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Quantile panel-type analysis for income inequality and healthcare expenditure

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ABSTRACT
This study investigates the causal relationship between Income Inequality and Healthcare Expenditure within a quantile panel-type causality framework using yearly panel data from 2004 to 2017. The empirical results show that within the high-growth regime of health expenditure to income ratio, reducing the deterioration of income inequality can make the ratio of health expenditure to income keep increasing. Besides, within the extreme income inequality regime, the ratio of health expenditure to income continues to increase, which can reduce the deterioration degree of income inequality. This paper presents evidence that to improve the continuous deterioration of income inequality; it should focus on the continuous increase in the ratio of health expenditure to income, not just the continuous increase in health expenditure. Accordingly, policy-makers should be cautious about the momentum between the ratio of health expenditure to income and income inequality when they reach the extremely quantiles.

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1. Introduction

Healthcare is not only a knowledge-intensive industry but also near as knowledge and information-intensive. Finding an effective policy on healthcare expenditure and balancing the income-spending are the challenges facing governments. Would income inequality hamper the growth of healthcare expenditure? Would it happen within the same social class or among different courses? These questions have become essential topics in social and economic research in the past few decades. Most of the previous studies were conducted from the perspective of the individual country; Feinstein (1993) and Robert and House (2000) found that socioeconomic status would reflect the need for health, and people with higher socioeconomic status usually require better medical and healthcare quality.

Additionally, Marmot (2003) and Robert and House (2000) also found that people in the top class of society enjoy better health levels than those in lower classes; and

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when health deteriorates, the medical resources for people of different types appear uneven phenomenon. Regarding the question that if the level of economic development is affecting the inequality in global healthcare standards? Research results are not consistent. Early studies (such as Preston, 1975; Wilkinson, 1992, 1996, etc.) provide a weak correlation between people's health and national welfare. However, many studies based on ecological aspects (e.g., De Vogli et al., 2005; Flegg, 1982; Ram, 2006; Rodgers, 1979; Wilkinson, 1992, 1996, etc.) found a negative correlation between life expectancy and income inequality. The results of other studies (Flegg, 1982; Hsieh & Pugh, 1993; Qi, 2012; Rodgers, 1979; Waldman, 1992; Wilkinson, 1996; etc.) that used different health indicators (such as age, particular etiological mortality, the average age of death, self-rated health, the height of the population and incidence of murders, etc.), are not consistent.

When measuring health status with health spending, there are two ways to determine international health expenditure; one is measured by demographic and non-demographic. The demographic aspect is mainly assessed by the labor force (age structure) and health status, while non-demographic statistics are primarily measured by income elasticity (Maisonneuve & Martins, 2013). Many studies suggest that neither the labor force nor the measurement of the elasticity of income, or the use of both to determine health expenditure, cannot fully explain the relationship between health expenditure and economic growth. From the above discussion, we can find that the issue's core factor is unequal income. Recently, several studies are exploring the data from OECD countries and finding that income inequality has a significant negative impact on economic growth and health expenditure growth, such as Cingano (2014), Bhattacharjee et al. (2017), etc. They also found that the degree of adverse shocks most affects the low-income household units, compared to the high-income household units. Primarily, Wang et al. (2018) studied the annual data of 22 countries and found that the health shocks, represented by perceived health by socio-economic status, have positive dynamic effects on economic growth, insurance consumption growth, and health expenditure growth. Under dynamic conditions, at high-income levels, health shocks stimulate economic growth. Still, at low-income levels, health shocks can make economic growth stagnant and reduce health expenditure, which poses a new challenge to the dynamic effect of income inequality on this study's health expenditure.

This study applies the quantile panel-type model for analyzing the relationship between income inequality and healthcare expenditure. Prior studies neglect the common feature - heterogeneity of macroeconomic time series. Therefore, we believe that the quantile-based interval causality approach can uncover the causal relation in the tail region of the conditional distribution. As such, policy-makers can use information from one macroeconomic variable to predict the other variable dependent on the latter's state, i.e., when the variable is in a high, normal, or low growth momentum state.

Against this background, we contribute to the existing literature in the following ways.

(1) We use two variables to measure the impact of health expenditure on income inequality. One is per capita health expenditure; the other is the ratio of health

expenditure to income; (2) We design two models for estimation; the first model includes three variables Gini index, health expenditure, and national income; the second model contains two variables Gini index and the ratio of health expenditure to income. Through the estimation results of these two models, we can further understand the differences in the outcome to the impact of health expenditure on income inequality based on the concept of 'expenditure per capita' and 'expenditure proportion'; (3) We apply the quantile panel causality approach and uncover a nuanced picture of the relationships among variables of the two models, which could not be revealed under the standard causality in a means test; (4) Our empirical models allows to uncover for the first time a feedback effect among variables of the two models in the tail of the conditional distribution.

The empirical results of quantile panel-type causality show that a reduction in deterioration of uneven distribution can make the ratio of health expenditure to income keep increasing within the high-growth regime of healthy income ratio. Moreover, when income is extremely unevenly distributed, the ratio of health expenditure to income keeps increasing, which can reduce the degree of deterioration of income inequality. Therefore, to improve the continuous deterioration of unequal distribution, the focus is on the continuous increase in the ratio of health expenditure to income, not just health expenditure that keeps rising. This paper's main contribution is to provide policy-makers with important information to continuously improve income inequality, focusing on the increase in the ratio of health expenditure to income, not just the increase in 'expenditure quota' on health expenditure.

The remainder of the study is structured as follows: Section 2 provides a brief literature review. Section 3 describes the Methodology. Section 4 presents the empirical results, and Section 5 concludes.

