Examining CO₂ Emissions, Health Expenditure, and Economic Growth Nexus for China: A Co-integration Approach

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Abstract. This study most importantly illustrates the long-run and short-run shocks between the three key variables of environmental pollution, health factors and economic development. The highly industrialized situation in China has caused a lot of energy consumption and a healthy decline. Therefore, this study examines the relationship between China’s health expenditure and CO₂ emissions taking into account economic growth using the bootstrap ARDL test variable. The results show that the long-term CO₂ emissions and medical costs have a critical impact on China’s economic development. On the other hand, this study found that there is a two-way causal relationship between China’s health expenditure and economic growth, as well as two-way causation between health expenditure and CO₂ emissions. But the impact of the economy on the environment is only one-way causality. Therefore, our research has important policy implications for China to develop energy plans and strategies to reduce carbon dioxide emissions and protect human health.

1. Introduction
According to global carbon dioxide emissions began increasing in 2017, achieving 32.8 billion tons of CO₂, and we found that data show they grew faster in 2018. The major country emissions were China (28%). From 2017 to 2018, China's CO2 emissions increased by 2.5%. EAI shows that the power generation of coal-fired power stations has increased by more than 5%. Despite the recent decline in coal use outside the power industry in China [1]. Air pollution is a crucial problem to link human health that World Health Organization (WHO) were reported 3 million deaths a year because outdoor air pollution [2].

Since China followed the introduction of the “Open Door” policy in 1978 and began a market economy that gross domestic product (GDP) became the second largest economy in all countries. Actually, GDP not only had a good life but also increased energy consumption that bring huge challenges related to health pressures in China [3]. China relies on natural gas and coal fuel to generate electricity and relies on oil to meet all its needs. These coal fuels produce more than half of the CO₂ emissions in the world, and carbon dioxide emissions have a negative impact on human health. Therefore, our research aims to explore the relationship between China's carbon dioxide emissions, health expenditure and economic growth, and find out to what extent carbon dioxide affects health
expenditure and economic growth that proposes some environmental policy suggests to government in China.

This study aims to examine China's health expenditure, CO2 emissions and economic growth links by using the new bootstrap autoregressive distribution lag (ARDL) test discovered by McNown, Sam, and Goh [4]. This new method uses the bootstrap model to re-evaluate the traditional ARDL can more effectively verify the long-run and short-run relationships. Our research work will provide the necessary explanations for similarly developed countries, which in turn will be helpful to the implementation of Chinese policies.

2. Literature Review
In academic research for many countries, the impact between health care expenditure, carbon dioxide emissions and economic growth is critical. However, in the past few decades, researchers first focused on the contribution of economic growth and carbon dioxide emissions. They studied whether the environmental Kuznets curve (EKC) hypothesis holds [5]. Economic development has a key role in the adjusting environmental pollution [6]. The second part is concerned about the interaction between health expenditure and macroeconomic development. Much of pervious test the health expenditures demand is a necessity or luxury goods [7]. Murthy and Okunade [8] found that income had a positive effect on U.S. health expenditures by ARDL bounds test. Finally, Yazdi et al. [9] used The ARDL method studies CO2 emissions that have a positive correlation with health expenditure. Boachie et al. [10] found that there is a negative correlation between health expenditure and carbon dioxide emissions. However, few studies have discussed the relationship between quality of environment and health spends. However, only a few researches have considered the influence between quality of environment, health spends and economic growth. Chaabouni and Saidi [11] used dynamic simultaneous-equations models to investigate the relation between CO2 emissions, health spend level and income for three groups of low, middle and upper countries. Wang et. al. [12] provide Bootstrap ARDL empirical evidence of causality between the three variables for 18 OECD countries.

