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Measuring the Contribution of Human Health Capital Using the IEPSVAR System

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Extensive and rapid economic development has brought serious threats to public health, and positive effect of human health capital on economic growth has been questioned. When calculating the GDP, the explicit cost of the resources should not be the only thing taken into account; the implicit health cost is another factor that should be considered. This paper constructs the group panel SVAR system with interaction effects to measure the contribution margin and dynamic trend of the human capital's health input in different urban and rural regions of China. The results show that the health GDP path in the eastern region is around 1.73% lower than the real path, while most contribution margin of the health input are negative in the central and western regions, and the health GDP is about 3.82% higher than the real path. The health GDP path in the rural middle region is about 2.25% lower than the real path, while the health GDP path in the western and eastern China is about 2.69% higher than the real path. Institutional changes have showed competitiveness in improving the health between urban and rural areas, especially before 2010, suggesting that the social health care system is still relatively inadequate.

Keywords: health human capital, health GDP, contribution margin, institutional evolution, group effect

1. INTRODUCTION

As one of the two forms of human capital, health is not only a basic human right, but also plays an important role in promoting economic growth [1,2]. Like equipment depreciation and material consumption, residents' health affects production and economic activities. However, due to the differences in the industrial structures, economic development levels, social cultures and social ideologies of various regions in China, there are obvious differences in the extent to which public health contributes to economic activities. Compromising health in exchange for economic growth is detrimental to people's overall well-being, and is not conducive to the long-term harmonious development of China's society. Moreover, China's economy has a typical urban-rural dual structure leading to a serious imbalance of regional development. Therefore, what kind of specific role does human health capital play in all key areas of economic activities? In terms of human health and its effects on economic development, what are the differences between urban and rural areas, and between regions? What kind of dynamic change or trend does human health capital show? An accurate understanding of these problems is essential if regional development strategies and the medical and health system are to improve.

Early studies on human health capital have mainly been conducted from a micro perspective, targeting individuals, families or manufacturers as the research objects. It has been found that human health capital influences personal income and the economy since better public health increases productivity and the labor force. Thomas & Strauss [3] examined cross-sectional data obtained from a survey of urban

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household budgets in Brazil from 1974 to 1975. They found that employees' health affects wages as it has an impact on productivity, and the extent of the impact is determined by gender, department and work type. Gannon & Nolan [4] conducted a survey of Irish laborers aged from 16 to 64 years old. They found that health issues can explain 11% of variation in labor supply.

In the literature examining the impact of health on the economy from the macro perspective, most studies included human health capital in the economic growth model to estimate the impact of human health on economic growth. Ehrlich & Lui [5] posited that human capital is the driver of economic growth, affirming the function of human health capital input as the intergenerational dependence in promoting the economic growth. Arora [6] carried out a study under the AK model framework and concluded that health's stimulation of economy was mainly actualized by improving productivity and increasing capital, and health improvements can explain 30%–40% of economic growth.

Regardless of whether the research was conducted at micro or macro level, previous studies were often conducted from the perspective of the one-way interaction of health on economic growth, ignoring the reverse: that is, the effects of economic development on people's health. There has been no systematic analysis of the interaction between health and economic growth; nor has the literature considered the effects of non-quantitative factors such as technological progress and institutional change etc. on the contribution of health.

China has a vast territory with huge differences in terms of economic growth patterns, levels of economic development, social concepts and geographical conditions in different regions (eastern, middle and western), and between urban and rural areas. As a production factor, human health capital may have different impacts on economic as differences in material capital, industrial structures and other factors will produce different ratios of elements. Therefore, studying the effects of human health capital on economy cannot be treated as the same, and neglecting its heterogeneous may lead to inaccurate results. Obviously, existing research did not analyze the within-group same effects and inter-group differential effects in different regions of China.

Given the above reasons, this paper expands the research on the contribution margin and its dynamic characteristics of the health human capital input in three aspects: (a) introducing the group testing to explore the within-group regional similarity and the inter-group regional heterogeneity by grouping urban and rural areas respectively at the provincial level, (b) measuring the unobservable technical progress and institutional change's impact on the contribution margin of health human capital input, and different individual's response to the factor, and (c) introducing the concept named health GDP, and measuring the paths of economic equilibrium growth in different regions of China under the circumstances of the non-health conflict.

This paper constructed the group panel SVAR system of interaction effects. Based on provincial urban and rural data, it measures the marginal effect and dynamic trends of human capital health input and its heterogeneity between urban and rural areas as well as in different regions, and accordingly, it further measures the path of health GDP.

2. MARGIN CONTRIBUTION OF HEALTH HUMAN CAPITAL INPUT IN ECONOMIC GROWTH

2.1 Transmission Mechanism between Health Input of Human Capital and Economic Growth

For the contribution margin of health human capital input on economic growth, the existing research have distinct conclusions.

On the one hand, much research suggest that health human capital has played a positive role in economic growth. First of all, health affects laborers' physical strength and working hours. That is to say, poorer health status lowers the labor productivity, while individual who is in better health conditions can be engaged in physical and mental work better to gain higher income[3].