2. Literature

There are two hypotheses, the Wilkinson (or Relative Income) hypothesis and the absolute income hypothesis for explaining the relationship between income inequality and health expenditure. Wilkinson (1992, 1996, 1997, 2005) believes that income inequality affects and causes harm to the health of people through psychosocial aspects. Scholars in the same field, such as Kawachi and Kennedy (1997, 1999), Kristenson et al. (2004), Marmot (2003), Marmot et al. (2001), Wilkinson and Pickett (2006), etc., also confirmed this statement. Wilkinson (1996, 1997, 2005) found that economic and social transformation through epidemics, chronic diseases replace epidemics as the leading cause of human health or death. Therefore, for a wide range of chronic diseases, the main reason for determining the state of personal destruction is the relative income that plays a more critical role than absolute income. He believes that the so-called rich diseases in developed countries; such as obesity, stroke, hypertension, coronary heart disease, etc., are more and more common among the poor, which means that for the vast majority of people, the living standard has been dramatically improved, the impact of absolute income on health is lower.

On the contrary, even in advanced countries, the relative effect of income is still a significant public threat to countries with social classes. If income inequality is an excellent proxy variable for social studies, the negative relationship between income inequality and population health is predictable. Kawachi and Kennedy (1997, 1999) argue that the relative income hurts health, the widening income gap between the rich and the poor leads to a worse health situation through the collapse of social cohesion and trust. Income inequality does not only affect the status of health. Still, it may also lead to the 'excessive spillover' effect of anti-social behavior such as crime and violence because of relative deprivation and social isolation. Kawachi and Kennedy (1997) found that the corrosive effects of inequality undermine trust and increase frustration, stress, and family breakdown, which are important risk factors for high crime rates and violence. The study by Daly et al. (2001) and Hsieh and Pugh (1993) support the positive relationship between income inequality and violent crime. In summary, the Wilkinson hypothesis, aka the income inequality hypothesis, indicates a negative relationship between income inequality and psychosocial health mechanisms.

Scholars who support the absolute income hypothesis (such as Deaton, 2003; Gravelle, 1998; Gravelle et al., 2002; Lynch et al., 2004) challenge the Wilkinson hypothesis and argue that the relationship between income inequality and population health (ecology) is only a statistical phenomenon. Gravelle (1998) explains that the relationship between income inequality and population health at the aggregate level is spurious but reflects the nonlinear relationship between personal income and personal health. Therefore, the relationship between income inequality and health at the aggregate level is only an example of an ecological paradox. Generally, the absolute income hypothesis is an individual-level survey that focuses on unusual income and health levels. Many studies have shown that the relationship between special income and health is monotonic but nonlinear. The higher the income, the less effective the response to health; that is, there is a ceiling effect on health for people with high socioeconomic status (Feinstein, 1993; Robert & House, 2000, etc.).

Furthermore, studies by Deaton and Lubotsky (2003), Mellor and Milyo (2001), and Ross et al. (2000) point out that the relationship between income inequality and health may be affected by other factors rather than income, such as ethnic structure, education, primary healthcare, health insurance, and other aspects of public infrastructure. However, when these confounding factors are brought under control, the correlation between income inequality and population health disappears. Wilkinson and Pickett (2006) argue that the interfering factors, such as healthcare and public policy, are the intermediaries in the transmission between income inequality and health. Nevertheless, both the Wilkinson hypothesis and the absolute income hypothesis expect a negative relationship between income inequality and population health.

Research methods are used to distinguish among studies on income inequality and health regarding the recent empirical literature. The least-squares method, Lhila (2009), uses this method to study the relationship among the U.S. government's health services, income inequality, and low birth rate. Using the data covering from 1991 to 2001, it was found that children born in an income unequal society are likely to be unhealthy, and income inequality is negatively correlated with healthcare services. Birčiaková et al. (2014) used the linear regression model and the two-factor analysis of variance method to explore the effect of income inequality on the family in the Czech Republic during the economic development period of 2005–2012. Research variables include household expenditure and income. The study found that income inequality harms the income of different household groups under different economic statuses. Zhang et al. (2014) applied the ordinary least squares method and structural variable estimation method to detect the correlation between health shocks, village elections, and family income in China with a sample of 1,185 households in 48 villages from 1987 to 2002. The study found that health shocks have a strong negative impact on household income; also, increased coverage through the social health insurance system helps reduce the shocks of family health risks.

In the cross-sectional method, Oshio and Kobayashi (2009) used the ordered logit model to explore the relationship between income inequality and health self-perception in poverty-stricken areas of Japan through the data of the Japanese General Social Survey for 2000, 2003, and 2006. The results show that there was a significant correlation between regional income inequality and personal health assessment. When assessing health status, it is vulnerable to the impact of income inequality, poor areas, and income inequality is negatively correlated with health. Zheng (2009) analyzes the relationship between income inequality, gender, and health self-perception in the United States using the hierarchical generalized linear model (HGLM) and the ordered logistic model (OLM). The analysis was conducted using data from the Social Survey and the U.S. Census Bureau from 1972 to 2004; the study found that income inequality was significantly correlated with health self-test and that income inequality and gender inequality in income affected men, not women. Minh Thoa et al. (2013) used logistic regression and the double-difference propensity matching technique to explore the impact of Vietnam's economic growth on healthcare, using the 2003–2007 data for analysis. As a result, regarding healthcare, the better the family's economic status (growth), the more efforts to reduce health inequalities, and the fact that income inequality is negatively correlated with health.

In the time series method, Qin et al. (2009) established a macro-economic model to analyze China's economic growth on income inequality from 2005 to 2010; it is found that the impact of income inequality on economic growth is negative. Dong (2014) used the nonlinear time series model to study the effect of eight countries' economic opening on living standards and income inequality. Using the data from 1950 to 2011, it is found that income inequality is negatively correlated with economic growth. Stevans (2012) used the unit-root test and co-integration test to analyze the correlation between income inequality and economic incentives in the United States from 1970 to 2006; empirical results present a negative relationship between income inequality and economic growth. Muinelo-Gallo and Roca-Sagalés (2013) used the seemingly unrelated regressions (SUR) and the simultaneous equation model (SEM) to explore the relationship between income inequality and economic growth in 21 high-income countries from 1972 to 2006 within the fiscal policy framework. The study found that distributive expenditure and direct taxes may impact gross domestic product and income inequality. For fiscal consolidation, the most appropriate fiscal policy is to reduce non-distributed spending, increasing gross domestic product, and reducing income inequality. This result also proves that there is a negative relationship between income inequality and income.

