribution of our work to the literature, previous studies have been grouped into three broad categories. The first group of these papers discusses the impact of many factors such as GDP per capita, public funding, the percentage of the population aged 65 and older, and medical advancement on healthcare expenditure. A number of these studies used a sample of panel data or various groups of countries, such as Wu et al. (2014), Bustamante and Shimoga (2018), Herwartz and Theilen (2003), Younsi et al. (2016), Samadi and Rad (2013), Nghiem and Connelly (2017), Murthy and Okunade (2009), Colombier (2018), Herwartz and Theilen (2010), Hartwig (2008), Hitiris and Posnett (1992), Okunade (2005), Okunade et al. (2004), Barros (1998), Hansen and King (1996), López-Casasnovas and Saez (2007), and Gbesemete and Gerdtham (1992).

Moreover, several studies are concerned with these determinants in a single country such as Khan et al. (2016) examined the factors influencing Malaysian healthcare costs. Bilgel and Tran (2012) reassess the impact of income and non-income factors on government healthcare expenditures in the Canadian economy. Prieto and Lago-penas (2012) and Blanco-moreno et al. (2013) analyzed the various factors that affect health expenditure in Spain. Murthy and Okunade (2016a), Murthy and Okunade (2016b), (Bose, 2015), and Murthy and Ketenci (2017) examine key drivers of health expenditure in the USA. Rezaei et al. (2015), Rezaei et al. (2016), and Kazemian et al. (2022) investigate the factors that influence healthcare expenditure in Iran. Goss (2022) and Ang (2010) identify the factors that affect healthcare expenses in Australia.

The second group of studies is concerned with the relationship between non-renewable energy and health expenses. Excessive energy use in a nation leads to environmental degradation and a rise in the prevalence of various health problems. To address these challenges and prevent the detrimental impacts of energy consumption on health in a nation, sufficient finances for health spending are required. As a result, higher energy consumption is said to contribute to greater public health expenses. Arouri et al. (2012) investigated the link between CO_2 emissions, energy usage, and real gross Domestic product in the MENA region. It has been found that energy consumption increases carbon dioxide emissions. Saboori and Sulaiman (2013) investigated the relationship between the country's growth rate, CO_2 emissions, and energy usage in ASEAN nations. This means that carbon emissions and energy use are inextricably linked. Nevertheless, these studies found no compelling evidence of a direct influence of energy usage on healthcare expenses.

Hao et al. (2018) empirically studied the impact of environmental pollution on inhabitants' health spending. Using panel data from Chinese regions from 1998 to 2015, this research showed that environmental pollution will definitely raise medical bills. Haseeb et al. (2019) examine the short-term and long-term effects of GDP growth, pollution, and energy usage on healthcare and Research and Development investment. Environmental degradation, energy usage, and GDP growth were noticed to have a considerable beneficial influence on health spending in the long run. It was also shown that none of the independent factors had a substantial short-run influence on health spending. Raihan et al. (2022) investigated the impact of CO_2 emissions, the use of fossil fuels, and the usage of renewable energies on Bangladesh's health expenditures. The findings found that rising CO_2 emissions led to a rise in healthcare expenses.

Finally, concerning the third group, it is concerned with the relationship between renewable energy and health spending. Shahzad et al. (2020) investigated the dynamic relationships between health spending, economic growth, CO_2 emissions, information and communication technologies, and renewable energy usage in Pakistan. The findings revealed that economic growth and CO_2 emissions have a favorable influence on health spending, but renewable energy usage has a negative impact. Sasmaz et al. (2021) investigated the relationship between renewable energy use and health-care costs in 27 EU nations. The results reveal that there is a bidirectional relationship between renewable energy consumption and health expenses in the nations that joined the EU post-2000 and a unidirectional for those that joined the EU pre-2000 nations.

