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Research article

Economic growth effects of public health expenditure in OECD countries: An empirical study using the dynamic panel threshold model

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ABSTRACT

Background: Member countries of the Organization for Economic Co-operation and Development (OECD) have experienced a downward trend in capital and macro investment returns. Countries rely on investments in healthcare and health-related sectors to ensure continuous input and an efficient labor market. Public healthcare coverage is a social welfare policy implemented by governments, which contributes to improving human capital quality and ensuring stable economic growth.
Methods: This study employs a method that combines theoretical modeling and empirical testing examining 33 OECD countries from 2001 to 2017. We first construct a nonlinear dynamic panel threshold model to examine the impact of public health spending on economic growth. We then employ the model to empirically analyze the threshold effect of public health expenditure on economic growth, validating the effectiveness of our theoretical model.
Results: When the level of household consumption is below the 9.63 threshold, the effect of public health expenditure on economic growth is significantly negative ($p < 0.1$); however, when consumption exceeds the 9.63 threshold, the effect becomes significantly positive ($p < 0.05$). Similarly, when employee wages are below the 10.57 threshold, the effect of public health expenditure on economic growth is significantly negative ($p > 0.1$), and it becomes significantly positive when it exceeds 10.57 ($p < 0.5$). Finally, when the level of physical capital investment falls below the 8.73 threshold, the effect of public health expenditure on economic growth is significantly negative ($p < 0.5$), and it becomes significantly positive when it exceeds 8.73 ($p < 0.5$). The positive impact of public health expenditure on economic growth gradually strengthens as household consumption, employee wages, and per capita physical capital investment continue to rise.
Conclusions: In an economic environment with higher household consumption, employee wages, and physical capital investment, public health expenditure will significantly promote economic growth.

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1. Introduction

Public health expenditure is a social welfare expenditure that benefits people's lives and wellbeing, as well as an investment in a country's health capital. According to previous research data, the capital and macro investment return rate in member countries of the Organization for Economic Co-operation and Development (OECD) from 2005 to 2020 had a fluctuating downward trend [1]. A well-developed social security system improves citizens' health conditions, promotes the market participation of an effective labor force, and advances rapid economic and social development. Appropriate public healthcare expenditure can also help to prevent excessive inflation in social consumption and maintain economic and social stability. Therefore, OECD countries rely on investments in healthcare and other social welfare functions to improve citizens' health and work efficiency, ensure the ongoing economic input of an effective labor market, and promote economic development. The relationship between public health expenditure and economic growth has become an important research topic in the fields of public health and social security. Considering the increased public health expenditure worldwide, it is essential to understand the relationship between public health expenditure and economic development, as well as its trends and heterogeneity. Investigating these issues can provide an important reference for the Chinese government in formulating appropriate healthcare system policies and improving the nation's existing healthcare service system.

Considering the emergence of the COVID-19 pandemic in 2019, data from 2019 onward may elicit significant biases for this study; thus, to balance the availability and completeness of the data, this article uses panel data from 33 OECD countries from 2001 to 2017. The per capita GDP growth rate is used as the indicator of economic growth, while per capita public health expenditure in OECD countries is the main explanatory variable. Residents' per capita consumption, wages, and physical capital investment are the chosen threshold variables. This study empirically analyzes the threshold effect of public health expenditure on economic growth in OECD countries employing the dynamic panel threshold model. To further validate the effectiveness of the threshold model regression, we also assess the coverage rates of public healthcare systems in each country as an instrumental variable (IV), conducting robustness tests on the economic growth effect of public health expenditure. The findings reveal the three threshold variables of per capita consumption, wages, and physical capital investment exhibit a significant threshold effect on public health expenditure affecting economic growth. In the lower range of each threshold variable, the economic growth effect of public health expenditure is either insignificant or significantly negative, whereas at higher ranges of threshold variables, public health expenditure has a significantly positive effect on economic growth.

2. Literature review

Scholars worldwide have conducted extensive research on the economic growth effects of public health expenditure. The OECD public health expenditure examined in this article references government-provided expenses for inpatient and outpatient treatment, rehabilitation care, long-term care, and preventive healthcare. In China, public health expenditure is usually referred to as government healthcare expenditure and is an important component of government public expenditure, and the related research literature in China has predominantly focused on the relationship between healthcare expenditure and economic growth. Previous research presents various perspectives on the relationship between public health expenditure and economic growth, and no consensus has been reached.

Some scholars have argued that public health expenditure has a restraining effect on economic growth. Rosa and Pueyo studied the relationship between economic growth, public health expenditure, and life expectancy by constructing an endogenous lifespan model, revealing a negative correlation between economic growth and public health expenditure [2]. Ghosh and Gregoriou used panel data from 15 countries between 1972 and 1999, determining that public health expenditure has a significantly negative effect on economic growth [3]. Liu and Zhang examined data from China between 1981 and 1999, finding that Chinese government healthcare expenditure has a significant negative direct impact on economic growth [4]. Sun used provincial panel data from China between 1995 and 2012 and employed generalized method of moments (GMM) estimation, concluding that healthcare security expenditure hinders economic development [5].

Conversely, some scholars have argued that public health expenditure benefits economic growth. Helms examined data from the US between 1965 and 1979, finding that public health expenditure significantly stimulates economic growth [6]. Devarajan and Bleaney et al. found public health expenditure to have a significant positive effect on economic growth [7,8]. Geng et al. argued that government healthcare expenditure has a higher contribution to economic growth [9]. Beraldo et al. examined panel data from 19 OECD countries between 1971 and 1998, determining that healthcare expenditure has a significant promotional effect on economic growth, with a contribution that surpasses that of education expenditure [10]. Constructing a generalized Cobb–Douglas production function model that included government healthcare investment, Jiang and Tian verified that increased government healthcare expenditure directly or indirectly promotes economic growth [11]. Luo used a stochastic dynamic general equilibrium model and health workforce input–output efficiency as a proxy variable for health human capital, concluding that public health expenditure significantly promotes economic growth [12]. Guo et al. analyzed the promotional effect of government healthcare expenditure on economic growth using an endogenous growth model [13]. Lan used provincial panel data from China between 2001 and 2010 and employed spatial panel models to analyze public health expenditure, finding that improving human capital promotes sustainable economic growth [14]. Fan and Chen (2016) determined that government healthcare expenditure significantly promotes economic growth based on provincial panel data using two-stage least squares and GMM methods [15]. Saida and Kais found medical security expenditure to have a positive impact on economic development, which becomes more significant as medical security expenditure increases [16], indicating that the government should implement policies to encourage medical security expenditure to establish a healthier and more productive economy and support national economic growth and development. Wang used a spatial econometric model and concluded that Chinese government healthcare expenditure has a significant positive promotional effect on economic growth [17]. Tao et al. used