In the panel data method, Wang (2011) analyzed the causal relationship between health expenditure growth and economic growth in 31 countries from 1986 to 2007 using panel regression and quantile regression with international healthcare expenditure data. The results show that the increase in health spending stimulates economic growth, but economic growth will reduce this spending. The quantile regression results show that the impact of expenditure growth on economic growth is not significant in low-income countries, and it is positive in countries with medium and high-level economic growth. Perera and Lee (2013) used the generalized method of moments (GMM) and panel unit-root test to check the effect of economic growth and quality systems of 9 Asian developing countries on poverty and income inequality during 1985 to 2009; the study found that although economic growth does not affect income inequality, it reduces poverty; also, government stability and social improvement would decrease poverty. Jaba et al. (2014) used the fixed-effects model based on geographic location and income levels to analyze the relationship among birth, health expenditure, and longevity in 175 countries worldwide from 1995 to 2010. It is found that people's health expenditure increases with the increase in life expectancy in developed countries, and this relationship exists not only in developed countries but also in developing countries and untapped countries.

Bhattacharjee et al. (2017) used the panel unit-root test and the fully modified ordinal least squares (FMOLS) to examine the relationship between health and income inequality in public and private sectors of 25 countries from 1980 to 2011. The study found in the public sector that rich countries show high-income growth and low-income inequality, while poor-countries present a vicious cycle of poor health and low income. In the private sector, the health effects of income inequality worsen over time. It can be seen that income inequality has a negative correlation between income and health. Huang et al. (2015) used the pooled mean group (PMG), mean group (M.G.), and GARCH models, and the data on income inequality in 48 states of the United States from 1945 to 2004 to examine the impact of growth volatility on income inequality. Empirically, it is found that high growth volatility is significantly correlated with high-income inequality, and growth volatility has a negative effect on economic growth.

In other methods, Chen and Meltzer (2008) used the multilevel linear probability model to analyze the effects of health status on income and income inequality in 9 provinces of China, using data from China Health and Nutrition Survey from 1991–2000. It is assumed that income and income inequality affect obesity and hypertension. It is found that the increase of average social income in rural China is positively correlated with obesity and hypertension, and income inequality is also positively correlated with obesity and hypertension; that is, income inequality has a negative impact on health. Goh et al. (2009) used the growth incidence curves (GIC) method to study the relationship among income growth, income inequality, and poverty in 8 provinces of China, using data from the China Health and Nutrition Survey from 1989 to 2004. This study found that when the income grows, the incidence of poverty declines. Still, the income of some parts of the population grows unevenly, especially residents in the area between coastal cities and inland cities.

Ourti et al. (2009) analyzed the effects of economic growth and income inequality on healthcare inequality in 13 European countries using the European Community

Household Panel User Database (ECHP-UDB), data covering from 1994 to 2001 is used for analysis. In most countries, income growth leads to better health, while reducing income inequality would improve health; that is, income inequality negatively correlates with income and health. Chu and Peng (2011) used the quality-ladder model to analyze the effect of intellectual property rights in China and the United States on their economic growth and income inequality with the data from 1985 to 2005. Within the framework of economic growth theory, it is found that strengthening patent protection in China and the United States would help increase economic growth and income inequality in these two countries. Fakthong (2012) used the internal generation model of human capital accumulation to study the relationship between income inequality and the growth of public sector capital investment in Thailand. There are two types of public sector capital investment, first is the education subsidy, and the second is research and development investment; using the 2000–2009 annual data, it is found that in the economic downturn, in addition to education subsidy, the impact of the increase in research and development investment on income and long-term economic growth is better than the education subsidy. Baeten et al. (2013) used the inverse probability weights (IPW) method and the income-related health inequalities (IRHI) data of the 1991–2006 period to study the effect of income inequality on health and income in China. The study suggests that the increase in income inequality would have an adverse impact on health and income, especially for the elderly. On the other hand, the study also found that alternative income and pensions are likely to reduce the healthcare gap between the rich and the poor and are the most crucial policy instruments.

Baeten et al. (2013), Chen and Meltzer (2008), and Goh et al. (2009) analyze the health and nutrition surveys in China to explore the effect of income inequality on health and income. The results show that income inequality has a negative impact on healthcare and income. Additionally, Oshio and Kobayashi (2009) explore the correlation between Japan's income inequality and health self-perception, and Zheng (2009) analyzes the relationships among U.S. income inequality, gender, and health self-perception; both studies showed that income inequality is significantly correlated with health self-perception. Besides, both Lhila (2009) and Minh Thoa et al. (2013) explored the effect of healthcare on income inequality, and their results present the negative impact of income inequality on health. Although scholars discuss different topics, their results mostly prove that income inequality significantly correlates with income and healthcare growth.

Conversely, Perera and Lee (2013) explored economic growth and quality systems on poverty and income inequality in 9 Asian developing countries. The study found that economic growth did not affect income inequality. This result is consistent with those of Das and Barua (1996), Deininger and Squire (1998), and Ravallion et al. (1991), who state that there is no significant correlation between income growth and inequality.

Dhrifi (2020) use a two-step system dynamic GMM method for 93 developed and developing countries over the 1995–2015 period to test the impact of public health spending on infant health considering the role that institutional quality can play; the findings show that there is an apparent positive and significant effect of health expenditure on infant mortality only for high-income countries. In contrast, for lower, lower-middle, and upper-middle-income ones, health spending does not have a significant impact on infant health status.

Recent related research, Sánchez-López et al. (2019) examines the relationship between income inequality and globalization in 29 European countries. The results indicate that both trade globalization and the degree of technological development are associated with a reduction in inequality. In contrast, financial globalization, particularly foreign direct investment inward, is associated with increased inequality. Furthermore, Gavurova et al. (2020) evaluate the effects of selected health indicators on the competitiveness of developed countries; they find that improve the health of men and women is likely to increase the competitiveness of developed countries. Finally, Puciato et al. (2020) think that lowered household income leads to a constrained fulfillment of individual and collective needs, significantly impacting the unemployed's quality of life and perceived health condition.