3. Methodology
The ARDL model can be stated in the following form:

\[ y_t = c + \sum_{i=1}^{m} \beta_{1i} y_{t-i} + \sum_{j=0}^{m} \beta_{2j} x_{t-j} + \sum_{j=0}^{m} \beta_{3j} z_{t-j} + \sum_{n=0}^{n} \phi_n D_{t,j} + \mu_t \]  

(1)

\( t \) implies time \( t = 1, 2, ..., T \). \( i \) and \( j \) are the lag period. \( i = 1, 2, ..., m; j = 0, 1, ..., m; h = 0, 1, ..., n \). \( y_t \) is the dependent variable in the equation. \( x_t \) and \( z_t \) are the independent variables and \( D_{t,j} \) is a dummy variable in the equation. The coefficients of the lag of \( y_t, x_t, z_t \) are \( \beta_{1i}, \beta_{2j}, \beta_{3j} \) and the error term is \( \mu_t \).

The equation (1) is involved estimating the following error correction models:

\[ \Delta l\text{gdp}_t = a + \beta_{11} l\text{gdp}_{t-1} + \beta_{21} l\text{health}_{t-1} + \beta_{31} l\text{CO}_2{t-1} + \sum_{i=1}^{m} \alpha_{1i} \Delta T D_{t-1} + \sum_{i=1}^{m} \delta_{11i} \Delta \text{gdp}_{t-1} + \sum_{i=1}^{m} \theta_{1i} \Delta \text{TR}_{t-1} + \sum_{i=1}^{n} \pi_{i1} D_{t,i} + \epsilon_{1t} \]  

(2)

\[ \Delta l\text{health}_t = a + \beta_{12} l\text{health}_{t-1} + \beta_{22} l\text{gdp}_{t-1} + \beta_{32} l\text{CO}_2{t-1} + \sum_{i=1}^{m} \alpha_{12} \Delta l\text{health}_{t-1} + \sum_{i=1}^{m} \delta_{12i} \Delta l\text{gdp}_{t-1} + \sum_{i=1}^{m} \theta_{12i} \Delta l\text{CO}_2{t-1} + \sum_{i=1}^{n} \pi_{i2} D_{t,i} + \epsilon_{2t} \]  

(3)

\[ \Delta l\text{CO}_2t = a + \beta_{13} l\text{CO}_2{t-1} + \beta_{23} l\text{gdp}_{t-1} + \beta_{33} l\text{health}_{t-1} + \sum_{i=1}^{m} \alpha_{13} \Delta l\text{CO}_2{t-1} + \sum_{i=1}^{m} \delta_{13i} \Delta l\text{gdp}_{t-1} + \sum_{i=1}^{m} \theta_{13i} \Delta l\text{health}_{t-1} + \sum_{i=1}^{n} \pi_{i3} D_{t,i} + \epsilon_{3t} \]  

(4)

In equations (2)-(4), \( \Delta \) is the difference operator, \( l\text{gdp}_t \) is real gross domestic product, \( l\text{health}_t \) is real health expenditure, and \( l\text{CO}_2t \) is \( CO_2 \) emissions.

McNown et al. [4] consider a cointegration that requires test three null hypotheses: \( H_0: \beta_1 = \beta_2 = \beta_3 = 0 \) (F1-test ), \( H_0: \beta_2 = \beta_3 = 0 \) (F2-test), and \( H_0: \beta_3 = 0 \) (T-test). The new cointegration test is Bootstrap ARDL cointegration test that requires meet all the three null hypotheses. However, McNown et al. complement the ARDL bound test because they suggest adding a null hypothesis that F2-test for
cointegration. They also show that case 1 is when the F1-test and the F2-test on the lagged independent variable are reject the null hypotheses but the T-test is not reject and case 2 show that the F1-test and the T-test are reject the null hypotheses, however, the F2-test are not reject the null hypotheses. Bootstrap ARDL cointegration test have more advantage in power and size than ARDL Bound test.

Bootstrap ARDL model can use Grange-causality test to exam the short-run relationship if they do not exist cointegration. More importantly, we should test $\beta_2 = 0$ or $\beta_3 = 0$ additional if there is cointegration.

4. Data and Analysis Result

4.1. Data

Our study used annual data for the period between 1978 and 2018. The CO$_2$ emission database is from online web in BP statistical (https://www.bp.com/). This data for real gross domestic product in CN dollars (1978=100) is from National Bureau of Statistics in China (http://www.stats.gov.cn) and real health expenditure in CN dollars (1978=100) data is come from National Health Commission of the People’s Republic of China (http://www.nhc.gov.cn). There is a logarithmic transformation of all three variables.