Lasso regression analysis and found that government medical security expenditure has a significant promotional effect on economic growth, also revealing a significant threshold effect of government medical security expenditure on economic growth that varies according to the per capita fixed assets in different ranges [18].

Notably, the threshold effect of public health expenditure on economic growth may not be reflected in public health expenditure alone, but may also be influenced by other factors. Namini found a strong long-term Granger causality relationship between economic growth and healthcare expenditure and inflation [19]. Based on provincial panel data in China Tang explored the mechanism of the impact of health expenditure on the quality of economic growth examining human capital, consumption demand, and productivity effects [20]. Sfakianakis et al. evaluated the impact of financial capacity and health policies on healthcare expenditure using static and dynamic econometric methods based on panel data from OECD countries from 2000 to 2017 [21]. Dong (2023) also reached the same conclusion [22]. Jin and Zhang (2022) used a Chinese private enterprise survey database, determining that healthcare expenditure improves health human capital, which promotes enterprises' export development [23]. Since health human capital is an important component of human capital, which promotes economic growth, and imports and exports are logical indicators for measuring a country's level of economic development.

The majority of previous research results have demonstrated that public health spending has a positive impact on the economy, while a limited number of studies have found negative results. Although there is a lack of consensus on the economic growth effect of public health spending, domestic and foreign scholars have largely found that the relationship between public health spending and economic growth is nonlinear. Carrion-I-Silvestre used OECD data, determining that even in the presence of a structural break in the time series level and slope a significant correlation is evident between per capita medical and health spending and economic growth after explaining the cross-sectional dependence [24]. Based on an analysis of Chinese provincial panel data from 1998 to 2006, Cha and Luo revealed a threshold effect for medical expenditure's contribution to economic growth [25]. Arshia and Bruno demonstrated bidirectional Granger causality between per capita medical and health spending and per capita GDP, asserting that endogeneity between explanatory and explained variables must be considered in empirical analyses [26]. Wang and Su tested a two-regime threshold cointegration model, revealing a nonlinear relationship between China's public medical and health spending and economic growth and health spending significantly promotes economic growth [27]. Based on provincial panel data analysis, Fang found a single-threshold effect for China's medical and health expenditure on economic growth [28]. Zhong et al. analyzed the impact of public and private medical and health expenditure on economic growth using a two-way fixed effects model, concluding that government medical and health expenditure exhibit an inverse U-shaped relationship with economic growth, and individual medical and health expenditure has a step-wise relationship with economic growth [29]. Tan et al. found government health spending to have a significant threshold effect on economic growth [30]. Jian and Yu (2016) revealed a multithreshold nonlinear relationship between China's government health spending and economic growth [31]. Song found that the impact of China's fiscal expenditure on livelihood service on economic development is nonlinear [32]. In the context of population aging, Le found a threshold effect of government health spending on economic growth, determining that a significant positive impact on economic growth can only be achieved when the ratio of health spending to fiscal expenditure exceeds a threshold value [33]. Chen analyzed the impact of government health expenditure on economic growth based on an endogenous growth model, finding the effect of government health expenditure on economic growth to be nonlinear, with a critical proportion of government effect, below which government health spending significantly promotes economic growth, and above which it significantly inhibits economic growth [34].

While existing research conclusions have not yet reached a consensus on the economic growth effect of public health spending, most scholars have recognized the threshold effect between the two. Therefore, based on previous studies, we propose an improved method to further examine the threshold effect of public health spending on economic growth, which is the main innovation of this article. First, we construct an economic growth and government decision-making model to analyze the health growth effects of public expenditure from a theoretical perspective. Second, this article considers economic growth as a dynamic process, employing a dynamic panel threshold model for econometric analysis. This study adopts the dynamic panel threshold model proposed by Seo its measurement method [16]. Third, this study uses international panel data to examine the threshold effects of public health expenditure on economic growth in OECD countries. The findings provide an insightful reference for improving China's basic medical insurance system.

3. Methods, data, and variables

3.1. Theoretical model analysis

3.1.1. Public medical insurance expenditure economic growth effect model

Referencing previous research, this study considers medical insurance expenditure as a capital investment that can have certain impacts on economic growth. Combining Solow's neoclassical growth theory and Barro's endogenous growth theory [35,36], this study constructs an economic growth model starting from the Cobb–Douglas production function. In this model, medical insurance expenditure is an endogenous variable, with the assumption of constant returns to scale. The expression is as follows:

$$Y = K^{\alpha} H^{\beta} M^{\gamma} (AL)^{1-\alpha-\beta-\gamma} \tag{1}$$

$$0 < \alpha < 1, 0 < \beta < 1, 0 < \gamma < 1, 0 < 1 - \alpha - \beta - \gamma < 1$$

In equation (1), Y represents economic output; K represents physical capital investment; and H represents human capital investment, referring to educational capital. M represents medical insurance expenditure, which is influenced by government financial decisions and private health insurance demands; therefore, this variable includes public health expenditure (G_M) and nonpublic health expenditure (P_M), which is assumed to be constant. L represents the labor force variable; A represents technological progress; and α, β, γ, and $1-\alpha-\beta-\gamma$ represent the corresponding marginal elasticities.

In this study, we assume that the technological progress and labor force variables are exogenous, and according to the laws of knowledge and labor evolution, we have $A(t) = A_0 e^{g_A t}$ and $L(t) = L_0 e^{nt}$, where respective growth rates are g_A and n.