Compared to past research, we first use the quantile panel-type causality to test the relationship between health expenditure and income inequality. On the other hand, we use two variables to measure the impact of health expenditure on income inequality, providing further reference information and policy implications different from the existent literature.

3. Methodology

The standard least-squares method provides estimates based on the average effect of the independent variable on the average firm. In this analysis, quantile regression estimation is more appropriate because two advantages are identified, quantile results are robust to outliers, and quantile regression can describe the entire conditional distribution of the dependent variable. The Granger (1969) approach allows us to examine the causal relationship between stationary variables. We conduct the novel non-causality test in quantiles proposed by Chuang et al. (2009) to expose a more nuanced causal relationship that accounts for the different quantiles. This study uses panel data and further develops the panel quantile model. Basing on the model with three variables, the Granger causality in panel quantile model is given by the following:

$$Q_{Yit}\left(\tau|(Y_i, X_i, Z_i)t-1\right) = Q_{Yit}\left(\tau_i|Y_{it-1}\right), \forall\tau \in [a, b] \tag{1}$$

where $Q_{Yit}(\tau|\Theta)$ denotes theτth quantile of $F_{Yit}(\cdot|\Theta)$; $F_{Yit}(\cdot|\Theta)$ is the conditional distribution of y_{it}, Θ be the information set at the time $t-1$ of country i. It includes three stationary time series, y_{it}, x_{it} and z_{it}, where$(Y_i, X_i, Z_i)_{t-1}$ is the information set generated by y_{it}, x_{it} and z_{it} up to the time $t-1$ of country i. x_{it} (or z_{it}) does not Granger-cause y_{it} in the quantile interval $[a, b]$ if Equation (1) holds. We can conduct the Granger non-causality test in quantiles by employing the usual quantile regression method proposed by Koenker and Bassett (1978). We test for the non-causal relation in quantiles between y_{it}, x_{it} and z_{it} by considering the conditional quantile panel-VAR model as follows:

$$Qy_{it}(\tau|Y_{it-1}) = \beta_{01i}(\tau) + \sum_{j=1}^{p} \beta_{11,ij}(\tau)y_{it-j} + \sum_{j=1}^{p} \beta_{12,ij}(\tau)x_{it-j} + \sum_{j=1}^{p} \beta_{13,ij}(\tau)z_{it-j} \tag{2}$$

$$Qx_{it}(\tau|X_{it-1}) = \beta_{02i}(\tau) + \sum_{j=1}^{p} \beta_{21,ij}(\tau)y_{it-j} + \sum_{j=1}^{p} \beta_{22,ij}(\tau)x_{it-j} + \sum_{j=1}^{p} \beta_{23,ij}(\tau)z_{it-j} \tag{3}$$

$$Qz_{it}(\tau|Z_{it-1}) = \beta_{03i}(\tau) + \sum_{j=1}^{p} \beta_{31,ij}(\tau)y_{it-j} + \sum_{j=1}^{p} \beta_{32,ij}(\tau)x_{it-j} + \sum_{j=1}^{p} \beta_{33,ij}(\tau)z_{it-j} \tag{4}$$

The null hypothesis of no Granger causality at the$\tau \in (0,1))$ quantile level is denoted by $H_0 : \beta(\tau) = 0$. For a fixed$(\tau) \in (0,1)$, the Wald statistic of $\beta(\tau) = 0$ is presented as follows:

$$W_T(\tau) = T\frac{\hat{\beta}_t(\tau)'\hat{\Omega}(\tau)-1\hat{\beta}_T(\tau)}{\tau(1-\tau)} \tag{5}$$

where $\hat{\Omega}(\tau)$ represents a consistent estimator of $\Omega(\tau)$, which is the variance-covariance matrix of$\beta(\tau)$. If H_0 is rejected, $\sum_{j=1}^{p} \beta_j(\tau)>0$ indicates that there is a positively significant causal relationship between variables, $\sum_{j=1}^{p} \beta_j(\tau)<0$ shows a significant negative causality.

Besides considering the non-causality at the fixed quantile level τ using the aforementioned Wald test, we are further interested in testing the non-causality in quantiles over certain quantile intervals, such as$\tau \in [a,b]$. Koenker and Machado (1999) showed that under suitable conditions, the null hypothesis$H_0 : \beta_j(\tau) = 0, \forall t \in T \subset [a,b]$ and the Wald statistic process follows the weak convergence, which is given by

$$W_T(\tau) = > \left| \frac{B_P(\tau)}{\sqrt{\tau(1-\tau)}} \right|^2, for\tau \in T, \tag{6}$$

where $B_p(\tau) = [\tau(1-\tau)]^{1/2}\ N(0, I_p)$ is a vector of$p$ independent Brownian bridges and the weak limit is the sum of the square of p independent Bessel processes. Koenker and Machado (1999) and Chuang et al. (2009) suggest a Sup-Wald test for the aforementioned null hypothesis. It follows

$$\underset{\tau \in \mathcal{T}}{sup}\ W_T(\tau) \rightsquigarrow \underset{\tau \in \mathcal{T}}{sup} \left| \frac{B_q(\tau)}{\sqrt{\tau(1-\tau)}} \right|^2. \tag{7}$$

The quantile range from which there are causal relationships can be captured by considering various$[a,b]$. Critical values for several quantile ranges are simulated. For the sup-Wald test, critical values are simulated with the standard Brownian motion using a Gaussian random walk with 3000 i.i.d.$N(0,1)$ innovations.

4. Empirical results

The yearly data in this study encompasses 36 sample countries: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States; the sample period is from 2004 to 2017. The data have been obtained from OECD.Stat Database, July 2020.[1]

This study uses four variables and establishes two panel models for analysis. The 4 variables are Gini index G (0–1 scale, disposable income, post taxes, and transfers), current expenditure on health H (measured in per capita, constant prices, constant PPPs, U.S. Dollar, OECD base year 2015), gross domestic product Y (measured in per capita, constant prices, constant PPPs, U.S. Dollar, OECD base year 2015), and the ratio of health expenditure to gross domestic product R(%). Model 1 includes three variables G, H and Y; Model 2 contains two variables G and R, where H and Y are in logarithmic form.