Table 1 shows that the three different unit root tests and reports results at level and first difference values for real GDP, health expenditure, and CO$_2$ emissions. We found that these variables were all variables are I(1) process because they are stationary in the first difference.

| Variables | Level P&P | Level ADF | Level KPSS | First differences P&P | First differences ADF | First differences KPSS |
|-----------|-----------|-----------|------------|------------------------|-----------------------|------------------------|
| lgdp      | -0.984 (3) | -1.841 (4) | 0.789(5)** | -2.965 (1)**           | -3.657 (3)**          | 0.166 (3)              |
| lhealth   | -0.910 (4) | -1.272 (1) | 0.791(3)** | -2.629 (5)*            | -2.600 (0)*           | 0.179 (4)              |
| ICO$_2$   | -0.410 (4) | -0.851 (1) | 0.771(5)** | -2.624 (2)*            | -2.806 (0)*           | 0.101 (4)              |

Note: Asterisks ***, ** and * represent 1% and 5%, 10% significance.

4.2. Long-Run relationship

This research uses the Bootstrap ARDL to estimate equations (2)-(4) and the long-run results are showed in table 2. From table 2, if the results exist cointegration that the model has to meet the threshold of the F1, F2, and T test. The cointegration results reported in table 2, when lgdp served as dependent variables, there was cointegration evidence and all three test statistics were significant. Actually, we find that exist Case 2 when lhealth served as dependent variable, but there was a special situation in Bootstrap ARDL that is on-cointegration in this model. Wang et. al. [13] test cointegration use ARDL bound test in Pakistan that had cointegration for health expenditure. Actually, Wang et. al. had existed to estimate incomplete. Also, table 2 shows that it does not exist cointegration when ICO$_2$ is dependent variable.

CO$_2$ emissions and health expenditure as the dependent variables play an important role in economic growth when our test the long-run relationship. Wang et. al. [12] empirical results for examining CO$_2$ emissions, health expenditure, and economic growth are same results with our research. They found that cointegration was existing in Netherland when economic growth was dependent variable. We are suggested that CO$_2$ emissions and health expenditure are main variables in determining China’s economic growth in the long run. As describe in table 3, the coefficients were significant for CO$_2$ emissions and health expenditure. When health expenditure increases by one percent, economic growth increases by 1.232 in the long-run. Health expenditure can promote economic growth that there was empirical evidence in support for classical growth theory. We also indicate that CO$_2$ emissions have positive impacts on economic growth in the long-run with a coefficient of 0.231 percent.
patients and increases.

In this research, we used empirical evidence to support China

emissions are a function of economic
development

ARDL test result, we indicate that had

run

relationship between CO\textsubscript{2} emissions and health expenditure. In fact, two-way relationship between these three variables, and the coefficient of economic growth is significantly positively related
to health expenditure. Table 4 show that in the short-run, increased CO\textsubscript{2} emissions and income will help
improve health expenditures. In CO\textsubscript{2} emissions equation, there is a negative relation with Granger
causality estimating from health expenditures and income to CO\textsubscript{2} emissions.

4.3. Short-Run Relationship

It can be observed from table 4 that has feedback between income and health expenditure. In fact, two-way relationship between CO\textsubscript{2} emissions and health expenditure. The short run, there is one-way causality from income to CO\textsubscript{2} emissions. In the Bootstrap ARDL model, there is a short-run relationship between these three variables, and the coefficient of economic growth is significantly positively related to health expenditure. Table 4 show that in the short-run, increased CO\textsubscript{2} emissions and income will help improve health expenditures. In CO\textsubscript{2} emissions equation, there is a negative relation with Granger causality estimating from health expenditures and income to CO\textsubscript{2} emissions.