4. MODEL SPECIFICATION AND DATA

4.1. Data

This paper attempts to investigate the link between per capita public health expenditures and green hydrogen generation in hydrogen-exporting countries. The study uses annual data of 67 hydrogen-exporting countries over the period from 2000 to 2021. The variables employed in the study are GDP growth rate, population growth rate, public health expenditure measured as domestic general government health expenditure per capita, CO_2 emissions (kg per PPP $ of GDP), and low-carbon hydrogen. The data for all variables are collected from the World Bank database except for low-carbon hydrogen. Green hydrogen production data is proxied by low-carbon energy production measured in Terawatt-hours and is obtained from the BP Statistical Review of World Energy. Low-carbon energy is measured as the summation of renewable and nuclear energy.

The key descriptive features of our data are shown in Table 1. Public health expenditure per capita has a mean of 1229.171 over the period 2000-2021. The mean of the GDP growth rate is 3.18%, with a maximum value of 34.5% and a minimum of −15.14%. CO_2 emissions and population growth rate have means of 0.32 and 1.013% respectively. CO_2 emissions and population growth rate have maximum values of 1.89 and 19.36% respectively. Low carbon energy production has an average value of 50.91, with a maximum value of 1560 Terawatt-hours and a minimum of Zero Terawatt-hours.

4.2. Model

The primary goal of this paper is to examine the relationship between hydrogen energy production, as proxied by low-carbon energy generation, on public health spending per capita. Based on the aforementioned literature on public health expenditures, a model will be developed taking into account environmental, demographic, and macroeconomic factors. Consequently, the following panel model, shown in equation (1), will be examined:

$$Healthcap_{it} = \beta_0 + \beta_1 GDPG_{it} + \beta_2 CO2_{it} + \beta_3 Hydrogen_{it} + \beta_4 POP_{it} + U_{it} \qquad (1)$$

One of the most influential factors that affect public healthcare spending is the country's GDP growth rate. It is easier for a nation to invest in its citizens' health when its economy is booming. As a result, it is suggested that economic expansion promotes health spending; in other words, economic growth increases the amount of money nations spend on healthcare. (Haseeb et al., 2019) From another point of view, economic growth may be detrimental to public health spending. Despite a slowdown in economic development, the government will maintain its commitment to funding health care (Nee et al., 2021).

CO_2 emissions is another factor that affects public health expenditures. Carbon dioxide emissions have resulted in significant health issues and added considerable financial strain to the healthcare system. (Žarkovi´ et al., 2022) The population growth rate is expected to put pressure on public health expenditures (Awais et al., 2021).

Another important factor affecting government spending on healthcare services is the hydrogen energy production proxied by low-carbon energy generation. Since the excessive combustion of fossil fuels is the primary driver of climate change, it is widely accepted that low-carbon hydrogen energy is the most ecologically friendly option. As a result, low-carbon hydrogen energy presents a tremendous chance to curb the release of greenhouse gases and slow the ensuing warming of the planet. In addition, low-carbon hydrogen energy aids in cutting down on harmful emissions and fossil fuel use, which is good for the environment and people's health.

The autoregressive distributed lag model (ARDL) will be employed to investigate the long- and short-run effects of hydrogen generation and other control variables on per capita public health spending. The ARDL model is recommended because it is applicable regardless of stationarity level. (Raouf, 2017) The ARDL model is expressed as follows:

$$\Delta Healthcap_{it} = \alpha_0 + \varphi_i \sum_{j=1}^{p} Health_{it} + \vartheta \sum_{j=1}^{q} \Delta GDPG_{it-j} + \theta_i \sum_{j=1}^{q} \Delta CO2_{it-j} + \omega_i \sum_{j=1}^{q} \Delta Hydrogen_{it-j} + \gamma_i \sum_{j=1}^{q} \Delta POP_{it-j} + \pi ECT_{t-1} + \lambda_i Health_{it-1} + \lambda_2 GDPG_{it-1} + \lambda_3 CO2_{it-1} + \lambda_4 Hydrogen_{it-1} + \lambda_6 POP_{it-1} + \varepsilon_{it}$$

where i is a counter from 1 to M representing the country and t is a counter from 1 to T representing the time period. Δ is the difference operator. ECT denotes the error correction term resulting from the long-run relationship, while λ_i are the long-term impact coefficients, the maximum number of lags is given by p and q and ε_{it} denotes the error. Equation (2) can be estimated using the pooled mean group, mean group model, or the dynamic fixed-effect estimator.