Table 1 shows the summary statistical data analysis of the variables and the results of the unit-root test. Among the four level-variables, R's standard deviation is the highest, indicating that there are relatively large differences in the ratio of health expenditure to national income between countries, and the standard deviation of G is the lowest, reflecting the small differences in the Gini coefficients between countries. The skewness coefficients show that G, Y and R are right-biased, while H is left-biased. The kurtosis coefficient shows that H is platykurtic, and the remaining three variables are leptokurtic. Among the four variables shown by the Jarque-Bera value, only the variable Y conforms to the normal distribution.

According to the first difference term, the average of ΔG equals 0, meaning that each country's Gini coefficient does not change much, and the average change of health expenditure growth (ΔH) is 0.023 and national income growth (ΔY) is 0.015. The change in the ratio of health expenditure to income (ΔR) presents a higher discrete degree, implying a larger difference in the tail's distribution, thereforeΔR is a crucial variable. Additionally, the standard deviation value of ΔR is $0.350 > 0.039$ (the standard deviation value of ΔH) shows that the change in the ratio of health expenditure to income is greater than the change in health expenditure. It reflects that the change in the ratio of health expenditure to income in each country is greater than the change in health expenditure per person. The Skewness coefficients show thatΔG and ΔY are left-biased, the rest are right-biased, and all variables in difference form are leptokurtic and non-normally distributed.

According to the panel unit-root test, the results of IPS, Fisher-ADF, and Fisher-PP show that all difference-terms are stationary. Therefore, we use the difference-terms of the variables for the model establishment and causality test. The Ljung- Box (Q) statistics for 1 and 5 lags show a significant serial correlation in the level and difference series. This result reflects the heterogeneity of time and variable distribution.

We design two models; Model 1 has three variables including $\{\Delta G, \Delta H, \Delta Y\}$ and Model 2 has two variables $\{\Delta G, \Delta R\}$. We further test whether these two models have a cointegration relationship. The results of Pedroni (1999) and the Kao (1999)

Table 1. Summary statistics, panel unit root results and panel cointegration test.

Level term	*G*	*H*	*Y*	*R*
Mean	0.316	7.983	10.517	8.489
Std. Dev.	0.054	0.535	0.375	2.172
Skewness	1.004	−0.433	0.073	0.851
Kurtosis	4.036	2.479	3.144	5.106
Jarque-Bera	107.3***	21.44***	0.892	154.0***
Probability	0.000	0.000	0.640	0.000
IPS	0.074	−1.275	0.736	−0.099
Fisher-ADF	75.08	81.54	61.68	63.16
Fisher-PP	100.8	73.13	75.61	59.71
Q(1)	419.21***	427.08***	425.00***	424.60***
Q(5)	1415.0***	1502.1***	1501.8***	1436.1***
Different term	ΔG	ΔH	ΔY	ΔR
Mean	0.000	0.023	0.015	0.063
Std. Dev.	0.009	0.039	0.034	0.350
Skewness	−0.122	0.112	−0.425	0.459
Kurtosis	7.463	8.636	9.015	11.405
Jarque-Bera	389.5***	620.45***	719.7***	1393.8***
Probability	0.000	0.000	0.000	0.000
IPS	−6.956***	−5.761***	−8.571***	−6.718***
Fisher-ADF	174.04***	125.4***	125.5***	168.5***
Fisher-PP	380.113***	170.8***	144.2***	210.6***
Q(1)	9.344***	91.52***	54.43***	13.28***
Q(5)	10.590**	112.3***	59.24***	14.72***

Panel Cointegration Test

	Model 1:{ΔG, ΔH, ΔY}		Model 2:{ΔG, ΔR}	
Method	Test statistics	*P*-value	Test statistics	*P*-value
Panel v-statistic	−0.630	0.735	0.670	0.251
Panel ρ-statistic	0.721	0.764	−1.227	0.109
Panel PP-statistic	−2.481	0.006***	−3.008	0.001***
Panel ADF-statistic	0.183	0.572	0.489	0.687
Group ρ-statistic	1.770	0.961	−0.159	0.436
Group PP-statistic	−5.774	0.000***	−5.589	0.000***
Group ADF-statistic	1.049	0.853	0.798	0.787
Kao cointegration test	−0.921	0.178	−0.846	0.198

Notes: (1) In ADF (Augmented Dickey-Fuller) test, the [.] is the optimal lag-periods that are automatic - based on AIC, and the maximum lags = 4; (2) The Q(1) and Q(5) are Ljung-Box statistics for 1 and 5 lags; (3) In panel cointegration test, the null hypothesis is no cointegration. The Pedroni's (1999) statistics are asymptotically distributed as normal, the specified lag length = 1; (4) The notations ** and *** indicate statistical significance at the 5% and 1% levels.
Source: Authors.

residual cointegration test show that, except for the significant effects of the Panel PP-statistic and Group PP-statistic, the rest do not show the existence of cointegration. These results do not support the cointegration relationship among variables in both models. The linear panel-type VAR model is firstly estimated for causality. Table 2 reports the results of the linear Granger causality test. Model 1 shows that, among the three variables of income distribution change ΔG, economic growth ΔY, and health expenditure growth ΔH, only economic growth has a one-way and positive impact on health expenditure growth $(\Delta Y \xrightarrow{+} \Delta H)$, which means that an increase in income leads to a raise in health expenditure and vice versa. The other results of Model 1 as well as of Model 2, do not present any other causal relationship. The linear causality test cannot find the effect of health expenditure on income distribution, which might be caused by the ignorance of the difference quantiles.

For explaining how different quantiles affect causality, Table 3 reports the estimated results of the quantile panel-type VAR model for the five quantiles of 0.05,

Table 2. Linear Granger causality test.