Table 2. Cointegration results.

| DV|IV | Dummy variables | F\textsubscript{1} | F\textsubscript{1*} | T | T* | F\textsubscript{2} | F\textsubscript{2*} | Long-run |
|---|---|---|---|---|---|---|---|---|---|
| lgdp|h|health,I|CO\textsubscript{2} [5] | 1987, 1995, 2007 | 8.624 | 3.013 | -4.057 | -1.891 | 8.324 | 3.251 | Cointegration |
| l|health|lgdp,I|CO\textsubscript{2} | 1988, 1996, 2002 | 5.768 | 3.745 | 1.941 | -0.929 | 3.339 | 4.388 | Case 2 |
| lCO\textsubscript{2}|lgdp,l|health [2] | 1988, 1994, 2003, 2008 | 2.203 | 3.049 | -1.035 | -1.836 | 1.482 | 3.369 | No-Cointegration |

Note: 1987 is a dummy variable in 1987. F\textsubscript{1} and F\textsubscript{2} are the F-statistics and t-statistics in T. The threshold values at the 10% significance level are F\textsubscript{1*}, T* and F\textsubscript{2*}.

Table 3. Long-run regression (Dependent variable = lgdp).

| Variables | Coefficient value | t-Statistic | Probability |
|---|---|---|---|
| lgdp(-1) | -1.388\* | -4.057 | 0.001 |
| l|health(-1) | 1.232\*** | 3.982 | 0.001 |
| l|CO\textsubscript{2}(-1) | 0.231\** | 2.665 | 0.019 |
| C | 4.025\** | 3.609 | 0.003 |

Note: When the 1%, 5% and 10% significantly levels are marked by asterisks \***, \** and \*.

Table 4. Short-run Granger Causality results.

| Variables | lgdp Eq | l|health Eq | lCO\textsubscript{2} Eq |
|---|---|---|---|
| | F-statics, (P-value) (Sign) | F-statics, (P-value) (Sign) | F-statics, (P-value) (Sign) |
| lgdp | - | 4.322 (0.014)** (+) | 2.963, (0.071) * (-) |
| l|health | 12.573 (0.000) ***(+ | - | 2.867(0.076) *(-) |
| l|CO\textsubscript{2} | 1.605 (0.223) (+) | 4.242 (0.015) ** (+) | - |

Note: When the 1%, 5% and 10% significantly levels are marked by asterisks \***, \** and \*. P-value and sign of coefficients are show in the ( ).

5. Discussion and Conclusion

In this research, we used bootstrap ARDL models and Granger causality test to investigate the linkage relationship between the three series in China over the period of 1978-2018. According to the bootstrap ARDL test result, we indicate that had cointegration when health care spending and carbon dioxide emissions are a function of economic growth. The health expenditures and CO\textsubscript{2} emissions variables exerts statistically significant and positive effects on economic growth. There are many literature reviews that pay attention in health expenditures that is an important part of the human capital. This article uses empirical evidence to support China’s health expenditure can promote economic development. That is, per capita productivity and quality of life will promote as health expenditures increases. Therefore, the positive effect of health care expenditure is to extend the life expectancy of patients and reduce infant mortality. In long-run relationship, we also conducted bootstrap ARDL testing
to confirm that real economic growth is positive affected by environmental quality. We show that China’s economic growth requires more amounts of energy using and thus CO₂ emissions.

CO₂ emission is a key factor to Granger cause health expenditures that shows a positive and significant relational in the short-run. Air pollution caused by energy consumption in China increases people’s health costs leading to higher social costs not only increasing the burden of living but also increasing the Chinese government’s fiscal expenditure. On the contrary, when people’s health expenditure increases, they will also be aware of the harm caused by pollution, and reduce CO₂ dioxide emissions as an important task. Thus, we found that two-way causality between health expenditures and CO₂ emissions. However, the results report that economic growth and health expenditures the relationship between short-run has positive and significant that exists two way causality. Chaabouni and Abdennadher [7], Chaabouni and Saidi [11] also indicated the same results and pollution from energy consumption impacts people’s health is related to the social economy, which not only reduces the quality of life, but also increases health expenditure. Finally, the impact of economic growth on CO₂ emissions is negative and significant in the results of this paper, and has a one-way causal relationship between these two variables. The empirical evident supported greater economic development would to reduce air pollution.

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