We also assume the depreciation rates of physical, human, and medical insurance capital are δ_K, δ_H, and δ_M, respectively. The growth rates of physical and human capital satisfy the following equations:

$$\dot{K} = s_K Y - \delta_K K \tag{2}$$

$$\dot{H} = s_H Y - \delta_H H \tag{3}$$

where s_K represents the physical capital investment rate (generally considered to be the savings rate), and s_H represents the human capital investment rate.

Dividing both sides of equation (2) by K, we obtain the following:

$$g_K = \frac{\dot{K}}{K} = s_K K^{\alpha-1} H^{\beta} M^{\gamma} (AL)^{1-\alpha-\beta-\gamma} - \delta_K = s_K k^{\alpha-1} h^{\beta} m^{\gamma} - \delta_K \tag{4}$$

Dividing both sides of equation (3) by H, we obtain the following:

$$g_H = \frac{\dot{H}}{H} = s_H K^{\alpha} H^{\beta-1} M^{\gamma} (AL)^{1-\alpha-\beta-\gamma} - \delta_H = s_H k^{\alpha} h^{\beta-1} m^{\gamma} - \delta_H \tag{5}$$

where $k = K/AL$, $h = H/AL$.

Taking the logarithm and derivative of equations (4) and (5), respectively, we obtain equations (6) and (7):

$$\frac{\dot{g_K}}{g_K} = (\alpha - 1) g_K + \beta g_H + \gamma \frac{1}{m} \frac{\partial m}{\partial G_M} \tag{6}$$

$$\frac{\dot{g_H}}{g_H} = \alpha g_K + (\beta - 1) g_H + \gamma \frac{1}{m} \frac{\partial m}{\partial G_M} \tag{7}$$

When the economy approaches steady state, we have $\dot{g_K} = \dot{g_H} = 0$, which implies the following:

$$g_K = g_H = \frac{\gamma \frac{1}{m} \frac{\partial m}{\partial G_M}}{1-\alpha-\beta} \tag{8}$$

Taking the logarithm and derivative of equation (1) on both sides, we have the following:

$$g_Y = \alpha g_K + \beta g_H + \gamma \frac{1}{m} \frac{\partial m}{\partial G_M} + (1-\alpha-\beta-\gamma)(g_A + n) \tag{9}$$

Substituting equation (8) into equation (9), we obtain the following:

$$g_Y = g_{K,H} + (1-\alpha-\beta-\gamma)(g_A + n) \tag{10}$$

Where g_(K, H) represents the growth rate of physical and human capital in an equal in steady state, i.e., $g_{K,H} = g_K = g_H$.

Substituting equation (8) into equation (10), we get the following relationship between public health expenditure and economic growth:

$$g_Y = \frac{\gamma \frac{1}{m} \frac{\partial m}{\partial G_M}}{1-\alpha-\beta} + (1-\alpha-\beta-\gamma)(g_A + n) \tag{11}$$

Equation (11) indicates that the impact of public health expenditure on economic growth is nonlinear, which provides a theoretical basis for using the panel threshold model to analyze the economic growth effect of public health expenditure. Additionally, since public health expenditure is predominantly led by the government, it is essential to consider the government's decision making.

3.1.2. Government behavioral making model

As the primary decision maker for public health expenditure, the government largely determines citizens' level of medical security. The government's provision of public health expenditure is an aspect of overall public fiscal expenditure. Therefore, fiscal expenditure can be divided into nonpublic health expenditure (G_N) and public health expenditure (G_M). According to the Cobb–Douglas utility function, the government's objective function can be defined as equation (12):

$$max A {G_N}^{\alpha} {G_M}^{1-\alpha} \tag{12}$$

Where A is a constant, and $0 < \alpha < 1$ represents scale elasticity.

We consider the government's role as a taxing entity and a provider of goods and services. The government primarily obtains resources through taxation on consumption income, labor income, and physical capital investment, and the effective tax rates on these three components are τ_C, τ_L, and τ_K, respectively. Additionally, the government maintains a balanced budget each period; therefore, the government's budget constraint can be expressed as follows:

$$\tau_C C + \tau_L WL + \tau_K (R - \delta) K = \mathrm{G}_N + \mathrm{G}_M \tag{13}$$

Where C represents consumption income, W and L represent wage income and labor quantity, respectively, and R, δ, and K respectively represent rental income, depreciation rate, and capital investment of physical capital.

The Lagrangian equation combines the utility function (equation (12)) and the government's budget constraint (equation (13)) using the Lagrange multiplier λ. The objective is to maximize the utility function while satisfying the budget constraint as equation (14):

$$\mathscr{L} = A{\mathrm{G}_N}^{\alpha}{\mathrm{G}_M}^{1-\alpha} + \lambda_1[\tau_C C + \tau_L WL + \tau_K(R - \delta)K - \mathrm{G}_N - \mathrm{G}_M] \tag{14}$$

The first-order conditions are as follows:

$$\frac{\partial \mathscr{L}}{\partial \mathrm{G}_N} = A\alpha{\mathrm{G}_N}^{\alpha-1}{\mathrm{G}_M}^{1-\alpha} - \lambda_1 = 0 \tag{15}$$

$$\frac{\partial \mathscr{L}}{\partial \mathrm{G}_M} = A(1-\alpha){\mathrm{G}_N}^{\alpha}{\mathrm{G}_M}^{-\alpha} - \lambda_1 = 0 \tag{16}$$

$$\frac{\partial \mathscr{L}}{\partial \lambda_1} = \tau_C C + \tau_L WL + \tau_K(R - \delta)K - \mathrm{G}_N - \mathrm{G}_M = 0 \tag{17}$$

From equations (15)–(17), the following is obtained:

$${\mathrm{G}_M}^{*} = (1-\alpha)[\tau_C C + \tau_L WL + \tau_K(R - \delta)K] \tag{18}$$

Equation (18) indicates that the optimal level of public health spending is related to resident consumption spending, employee wage income, and physical capital investment.