	P-values	Causality or not	Coefficient	Direction
Model 1:{$\Delta G, \Delta H, \Delta Y$}				
$\Delta Y \neq \triangleright \Delta H$	0.000	Yes	0.309	+
$\Delta G \neq \triangleright \Delta H$	0.125	Not	−0.254	−
$\Delta H \neq \triangleright \Delta Y$	0.091	Not	0.069	+
$\Delta G \neq \triangleright \Delta Y$	0.169	Not	−0.221	−
$\Delta H \neq \triangleright \Delta G$	0.310	Not	−0.016	−
$\Delta Y \neq \triangleright \Delta G$	0.451	Not	0.016	+
Model 2:{$\Delta G, \Delta R$}				
$\Delta G \neq \triangleright \Delta R$	0.754	Not	−0.564	−
$\Delta R \neq \triangleright \Delta G$	0.333	Not	−0.001	−

Note: This table tests the null hypothesis of no Granger causality. AIC determines the optimal lag order. The VAR lags = 1 in model 1 and model 2. The notations ** indicates statistical significance at the 5% level.
Source: Authors.

Table 3. Quantile panel-type causality test.

Null hypothesis	Quantile	Coefficient	Wald test statistics *P*-values	Causality or not
Model 1:{$\Delta G, \Delta H, \Delta Y$}				
$\Delta Y \neq \triangleright \Delta H$	0.050	0.288	0.000	Yes
	0.250	0.334	0.000	Yes
	0.500	0.310	0.000	Yes
	0.750	0.339	0.003	Yes
	0.950	0.360	0.193	
$\Delta G \neq \triangleright \Delta H$	0.050	−1.055	0.011	Yes
	0.250	0.093	0.561	
	0.500	−0.140	0.421	
	0.750	−0.253	0.261	
	0.950	−0.337	0.070	
$\Delta H \neq \triangleright \Delta Y$	0.050	−0.040	0.633	
	0.250	0.105	0.021	Yes
	0.500	0.106	0.024	Yes
	0.750	0.130	0.003	Yes
	0.950	0.130	0.096	
$\Delta G \neq \triangleright \Delta Y$	0.050	−0.453	0.300	
	0.250	−0.097	0.610	
	0.500	0.033	0.805	
	0.750	−0.081	0.612	
	0.950	−0.554	0.001	Yes
$\Delta H \neq \triangleright \Delta G$	0.050	−0.024	0.649	
	0.250	−0.016	0.240	
	0.500	0.000	0.999	
	0.750	−0.013	0.276	
	0.950	−0.038	0.022	Yes
$\Delta Y \neq \triangleright \Delta G$	0.050	0.056	0.796	
	0.250	−0.001	0.966	
	0.500	0.000	1.000	
	0.750	0.006	0.720	
	0.950	0.056	0.002	Yes
Model 2:{$\Delta G, \Delta R$}				
$\Delta R \neq \triangleright \Delta G$	0.050	0.002	0.224	
	0.250	−0.001	0.466	
	0.500	0.000	1.000	
	0.750	−0.000	0.522	
	0.950	−0.007	0.000	Yes
$\Delta G \neq \triangleright \Delta R$	0.050	−1.111	0.661	
	0.250	−0.262	0.871	
	0.500	1.572	0.431	
	0.750	0.530	0.792	
	0.950	−7.017	0.377	

Note: This table tests the null hypothesis of no Granger causality and reports the *p*-value of Wald test statistics. AIC determines the optimal lag order. The VAR lags = 1 in model 1 and model 2.
Source: Authors.

0.25, 0.50, 0.75, and 0.95. The estimated results of Model 1 present the following findings: (1) To analyze the effect of ΔY on ΔH, it shows that the coefficient values imply the positive effect of economic growth on the growth of health expenditure ($\Delta Y \xrightarrow{+} \Delta H$) under the quantiles of 0.05, 0.25, 0.50, and 0.75. In other words, as health expenditure keeps growing (the quantiles of variables are preserved under increasing), economic growth can stimulate growth in health expenditure. However, this effect is insignificant if the growth of health expenditure is at a high quantile (0.95); (2) To analyze the effect of ΔG on ΔH, only if ΔH is at the 0.05 quantile, the change in income distribution negatively affects the growth of health expenditure ($\Delta G \xrightarrow{-} \Delta H$), which means that when the growth of health expenditure is at a lower quantile (0.05), the inequality of income distribution keeps reducing (the quantiles of variables are preserved under decreasing) would further stimulate the growth of health expenditure; on the contrary, if the inequality of income distribution keeps deteriorating (increased changes in income distribution), it would cause the growth of health expenditure to decline; (3) To analyze the effect of ΔH on ΔY, under the $0.25 \sim 0.75$ quantiles of ΔY, the health expenditure growth positively affects the economic growth ($\Delta H \xrightarrow{+} \Delta Y$), which denotes that at middle quantile of income growth (ΔY), an increase in health expenditure growth causes an increase in economic growth. This result indicates that the most crucial expenditure may be spent on food and infrastructure in countries with relatively middle economic growth levels. (4) To analyze the effect of ΔG on ΔY, only on 0.95 quantile of ΔY, $\Delta G \xrightarrow{-} \Delta Y$. This means that under a high economic growth level, the continuous deterioration of income inequality will reduce economic growth; and conversely, the continuous improvement of income inequality will expand economic growth. (5) To examine the effect of ΔH on ΔG, only on 0.95 quantile of ΔG, $\Delta H \xrightarrow{-} \Delta G$. This means that under a high degree of uneven distribution, the continued growth of health expenditure will reduce the uneven distribution of income, and vice versa. (6) To analyze the impact of ΔY on ΔG, at the 0.95 quantile where the income inequality is high (income distribution keeps deteriorating), economic growth on the change in income distribution is positive ($\Delta Y \xrightarrow{+} \Delta G$). At this point, continuous economic growth would worsen income inequality.

Model 2 is used for analyzing the effect of ΔR on ΔG. At the 0.95 quantile where the income distribution is extremely uneven, the growth of the ratio of health expenditure to income (ΔR) is one-way and negatively affects the change in income distribution ($\Delta R \xrightarrow{-} \Delta G$). In other words, the ratio of health expenditure to income (ΔR) keeps growing, which can improve income inequality (keep improving), thereby resulting in a better result in social justice.