Table 1: Descriptive statistics

Variable	Public health expenditure per capita	GDP growth rate	CO_2 emissions	Low-carbon energy production	Population growth rate
Mean	1229.171	3.186451	0.315608	50.91403	1.013105
Median	522.9478	3.190424	0.270199	6.168050	0.852215
Maximum	7857.195	34.50000	1.889207	1560.032	19.36043
Minimum	3.616282	−15.13647	0.060514	0.000000	−4.170336
SD	1525.600	4.096546	0.209060	160.5396	1.679133

Pooled mean group (PMG) allows for heterogeneity in the short-run coefficients (such as the pace of adjustment to the long-run equilibrium values, the error variances, and the value of the intercepts) but requires homogeneity in the long-run coefficients. This method should be used because it is more effective and consistent in the presence of long-term relationships. This model has an assumption that the residual is exogenous and serially uncorrelated. (Pesaran, 1997; Shaari et al., 2020; Zardoub, 2021).

The second estimator (MG) approach requires estimating independent regressions for each nation. It allows for the long- and short-term variation and heterogeneity of all coefficients. However, sufficiently large time series data is required for the consistency and validity of this technique. (Shaari et al., 2020; Zardoub, 2021).

Similar to the pooled mean group, the third estimator (DFE) places restrictions on the slope and error variances to guarantee their long-term equality across all countries. It also confines the temporal adjustment coefficient and provides a consistent short-run estimate. The model, however, includes intercepts for each country. (Chavula, 2016; Shaari et al., 2020).

5. RESULTS

5.1. Diagnostic Tests

The analysis begins by determining whether cross-section dependency exists. The cross-section dependency (CD) test is used to choose between using first-generation or second-generation econometric methods. If cross-section dependency exists, then first-generation econometric methods are unreliable as they fail to take cross-section dependence into account, while second-generation methods are acceptable since they do so (Pesaran, 2004).

The CD test findings, shown in Table 2, show that the alternative hypothesis which indicate the presence of cross-section dependency is accepted at a 1% significance level for all variables under consideration. Accordingly, further estimating work should make use of second-generation econometric methods.

Next, the unit root tests for cross-sectional dependence should be performed. Pesaran (2007) created the CADF (Cross-Sectionally Augmented Dickey-Fuller) test by incorporating the ADF regression with lagged cross-section averages. It is used when there are more cross-sections (N) than time series (T), and vice versa. Furthermore, even if T and N are small, this test produces trustworthy findings. The CADF test is a kind of test that accounts for the interdependence of cross-sections and their heterogeneous structure. The Cross-Sectionally Augmented IPS (CIPS) test is another unit root test that is derived from the average of the CADF numbers (Hacıimamoğlu et al., 2020; Pesaran, 2007).

The findings of the CIPS unit root test are shown in Table 3, and it is found that the null hypothesis of variable stationarity is rejected at the level for both per capita healthcare expenditure and hydrogen. Moreover, the null hypothesis is accepted for all other variables at the level and for all variables at the first difference.

Then, a cointegration test should be conducted. Testing cointegration in panel data often makes use of well-established methods, such as (Pedroni, 1999). However, the preceding first-generation cointegration tests may provide inaccurate results in the presence of cross-sectional dependency, since they are predicated on the assumption of cross-sectional independence. (Le and Van, 2020; Westerlund, 2007) To take the cross-section dependency into account, Westerlund (2007) introduced the cointegration test based on the error correction model.

The test statistic of the Westerlund cointegration test, illustrated in Table 4, rejects the null hypothesis of no cointegration. This confirms the existence of a long-run relationship between the variables under consideration.

5.2. ARDL Models

Before estimating the ARDL model, the Hausman test is employed to assess which estimator of the three ARDL estimators (PMG, MG, or DFE) is most appropriate. The Hausman similarity test is first estimated to choose between PMG and MG estimators. Then, it is applied to choose between PMG and DFE estimators.