Based on our literature review and theoretical model analysis, we assert that the effect of public health insurance on economic growth is nonlinear and primarily influenced by resident consumption spending, employee wage income, and physical capital investment. In the following sections, we use a dynamic panel threshold model for empirical research concerning these assumed correlations.

3.2. *Model specification*

3.2.1. *Specification of dynamic panel threshold model*

The conclusions of the theoretical model in the previous section indicate that the optimal scale of public health expenditure is related to resident consumption expenditure, employee wage income, and physical capital investment, which subsequently affect total economic output. Considering that economic growth is a dynamic process, the economic growth effect of public health expenditure may vary significantly for countries at different stages of development. If traditional static panel models are used for such analyses, there may be problems with significant bias and endogeneity. The panel threshold model proposed by Hansen is the most widely used estimation model [37]. The model is static and uses a fixed effects estimation method. Wang developed a Stata command called xthreg that can be used for estimating static panel threshold models, which is also the most widely used command in empirical research in China [38]. However, Hansen's model has strict requirements for covariates. They must be strongly exogenous for the estimation results to be consistent, which is difficult to achieve in many studies, particularly in research related to economic growth. Therefore, we select a dynamic panel threshold model for our estimation and analysis. The research approach of our dynamic panel threshold model primarily references Seo's paper "Estimation of dynamic panel threshold model using Stata," which was published in *The Stata Journal* in 2019 [16]. As described previously, we select resident consumption expenditure, employee wage income, and physical capital investment as threshold variables to construct a dynamic panel threshold regression model for economic growth and public health expenditure. Unlike the fixed effects analysis used in static panel threshold models, Seo used GMM for estimation. Since Seo's Stata command can only produce a single-threshold model, we do not consider the circumstances of multiple thresholds for now. The basic model specification is as equation (19):

$$G_{y_{it}} = \alpha_0 + \alpha_1 G_{y_{it-1}} + x_{it}^{'}\beta + (1, x_{it}^{'})\delta \bullet \mathbf{1}(q_{it} > \gamma) + \varepsilon_{it} \tag{19}$$

$$(\mathrm{t} = 1, \ldots, 17\ ;\ \mathrm{i} = 1, \ldots, 33)$$

In equation (19), $G_{y_{it}}$ represents the per capita GDP growth rate, which represents economic growth, and $G_{y_{it-1}}$ represents the lagged dependent variable. The function (•) is an indicator function that takes a value of 1 if the expression in parentheses is true and 0 otherwise. q_{it} is the threshold variable used to divide the sample, and the threshold variables of per capita consumption expenditure, full-time employee wage income, and material capital investment. Threshold variables are also explanatory variables, and other explanatory variables (represented by $x_{it}^{'}$) include public health expenditure, degree of economic openness, employment rate, share of agriculture, share of industry, share of services, and education capital. γ is the threshold value to be estimated. ε_{it} is a random disturbance term that follows a normal distribution with a mean of 0, a variance of 0, and a covariance of 0.

In addition, although a threshold model typically implies the existence of a discontinuous regression function $(1, x_{it}^{'})\delta = k(q_{it} - \gamma)$ indicates that there is a node instead of a jump for some values of k. This occurs when one element of x_{it} is q_{it}, the coefficient is k, and the first element of δ is $-\gamma\,\delta$. Therefore, under this restriction, equation (20) becomes a *Kink* model as follows:

$$G_{y_{it}} = \alpha_0 + \alpha_1 G_{y_{it-1}} + x_{it}^{'}\beta + k(q_{it} - \gamma) \bullet \mathbf{1}(q_{it} > \gamma) + \varepsilon_{it} \tag{20}$$

$$(\mathrm{t} = 1, \ldots, 17\ ;\ \mathrm{i} = 1, \ldots, 33)$$

In the *Kink* model, the asymptotic distribution of the GMM estimation remains valid. Considering the threshold variables used in this study and the previous theoretical analysis, it is closer to a *Kink* model, where the threshold of the threshold variables is a node rather than a jump. Therefore, the estimation primarily relies on the *Kink* model, and we use Stata 15.1 econometric software. Notably, the estimation results of the *Kink* model only provide regression coefficients for all independent variables (including the threshold variables) when the threshold variables are above the threshold. Obtaining the regression coefficients for the threshold variables that are below the threshold requires application of the non-*Kink* model. To address the potential endogeneity issue arising from the bidirectional causality between the explanatory variables and economic growth, we employ a lagged one-period approach for all explanatory variables in the empirical regression analysis.

3.2.2. Variable selection and data description

This study examines data for 33 OECD countries using panel data from 2001 to 2017. The data sources include the official OECD website and the China Economy Network Statistics Database. Considering the requirement of strong balanced panels for the estimation of dynamic panel threshold models, we handle individual missing values through mean imputation and interpolation. The variable selection is as follows.

Dependent variable: The economic growth rate (y) is measured by the per capita GDP growth rate for each OECD country, based on purchasing power parity.

Key explanatory variables: Public health expenditure (pgmed) is derived from the per capita government spending on healthcare for each OECD country, including expenses related to hospitalization, outpatient services, medication, long-term care, and health management. To further examine the threshold effect of public health expenditure on economic growth, we include public health insurance coverage as an exogenous IV for public health expenditure. Public health insurance coverage significantly affects government healthcare expenditure but does not directly impact economic growth [39], making it an appropriate IV.

Threshold variables: Based on our theoretical model analysis, this study uses per capita consumer expenditure (pc), wages (w), and physical capital investment (pk) levels as threshold variables. Per capita consumer expenditure is represented by the per capita

Table 1
Descriptive statistics of main variables.