To facilitate the identification of the quantile intervals, where the causal relationship is significant, we transform the results of Table 3 into Figures 1 and 2. Figure 1 reports the impact coefficient path of quantile causality of Model 1. We use the confidence interval that does not contain 0 value to judge the significance of the quantile coefficients. Figure 1 shows that economic growth has a significant positive impact on the health expenditure growth ($\Delta Y \xrightarrow{+} \Delta H$) within the quantile interval of [0.05–0.95]; and health expenditure growth has a significant positive impact on the economic growth ($\Delta H \xrightarrow{+} \Delta Y$) within the quantile interval of [0.25–0.95]. Because the

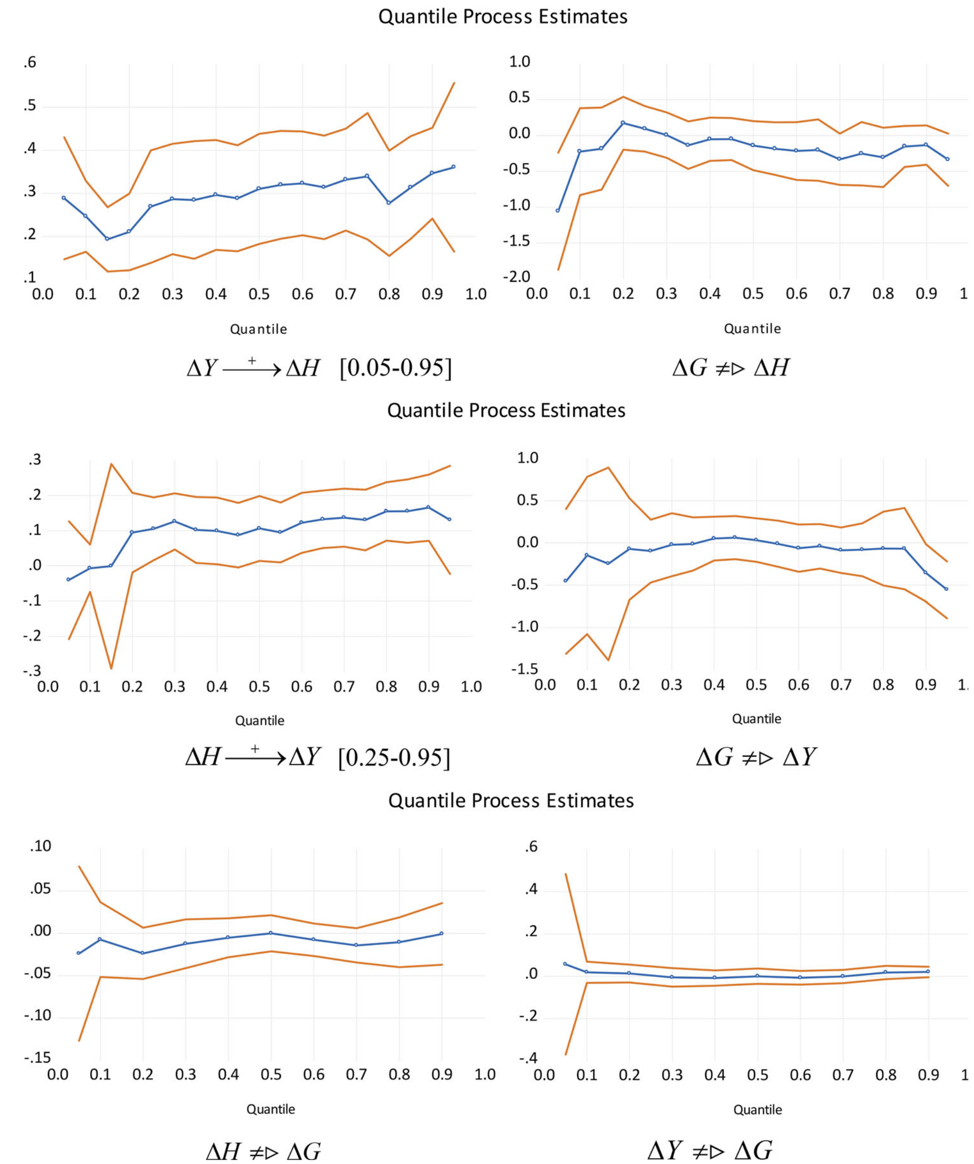

Figure 1. The impact coefficient path of quantile causality of Model 1.
Source: Authors.

confidence interval does not contain 0, the causality of$\Delta G \neq \triangleright \Delta H$ $\Delta G \neq \triangleright \Delta Y$ and $\Delta H \neq \triangleright \Delta G$ imply the insignificant effect of the quantile interval coefficient.

Figure 2 reports the impact coefficient path of quantile causality of Model 2. According to Figure 2, the change in income distribution negatively and significantly influence the growth of health expenditure to income ratio ($\Delta G \rightarrow \Delta R$) within the quantile interval of [0.85–0.95]; and the growth of health expenditure to income ratio negatively and significantly influence the change in income distribution ($\Delta R \rightarrow \Delta G$) within the quantile interval of [0.95–0.99]. Therefore, we perform the causality test for the quantile intervals according to the above results.

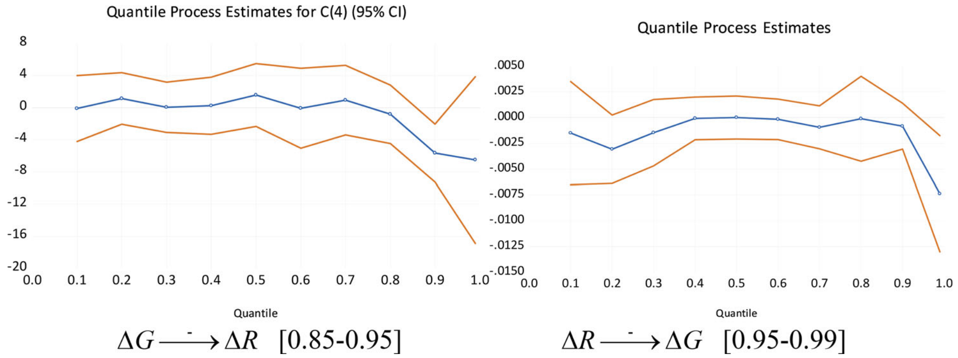

Figure 2. The impact coefficient path of quantile causality of Model 2.
Source: Authors.