The Hausman test findings, in Table 5, reveal that the pooled mean group model is preferred to the mean group model because the null hypothesis of systematic differences in coefficients is accepted. While DFE is preferred to PMG as the null hypothesis will be rejected at a 5% significance level.

The results of the estimated ARDL models are represented in Table 6. The first section of Table 6 shows long-run coefficients. It suggests that in the long term, low carbon energy (Hydrogen)

Table 2: Cross-section dependency test results

Variable	Test	P-value
Healthcap	174.5389	0.000
Hydrogen	135.2235	0.000
Pop	19.31478	0.000
GDPG	111.9192	0.000
CO_2	150.3366	0.000

Table 3: CIPS unit root test

Variable	Level	P-value	Difference	P-value
Healthcap	−1.99931	≥0.1	−2.64022	<0.01
GDPG	−2.94721	<0.01	−5.07479	<0.01
Hydrogen	−1.87880	≥0.1	−3.34780	<0.01
CO_2	−2.70748	<0.01	−4.37502	<0.01
Pop	−2.86654	<0.01	−4.06748	<0.01

Table 4: Westerlund cointegration test

Westerlunda test for cointegration	t-Statistic	Prob.
Variance ratio	2.8353	0.0023

Table 5: PMG Hausman specification test

Estimator	Stat.	P-value
Mean group	7.724965	0.1022
Dynamic fixed effects	9.704591	0.0457

Table 6: ARDL regression model results

Variable	PMG-ARDL estimator	MG-ARDL estimator	DFE- ARDL estimator
Long-run coefficients			
GDPG	0.125356 (0.0899)	−13.8947 (0.6239)	23.90535 (0.0469)
Hydrogen	0.056535 (0.0000)	120.9639 (0.7897)	1.607870 (0.0386)
CO_2	−50.23286 (0.0000)	−6500.894 (0.0278)	−367.3939 (0.1877)
POP	−2.094517 (0.0681)	818.2874 (0.9189)	2.175325 (0.9398)
Short- run Coefficients			
COINTEQ	−0.122392 (0.0000)	−0.475419 (0.0000)	−0.162867 (0.0000)
D (GDPG)	1.488554 (0.3081)	6.403298 (0.3529)	−0.705897 (0.6671)
D (GDPG(−1))	7.051477 (0.0006)	12.72579 (0.0048)	2.121911 (0.1330)
D (Hydrogen)	36.97995 (0.7303)	57.36061 (0.4537)	−1.816653 (0.0006)
D (Hydrogen(−1))	22.08458 (0.6872)	19.98941 (0.9174)	0.988024 (0.0852)
D (CO_2)	−693.6852 (0.1454)	1729.543 (0.0518)	−115.3120 (0.5020)
D (CO_2(−1))	194.1020 (0.6615)	826.4509 (0.2472)	128.1603 (0.4620)
D (POP)	93.35915 (0.0265)	−113.2710 (0.0668)	4.953742 (0.4761)
D (POP(−1))	−23.50451 (0.7224)	−248.8324 (0.0238)	−4.209055 (0.6032)
C	231.8026 (0.0000)	1245.698 (0.0049)	245.2351 (0.0000)

has a beneficial impact on public health expenditure per capita as an increase in hydrogen production will result in a reduction in environmental degradation and improve health status, which helps to increase the share of health expenditure per person. Moreover, Hydrogen-exporting countries will export more hydrogen and use the generated funds to invest more in human capital.

The GDP growth rate has a positive and statistically significant impact on per capita public health expenditure according to the results of the PMG and the DFE models. Because of the positive coefficient, it seems that public health expenditure increases when the GDP growth rate rises. This result is consistent with the results of Jakovljevic et al. (2020), Wu et al. (2021) and Ahmad et al. (2021).