Variables	Variable meaning	Sample number	Average value	Standard deviation	Minimum value	Maximum value
Economic growth rate (y)	Per capita GDP growth rate (%)	561	2.270	3.230	−14.81	25.12
Public health expenditure (pgmed)	Per capita government spending on healthcare (USD)	561	2287	1178	310.3	7311
Public health insurance coverage (IV)	Public health insurance coverage rate (%)	527	94.27	14.52	23.10	100
Per capita consumer expenditure (pc)	Per capita consumption expenditure (USD)	561	22,922	7158	7381	39,593
wages (w)	Salary condition (USD)	561	38,098	13,563	11,004	65,891
Physical capital investment levels (pk)	USD	561	5754	2489	1231	19,215
Economic openness (open)	Ratio of total imports and exports to GDP (%)	561	74.11	39.51	7.660	179.1
Employment rate (emp)	Employment-to-population ratio (%)	561	54.21	11.23	7.660	81.30
Percentage of children (child)	Percentage of children in the population (%)	561	17.81	3.790	13.17	33.77
Primary sector to GDP (agri)	Agricultural value added as a percentage of GDP (%)	561	5.230	3.830	1	19.24
Secondary sector to GDP (indus)	Industrial value added as a percentage of GDP (%)	561	24.81	6.100	8.510	40.52
Service sector to GDP (serve)	Services value added as a percentage of GDP (%)	561	69.96	7.990	50.43	90.34
Educational capital investment (pedu)	Capital investment in the education field (USD)	561	8064	3844	1944	19,700

Note: The continuous variables in this table are logarithmically transformed.

annual consumption expenditure for each OECD country that is measured in US dollars based on purchasing power parity. Wage levels refer to the annual average wage for full-time employees in each OECD country, using a consistent definition across countries that are measured in US dollars based on purchasing power parity. Physical capital investment levels are represented by the per capita fixed asset investment rate, calculated as the total fixed asset investment divided by the total population for each OECD country.

Control variables: Since economic growth is a macroeconomic variable that is influenced by numerous factors, this study includes per capita consumer expenditure and physical capital investment levels (from the threshold variables) as explanatory variables for economic growth. Control variables include economic openness (open); employment rate (emp); percentage of children in the population (child); contributions of primary (agri), secondary (indus), and service (serve) sectors to GDP; and educational capital investment (pedu). Economic openness is measured as the ratio of total imports and exports to GDP for each OECD country. The employment rate is calculated as the ratio of total employment to the labor force for each OECD country. The percentage of children refers to the proportion of the population below the age of 15 to the total population for each OECD country. The contribution of the primary sector is the share of agricultural output in the GDP, the contribution of the secondary sector is the share of industrial output in the GDP, and the contribution of the service sector is the share of service industry output in GDP for each OECD country. Educational capital investment is the government's expenditure on education per secondary school student for each OECD country. Table 1 presents the basic statistical descriptions of each variable.

4. Results

4.1. Analysis of dynamic threshold effects

Based on the dynamic panel threshold model detailed above, this study takes economic growth as the dependent variable using residents' consumption, workers' wage, and physical capital investment levels as threshold variables. Lagged terms of economic growth are included to control for dynamic changes and conduct empirical analysis to examine the economic growth effects of public health expenditure. Table 2 presents the results of our dynamic threshold effects tests and the estimated threshold values.

Table 2 reveals that under the impact of public health expenditure on economic growth passed the single-threshold test, with threshold values of 9.63, 10.57, and 8.73 for consumption, wage, and physical capital investment, respectively, all of which are significant at the 1% confidence level. The estimation results for other independent variables are presented in Table 3, and we employ the system GMM for analysis as a comparison.

Regarding the system GMM estimation results, the Arellano–Bond AR(1) test statistic is significant, indicating the existence of first-order autocorrelation in the disturbance term, and the Arellano–Bond AR(2) test statistic is not significant, indicating the absence of second-order autocorrelation in the disturbance term. Therefore, the hypothesis that the disturbance term is not autocorrelated is accepted, indicating that the model is appropriate. The Hansen test statistics are not significant, accepting the hypothesis that all IVs are effective. The GMM regression results in Model 1 indicate that the impact of public health expenditure on economic growth is positive and significant at a 5% confidence level.

Models 2–4 respectively estimate the threshold effects of the three variables examined in this study. The results show that when residents' consumption is below the threshold of 9.63, the effect of public health expenditure on economic growth is negative and significant at the 10% confidence level, and when residents' consumption level is above this threshold, the effect of public health expenditure on economic growth is positive and significant at the 5% confidence level. When workers' wages are below the threshold of 10.57, the effect of public health expenditure on economic growth is negative but insignificant, and when wages are above this threshold, the effect of public health expenditure on economic growth is positive and significant at the 5% confidence level. Finally, when the physical capital investment level is below the threshold of 8.73, the effect of public health expenditure on economic growth is negative and significant at the 5% confidence level, and when the physical capital investment level is above this threshold, the effect of public health expenditure on economic growth is positive and also significant at the 5% confidence level. Therefore, it can be concluded that as the residents' consumption, workers' wage, and per capita physical capital investment levels increase and reach a certain value, the positive impact of public health expenditure on economic growth strengthens.

The estimations of the remaining independent variables in models 2–4 reveal that the regression coefficients of per capita consumption level, the proportion of children, per capita physical capital investment, and industrial structure are all significantly positive within the confidence interval, indicating significant promotional effects on economic growth. In contrast, the regression coefficients of economic openness, employment rate, and educational capital investment are all significantly negative within the confidence interval, indicating significant reductions in economic growth.

Table 2
Threshold effects and threshold estimation tests.

Threshold variables	Threshold value	z-value	p-value	95% confidence interval	
Lnpc	9.63	753.4	0.000	9.604232	9.654333
Lnw	10.57	389.98	0.000	10.5156	10.62183
Lnpk	8.73	115.26	0.000	8.580868	8.877746

Table 3
The impact of public health expenditure on economic growth.