Table 4. The causality test for the quantile intervals.

Quantile interval	Null hypothesis	Sup-Wald test statistics *P*-values	Causality or not	△ of coefficients
Model 1:{$\Delta G, \Delta H, \Delta Y$}				
[0.05-0.95]	$\Delta Y \neq \triangleright \Delta H$	0.551		0.071
[0.25-0.95]	$\Delta H \neq \triangleright \Delta Y$	0.771		0.025
Model 2:{$\Delta G, \Delta R$}				
[0.85-0.95]	$\Delta G \neq \triangleright \Delta R$	0.040**	Yes	−2.975
]0.95-0.99]	$\Delta R \neq \triangleright \Delta G$	0.000***	Yes	−0.006

Note: This table tests the null hypothesis of no Granger causality and reports the *p*-value of Sup-Wald test statistics. AIC determines the optimal lag order. The VAR lags = 1 in model 1 and model 2.
Source: Authors.

Table 4 reports the results of the causality test for the quantile intervals. We find that: (1) According to the results of Model 1, the null hypothesis $\Delta Y \neq \triangleright \Delta H$ and $\Delta H \neq \triangleright \Delta Y$ are not rejected within the quantile intervals of [0.05–0.95] and [0.25–0.95] basing on the Sup-Wald test, (2) According to the results of Model 2, the null hypothesis $\Delta G \neq \triangleright \Delta R$ is rejected within the quantile interval of [0.85–0.95], and the coefficient between the intervals decreases by 2.975, implying that the change in income distribution (ΔG) has a negative momentum ($\Delta G \rightarrow \Delta R$) on the growth of health expenditure to income ratio (ΔR); (3) The null hypothesis $\Delta R \neq \triangleright \Delta G$ is rejected within the quantile interval of [0.95–0.99], which means that the growth of health expenditure to income ratio also has a negative momentum ($\Delta R \rightarrow \Delta G$) on the changes in income distribution.

From the economic perspective, the above results indicate that reducing the deterioration of income distribution ($\Delta G \downarrow$) can make the ratio of health expenditure income keep increasing ($\Delta R \uparrow$) under the high-growth of health expenditure to income ratio. In addition, the ratio of health expenditure to income keeps growing ($\Delta R \uparrow$) can reduce the degree of deterioration of income inequality ($\Delta G \downarrow$) under the extreme unequal income distribution. Therefore, to improve the continuous deterioration of income inequality, the focus is on the continuous increase in the ratio of health expenditure to income ($\Delta R \uparrow$), not just the continuous increase in health expenditure per person ($\Delta H \uparrow$).

To summarize, the results of the linear causality model show that only economic growth has a one-way and positive effect on the growth of health expenditure.

However, they obviously ignore the impact of income inequality. As the quantile causality model results, the continuous improvement in the income inequality can stimulate the growth of health expenditure under lower health expenditure growth quantile, and stimulate the growth of economic under higher economic growth quantile. In addition, the ratio of health expenditure to income (ΔR) keeping growing can also continuously improve the income inequality. Finally, the quantile interval causality model results further find that to improve the continued deterioration of income inequality; the focus is on the continuous increase in the ratio of health expenditure to income, not just the continuous increase in per capita health expenditure. In the past, most studies supporting Wilkinson's relative income hypothesis (Younsi & Chakroun, 2018) only point out that income inequality is negatively correlated with health expenditure. Therefore, it is recommended to increase health expenditure to improve the unequal distribution of income. The results of this article also show that when one country's economy develops to a certain extent, the impact degree of absolute income on health would significantly reduce; on the contrary, the relative income and health are closely related. Although economic development has lifted many people out of poverty, inequality in income distribution pushes those who are relatively poor and economically weak compared with their peers in the negative psychological feeling of being deprived. To relieve stress, health risk behaviors may increase the risk of causing diseases, which may harm health.

From the perspective of financial development, Dhrifi (2015) also believes that financial development has promoted economic growth and poverty reduction in high- and middle-income countries, while in low-income countries, the financial system has no positive impact on these economies. The empirical results also show that economic development has exacerbated income inequality in low- and middle-income countries. For high-income countries, any improvement in the financial system has led to a reduction in inequality. Therefore, the most important finding of this study is that if a country can make income distribution more, health expenditure will continue to grow. At the discussion on improving income inequality, Shahabadi et al. (2017) mention that knowledge economy factors can benefit income inequality. Younsi and Bechtini (2020) believe that sustained economic growth and financial development can mitigate income inequality, while Kaidi and Mensi (2020) suggest that in addition to financial development, an excellent democratic political system can also improve income inequality.

5. Conclusions

The instability of the global economy, the widening gap between the rich and the poor, and the increase of income inequality seriously hamper countries' future economic growth and health spending. The light of this study is extending the research of Wang (2011) and developing the panel quantile causality for testing whether income inequality is harmful to health expenditure growth.

Using the quantile interval causality model, the most important finding of this article is that the continuous improvement of income inequality can stimulate the growth of health expenditure; and the ratio of health expenditure to income (ΔR) can keep growing, which can also continuously improve the inequality of income. Finally, it is found that to improve the continued deterioration of inequality of income; the focus should be the continuous increase in the ratio of health expenditure to income, not just the continuous increase in per capita health expenditure.

The previous literature discussing international health expenditure, whether it is based on relative income or absolute income hypothesis, expects a negative relationship between income inequality and population health. However, this relationship is shaped by ecology, while this article constructs this relationship based on the micro basis of macroeconomics. This study provides strong evidence that different countries should use other policies to improve their healthcare system through unequal income reduction and economic growth.

This paper contributes to empirical literature related to how to improve the quality of health expenditure when income is inequality. The panel quantile causality model is developed to test for the impact of unequal income on health expenditure so that we can understand the different effects of unequal income on health expenditure growth and economic growth from low to a high level of health expenditure growth and economic growth, which is the important key for more effective policy.

Note

1. According to the completeness of the data in the OECD.Stat database, we deleted the countries and periods with incomplete data, 36 sample countries and the period of 2004-2017 are used for this study.

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