The results also indicate that CO_2 emissions is inversely correlated with public health expenditure per capita, which means raising health spending will contribute to a decrease in environmental pollution. These findings are in line with that of Li et al.(2022) and Metu et al. (2017). According to PMG estimators, the population growth rate has a negative and significant impact on government health spending per capita, but this is not consistent with the results of the DFE and the MG estimator.

According to the PMG, MG, and DFE estimators, the existence of cointegration in the long run exists at a level of significance of 1%, and any divergence from equilibrium in the long run is rectified in the short run at a 12%, 47%, and 16% adjustment speed, respectively. The error component's expected sign is predicted to be negative, indicating that any divergence in the relationship in the long-term will be corrected in the subsequent time span.

Short-run causality between variables is not supported by the PMG estimators except for the lagged economic growth and the population growth rate. However, at the 5% level of significance, the MG estimator reveals the presence of short-run causation between the lagged value of GDP growth rate, CO_2 emissions, and population growth rate. As per DFE estimator, only hydrogen production and its lagged value affect per capita public health expenditure, in the short run.

Table 7: Results of fully modified OLS and dynamic OLS models

Variable	Fully Modified OLS	Dynamic OLS
GDPG	−14.63198 (0.0001)	−25.31732 (0.0000)
HYDROGEN	0.667579 (0.0453)	1.471416 (0.0000)
CO_2	−1227.968 (0.0000)	−2530.584 (0.0000)
POP	−4.290501 (0.6673)	−0.439943 (0.7063)
R-squared	0.916663	0.982871
Adj. R-squared	0.912296	0.945256

5.3. Robustness Check

The existence of cointegration helps to estimate long-run coefficients. A number of econometric methodologies can be used to compute long-run coefficients. As a robustness check for the estimated model, Fully Modified OLS and Dynamic OLS have to be employed.

These models have the benefit of eliminating the effects of serial correction and endogeneity in the error term of heterogeneous panel cointegrated variables. Although fully modified OLS aids in the correction of the autocorrelation of the error term's, dynamic OLS addresses the issue with lead and lag variables that are included in the model. DOLS is useful for dealing with CSD and heterogeneity in small sample sets (Bhujabal et al., 2021).

The model's explanatory power is good in both scenarios since the adjusted R2 value is high, as shown in Table 7. According to FMOLS, economic growth and hydrogen production have a substantial effect on per capita public health expenses. Similarly, according to the DOLS model, all the variables have a substantial effect on per capita government health expenditure except for the population growth rate.

The sign of the coefficients of all variables in the FMOLS and DOLS models are consistent with the PMG model except for the economic growth. Moreover, concerning the sign of the coefficient of hydrogen production and CO_2 emissions are consistent with the results of the DFE estimators.

6. CONCLUDING REMARKS AND POLICY REPERCUSSIONS

This paper's primary goal is to investigate the interaction between hydrogen energy production, as proxied by low-carbon energy production, and per capita public health expenditure. To examine the interaction between the variables under consideration, our empirical research employs a variety of procedures relevant to panel data, such as panel cointegration tests, second-generation panel stationarity tests, and panel long-run estimates. A sample of 67 hydrogen-exporting countries has been selected for a period spanning from 2000 to 2021.

The long-run coefficients emphasize that both hydrogen energy production and economic growth contribute to increasing per capita public health expenditure, while CO_2 emissions and population growth rate decrease per capita public health expenditure.

Despite this, health issues in the community and the associated healthcare costs have a significant impact on both labor productivity and economic expansion. As the findings of this paper could imply, governments should implement policies to reduce carbon emissions, which might reduce healthcare costs related to air pollution. There must be regulations in place to minimize industrial emissions, however, so that people may live in a healthier environment and governments can save money on health care costs.

The most appropriate method to reduce CO_2 emissions is to increase the usage of green hydrogen. Future investment in green hydrogen R and D, green hydrogen generation, and low-carbon infrastructure will be critical to achieving this goal.

Policymakers should offer long-term policies to minimize uncertainties and threats for producers, endorse the production of green hydrogen, and create distribution infrastructure if it is to play a vital part in decarbonizing the future energy system.

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