Variables		y			
		Model 1 GMM	Model 2 Threshold variable (lnpc)	Model 3 Threshold variable (lnw)	Model 4 Threshold variable (lnpk)
L.y		0.3296***	0.2379***	0.1718***	0.5225***
		(0.0284)	(0.0668)	(0.0608)	(0.1735)
lnpgmed	Below the threshold	12.7134** (4.5739)	−86.96*	−26.55	−105.99**
			(55.03)	(31.88)	(49.06)
	Above the threshold		51.48***	33.09**	25.89**
			(16.27)	(16.64)	(12.55)
open		−0.0133	−0.1672***	−0.1652***	−0.3176***
		(0.0174)	(0.237)	(0.0483)	(0.0285)
Lnpc		−24.8808***	178.47***	90.1519***	59.58***
		(5.4658)	(25.20)	(29.87)	(18.81)
Emp		−0.0635	−1.475***	−3.638***	−2.38**
		(0.0926)	(0.3591)	(0.9151)	(1.0114)
child		0.1699	10.993***	5.099*	8.614**
		(0.1127)	(2.898)	(2.885)	(3.40)
agri		10.2005**	35.13*	46.79	46.45
		(4.2250)	(21.23)	(29.85)	(29.43)
indus		10.1543**	31.19	45.13	38.78
		(4.1654)	(20.71)	(28.95)	(28.29)
serve		10.4243**	29.17	45.17	37.34
		(4.1671)	(20.78)	(28.76)	(28.56)
lnpk		−3.2845	31.30***	45.17***	56.59***
		(2.0794)	(7.33)	(8.41)	(18.90)
lnpedu1		−0.2093	−25.29***	−42.19***	−10.78
		(2.0424)	(10.655)	(8.406)	(7.408)
Constants		−8.5e + 02*	–	–	–
		(435.7508)	–	–	–
Effective sample size		528	420	420	420
Arellano–Bond AR(1) test		−3.58***	–	–	–
Arellano–Bond AR(2) test		−1.55	–	–	–
Hansen overidentification test		31.73	–	–	–

Note: *, **, and *** denote significance at 10%, 5%, and 1% confidence levels, respectively; standard deviations are in parentheses.

4.2. *Instrumental variable robustness test*

This study uses the public medical insurance system coverage rate in the 33 OECD countries as an exogenous IV for public health expenditures to address the endogeneity issue that may exist between public health expenditure and economic growth and obtain the net effect of public health expenditure on economic growth. This also serves as a robustness test of the threshold effects of public health expenditure on economic growth. Considering that there are many missing values for the coverage rate of public medical insurance systems in OECD countries before 2005, the following models are based on the panel thresholds from 2005 to 2017 for analysis, and individual missing values are determined by taking average values or using interpolation. The empirical results are presented in Tables 4 and 5.

The robustness test results in Table 4 indicate that even after using public healthcare coverage as an IV, the dynamic panel threshold model remains significant. The thresholds for the three threshold variables are significant at a 1% confidence level and are generally consistent with the thresholds in Table 2.

Table 5 reveals that in the low threshold interval of the three threshold variables, the effect of public health expenditure on economic growth is negative but insignificant; however, the effect of public health expenditure on economic growth is significant and positive in the interval above the threshold. This is consistent with the regression results in Table 3, indicating that the dynamic threshold effect of public health expenditure on economic growth is robust.

4.3. *Heterogeneity analysis*

The previous analyses examined the significant dynamic threshold effects of public health expenditure on economic growth

Table 4
Threshold effects test and threshold values estimation: IV robustness test.

Threshold variables	Threshold value	z-value	p-value	95% confidence interval	
lnpc	10.25	500.11	0.000	10.2142	10.29457
lnw	10.29	126.63	0.000	10.13294	10.45155
lnpk	8.43	53.27	0.000	8.127144	8.127144

Table 5
Results of dynamic panel threshold model parameter estimation: IV robustness test.

Variables		Model 5 Threshold variable (lnpc)	Model 6 Threshold variable (lnw)	Model 7 Threshold variable (lnpk)
L.y		0.3355***	0.3860***	0.43658***
		(0.0336)	(0.0662)	(0.0345)
lnpgmed	Below the threshold	−13.60	−20.15	−6.599
		(102.3)	(82.06)	(38.13)
	Above the threshold	7.36**	20.62**	27.35*
		(3.32)	(8.01)	(17.56)
open		−0.0027	−0.0305	−0.0395
		(0.0305)	(0.03)	(0.055)
lnpc		−87.6351***	−101.62***	−85.11**
		(13.8316)	(15.61)	(24.57)
emp		0.6873***	1.1143**	0.1564
		(0.2343)	(0.4681)	(0.3966)
child		−6.4713***	−3.897***	−8.12***
		(0.9977)	(1.2464)	(1.25)
agri		89.7424	52.12	155.5*
		(65.1609)	(51.40)	(84.21)
indus		89.3647	48.68	157.1*
		(64.9539)	(51.45)	(84.23)
serve		89.5883	49.19	156.5*
		(65.0432)	(51.61)	(84.31)
lnpk		4.4386	5.82	−14.3
		(2.9462)	(5.37)	(11.83)
lnpedu1		−5.5582*	−14.77***	−7.69
		(3.1568)	(4.66)	(4.99)
Effective sample size		319	319	319

Note: *, **, and *** denote significance at 10%, 5%, and 1% confidence levels, respectively; standard deviations are in parentheses.

Table 6
Results of public health expenditure on economic growth for different system coverage.

Variables	Model 8 ghi = 100	Model 9 ghi <100
L.y	−0.1473	0.9107**
	(0.2259)	(0.3164)
lnpgmed	26.1332**	51.5155
	(11.7847)	(39.4241)
open	−0.1743**	−0.0870
	(0.0798)	(0.1295)
lnpc	−1.1e + 02*	−1.1e + 02
	(62.8304)	(109.9164)
emp	2.3447*	0.9522
	(1.2429)	(1.3565)
child	−3.3908	5.0178
	(2.2740)	(3.4303)
Agri	31.0777**	5.3307
	(15.6258)	(5.1692)
indus	31.4559**	6.3226
	(15.2800)	(11.7033)
serve	33.2543**	8.8418
	(15.7277)	(11.3799)
lnpk	−15.7565	20.7814
	(10.5187)	(26.7067)
lnpedu1	2.0143	−31.9497
	(14.2720)	(24.1600)
Constants	−2.3e + 03	−1.0e + 02
	(1.6e + 03)	(433.0473)
Effective sample size	256	240
Arellano–Bond AR(1) test	−0.12	−1.19
Arellano–Bond AR(2) test	−1.65	1.08
Hansen overidentification test	6.91	9.73

Note: *, **, and *** denote significance at 10%, 5%, and 1% confidence levels, respectively; standard deviations are in parentheses.

defining threshold variables as per capita consumption, employee wage, and physical capital investment levels in OECD countries. Considering the variations in the coverage scope of public healthcare systems in OECD countries, the economic growth effects of public health expenditure exhibit heterogeneity, and the impact of public health expenditure on economic growth may differ between countries with full coverage public healthcare systems and those that do not have full coverage or primarily rely on private health insurance systems. Therefore, we divide the sample into countries with full public healthcare coverage (ghi = 100) and those without full coverage (ghi <100). We analyze the heterogeneity of the economic growth effects of public health expenditure using the system GMM. The sample categorization shows that 16 OECD countries had full coverage of public healthcare in 2017, while 15 countries did not achieve full coverage. Latvia and Luxembourg do not disclose data on public healthcare system coverage and are therefore excluded from the sample. Table 6 presents the GMM regression results of the economic growth effects of public health expenditure for different levels of system coverage from 2005 to 2017.

The estimation results of the system GMM, Arellano–Bond AR (1) test statistic, and Arellano–Bond AR(2) test statistic are insignificant, indicating no first-order or second-order autocorrelation in the perturbation terms, confirming the original hypothesis of no autocorrelation in the perturbation terms and the model is appropriate. The Hansen test statistic is insignificant, verifying the hypothesis that all IVs are valid. The GMM regression results in model 8 show that the effect of public health expenditure on economic growth is positive and significant at the 5% confidence level when the coverage rate of the social medical insurance system in a country is 100%. The GMM regression results in model 9 show that when the coverage rate of the social medical insurance system in a country is less than 100%, the impact of public health insurance expenditure on economic growth is positive but insignificant. Therefore, we conclude that a higher social medical insurance system coverage rate has stronger effects on economic growth.

5. Discussion

This article constructs a theoretical economic growth model and a government decision-making analysis model from the perspective of public health expenditure in OECD countries. The theoretical analysis indicates that a nonlinear relationship exists between public health expenditure and economic growth, and the optimum level of public health expenditure is influenced by residents' consumption, workers' wage, and physical capital investment levels. To verify the correctness of the theoretical model, we use panel data from 33 OECD countries from 2001 to 2017. Based on the dynamic panel threshold model, the study investigates the dynamic threshold effects of public health expenditure on economic growth by setting the consumption, wage, and physical capital investment variables as threshold variables. The empirical results indicate a significant threshold effect of public health expenditure on economic growth under the constraints of residents' consumption, workers' wage, and physical capital investment levels. Specifically, as residents' consumption increases, workers' wages rise, and per capita physical capital investment increases, and the positive impact of public health expenditure on economic growth gradually strengthen when they reach certain values. Most OECD countries' economic development has tended to mature and they have long been classified as developed countries. OECD countries' consumption, wage, and physical capital investment levels are higher than those of developing and underdeveloped countries; therefore, increasing public health expenditure is not only a requirement for maintaining a healthy population, but it is also beneficial for further promoting economic growth.

First, the effect of public health expenditure on economic growth is constrained by different external factors. Per capita consumption, the proportion of children, per capita physical capital investment level, and industrial structure have significant positive effects on economic growth. Conversely, the degree of economic openness, employment rate, and investment in education capital have significant inhibitory effects on economic growth. The final effect of public health expenditure on economic growth is significantly positive, which is consistent with the research findings of Namini [19] based on data from G7 countries, and those of Wang [17] based on provincial panel data from China. However, there is limited research on the effect of public health expenditure on economic growth in OECD countries. To address this gap, we use panel data from OECD countries from 2000 to 2017 to explore these relationships in a more comprehensive and in-depth manner. The measure of economic openness in this study is represented by the ratio of total imports and exports to GDP. If a country has a large amount of imports, it may have a negative impact on its economy, and there may be a significant negative relationship between economic openness and economic growth. According to the Phillips curve, an inverse relationship exists between unemployment rate and inflation; therefore, a higher employment rate implies a lower unemployment rate and a higher inflation rate. Studies by Fischer and Harbergerhave demonstrated the negative correlation between economic growth and inflation [40,41]; hence, the empirical results of this study further support this conclusion. Previous studies have also shown that different types of capital have different investment return periods. The effect of physical capital investment is obviously faster than human capital investment, which belongs to short-term capital return. Education is predominantly invested in using the previous generation's accumulated wealth to benefit the next generation, resulting in the longest return period [42]. Building on this research, this study finds that as a nondirect productive expenditure, education expenditure may have a negative correlation with economic growth in the short term, which aligns with the findings of Devarajan [7]. In addition, this study also confirms that the proportion of children, per capita physical capital investment level, and industrial structure have a significant positive impact on economic growth, which has received less attention from previous researchers.

Second, a significant threshold effect of public health expenditure on economic growth is found in terms of residents' consumption level. The threshold value for residents' consumption is 9.63, which is statistically significant at a 1% confidence level. When lnpc $\leq$9.63, public health expenditure has a significant negative impact on economic growth, primarily acting as a suppressor. Moreover, this suppressive effect weakens as per capita consumption level increases. When lnpc >9.63, public health expenditure has a significant positive impact on economic growth, and this promotional effect strengthens as per capita consumption level increases. This echoes the findings of Tang et al. [30] that consumer demand is the mechanism through which public health expenditure affects the quality of economic growth. Specifically, the consumption demand generated by public health expenditure can have an economic multiplier effect, amplifying the impact of health expenditure on the economy. By purchasing healthcare services and products, the government and residents promote healthcare industry development, drive the development of related industries, and foster economic growth. We employ different research methods to validate the robustness of this conclusion, providing more empirical support for research in this area.

Third, a significant threshold effect of public health expenditure on economic growth is evident concerning wage level. The threshold value for wage levels is 10.57, which is significant at a 1% confidence level. When lnw $\leq$10.57, the impact of public health expenditure on economic growth is negative but insignificant; however, when lnw $>$10.57, public health expenditure has a significant positive impact on economic growth, and this promotional effect strengthens as wage levels rise. Limited research has examined this in the past. This study determines the potential threshold effect of wage level on economic growth through a theoretical model, which is a marginal contribution of this study to the existing research.

Fourth, a significant threshold effect of public health expenditure on economic growth is evident concerning physical capital investment levels. The threshold value for physical capital investment is 8.73, which is significant at a 1% confidence level. When lnpk $\leq$8.73, the impact of public health expenditure on economic growth is significant and negative, and this impact weakens as per capita physical capital investment rises. However, when lnpk $>$8.73, public health expenditure has a significant positive impact on economic growth, and this impact strengthens as physical capital investment rises. Based on provincial-level panel data from China, Tao et al. [18] conducted a comprehensive analysis using Lasso regression and static panel threshold regression models, finding that public health expenditure has different promotional effects on economic growth when per capita fixed assets are within different intervals. Building on this, we examine OECD international panel data and improve the empirical research methodology, obtaining consistent results by employing dynamic panel threshold model analysis. The results of this study also validate the robustness of this conclusion and provide additional empirical support for related research.

Fifth, we reveal heterogeneity in the institutional coverage of the promotional effect of public health expenditure on economic growth, determining that countries with 100% public healthcare, the results of the GMM dynamic panel regression show a significant promotional effect of public health expenditure on economic growth. However, in countries where public healthcare coverage is not achieved, the economic growth effect of public healthcare systems is insignificant. Previous research has proposed that government healthcare expenditure in China exhibits an inverted U-shaped relationship with economic growth, meaning that as regional economies develop, the impact of public health expenditure on different regional economic growth has a wave-like pattern of initial increase followed by decrease [29]. Considering the limited coverage of early social healthcare systems in China and the significant differences in the coverage rates of public healthcare systems compared to most OECD countries, the different conclusions obtained in this study further validate the institutional coverage heterogeneity in the promotion of public health expenditure on economic growth.

In general, this study has reached broadly consistent research conclusions with previous scholars, revealing significant threshold effects of public health expenditure on economic growth [3,19,23,30]. However, compared with previous research, this study integrated additional innovations in research methods and applications. First, the study combines theoretical models and empirical analyses to examine the economic growth effects of public health expenditure, providing a theoretical foundation and practical basis for our research conclusions. In terms of theoretical model construction, we construct an economic growth model based on the Cobb–Douglas production function, combining Solow's neoclassical growth theory and Barro's endogenous growth theory. The results indicate that the impact of public health expenditure on economic growth is nonlinear; thus, the panel threshold model is selected as the main econometric model. Furthermore, previous research has primarily used static panel threshold models in studying economic growth; however, considering that economic growth is a dynamic process, we use the dynamic panel threshold model for our econometric research. Unlike static panel threshold models that primarily rely on fixed effects analysis, the dynamic panel threshold model is based on GMM estimation, which is more suitable for analyzing dynamic behaviors such as economic growth. Second, unlike previous studies that typically applied bootstrap resampling to obtain threshold values when using dynamic panel models and then estimate the slope coefficients in different threshold intervals using the system GMM based on the threshold parameters, we adopt the econometric method of the dynamic panel threshold model proposed by Seo and uses Stata software to analyze the threshold effects of public health expenditure on economic growth [16]. Third, previous research regarding the relationship between government health expenditure and economic growth in China has predominantly employed domestic provincial panel data for correlation analysis [25,27,34]. In contrast, this study uses international panel data combined with China's macroeconomic development data for analysis, providing a valuable reference for improving China's basic medical insurance system.

This study has some limitations. Due to the considerable number of missing values in the data published on the OECD website, we only use data from 33 countries from 2001 to 2017 to construct a balanced panel model. We hope that after the OECD data is supplemented and updated, further investigations will be conducted on the short-term, medium-to-long-term, and long-term economic growth effects of public health expenditure.

6. Conclusions and policy implications

This study finds that as the level of residents' consumption increases, employee wages rise, and per capita physical capital investment increases within certain thresholds, the positive impact of public health expenditure on economic growth gradually strengthens. This demonstrates that in an economic environment with higher levels of consumption, employee wages, and physical capital investment, public health expenditure will significantly promote economic growth. Increasing the coverage of the public healthcare system in an economic environment with higher levels of these three factors will significantly promote a country's economic growth, and this promotional effect will continue to strengthen. Therefore, China should prioritize improving the level of resident consumption and employee wages by encouraging the accelerated development of various industries to drive domestic demand and raise industry wages. China must also prioritize the construction of a basic medical insurance system, achieve full coverage, and ensure that Chinese residents have access to basic medical insurance.

The research findings have important implications for China's emphasis on the construction of the basic medical insurance system, and we propose the following policy implications. First, it is necessary to increase residents' per capita consumption level. To do so, the government should moderately increase workers' wages and improve the social security system, which will improve residents' consumption capacity and provide greater impetus for healthcare expenditure and economic growth. Second, the government and society should collectively improve the use of healthcare services. The government should strengthen the supply-side reform of healthcare services, improve the quality of medical care, and enhance the accessibility of healthcare services, which will stimulate residents' demand for healthcare services and promote increased healthcare expenditure. The government can also encourage residents to invest in and innovate healthcare to improve the level of medical technology and equipment to meet the demand for higher-level healthcare services. Third, the government should strengthen the construction of a multilevel medical security system and increase the coverage and protection of medical insurance to reduce the burden of medical expenses for residents. This will encourage people to seek medical services more actively and promote the growth of healthcare expenditure. Fourth, the government should actively promote the development of the healthcare industry and increase fixed asset investment in the healthcare sector. Providing high-quality healthcare services and medical technology can attract domestic and foreign consumers to purchase medical services, which will drive the development of related industries, promote economic growth, and increase employment opportunities.

Data availability statement

The data used in this study are available in a publicly accessible repository (OECD official website). https://stats.oecd.org/. The datasets used and analyzed in this study are available from the corresponding author upon reasonable request.

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CRediT authorship contribution statement

Qi Hu: Writing – original draft, Resources. **Lianjie Wang:** Writing – review & editing, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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