On the other hand, some research indicated that health human capital did not show significant effects on economic growth, and even produced negative effects. Zon & Muysken[7] brought in production function and utility function based on Lucas's endogenous growth model in order to investigate the effect of health human capital on economic growth. A reciprocal relationship was found between health input and physical capital accumulation. When the health input exceeds the optimum level, namely health input's contribution margin is equal to the marginal cost, material capital used for real investment will be diverted, so as to restrain the economic growth. Yang[8]employed the panel SVAR model with interaction effect to study China's environment and social health costs. The empirical results show that the long-run elasticity of economic growth on medical expenditure of is negative, reflecting the resident health input caused by environmental problems will restrain the economic growth.

To sum up, the health input of human capital affects economic growth in two ways.

Firstly, as a element input of human capital, health uses health loss in exchange for the increase of labor time and labor intensity, which is playing a catalytic role in economic growth.

Secondly, health is a special kind of element input, and it also can produce inhibitory effect on economy, which is mainly embodied in two circumstances. On the one hand, when the factor allocation structure is unreasonable, such as insufficient amount of capital, the imbalance of industrial structure, and the over-reliance of economic growth on health input, excessive input in health leads to the decrease of the quality of the human capital. According to the principle of diminishing marginal utility of production factors, the unreasonable factor allocation structure offsets the positive utility brought by the health input, and thus inhibiting economic growth. On the other hand, when the regional environment is deteriorating, even if the factor allocation structure is reasonable, invalid health input caused by the environmental pollution actually produce negative effects on economic growth.

So, do Chinese residents' health human capital input on earth play a positive or negative effect on economic growth? This is the core question to answer in this paper. Given China's urban-rural dual structure and the imbalance of regional development, this study conducts grouping test urban and rural areas respectively to reveal the common characteristics as well as the heterogeneity of different regions.

2.2 The Setting of the Measuring System

We extended and improved the existing model, and sets up the dynamic multi-equation system for quantitatively measuring the relationship between health input and economic growth on the basis of relevant research literature. In essence, the health human capital input is a kind of factor input of economic activities. As a result, the relationship can be described by Cobb-Douglas production function [9,10]. Considering the multiple individuals (areas), the equation can be specified as.

$$Y_{it} = A_{it} K_{it}^{\alpha_i} L_{it}^{\beta_i},\ i = 1, 2, \ldots, N,\ t = 1, 2, \ldots, T \quad (1)$$

where Y_{it} is income, A_{it} is knowledge accumulation and technological progress, K_{it} is per capita capital and L_{it} is per capita labor input. α is the elasticity of capital to economic growth, and β is elasticity of economic growth to labor input.

Employment normally is employed to reflect labor input in existing literature. When studying health human capital, due to the health loss can redeem labor time and improve the amount of labor, thus

$$L_{it}^{\beta_i} = H_{it}^{\gamma_i} e^{u_{it}} \quad (2)$$

where H_{it} represents per capita health human capital input. u_{it} denotes other factors influencing the human capital, such as the institutional factors f_{1t} influencing residents' health level. All individuals' reaction sensitivity are different in the face of the same f_{1t}. u_{it} can be represented as

$$u_{it} = \lambda_{1i} f_{1t} + \varepsilon_{1it} \quad (3)$$

where ε_{1it} is the pure random factors. Model (1) is converted into an equation through the logarithmic linearization.

$$y_{it} = \ln A_{it} + \alpha_i k_{it} + \gamma_i h_{it} + \lambda_{1i} f_{1t} + \varepsilon_{1it} \quad (4)$$

where $y_{it} = \ln Y_{it}$, $k_{it} = \ln\ K_{it}$ and $h_{it} = \ln H_{it}$.

Technological progress factor $\ln A_{it}$ can be decomposed into three parts, a) measurable part, like upgrading the industrial structure (x_{it}), b) unmeasurable common environmental factors, like social and cultural level and institution improvement (f_{2t}), this kind of common factor may have heterogeneous effect (λ_{2i}) on different individuals, and c) unmeasurable individual environmental factors such as special resources, historical background and geographical location (μ_i) and so on. Thereout

$$\ln A_{it} = \gamma x_{it} + \lambda_{2i} f_{2t} + \mu_i + \varepsilon_{2it} \quad (5)$$

Where ε_{2it} is the pure random factor.

Considering the free flow of capital, the elasticity of different individuals' income to capital should be equal, namely $\alpha_i = \alpha$. Given the difference of economic behavior, different individuals' health input may have various benefits. Therefore, γ_i is heterogeneous, reflecting the corresponding income heterogeneity of the health human capital input. Besides, as the health human capital input may either promote or prohibit the economic growth, thus γ_i can be positive or negative.

Due to the common factors f_{1t} and f_{2t} both are not quantitative; it can be expressed as $\lambda_i f_t = \lambda_{1i} f_{1t} + \lambda_{2i} f_{2t}$. Similarly, $\varepsilon_{it} = \varepsilon_{1it} + \varepsilon_{2it}$. So, model (4) can be equivalently expressed as

$$y_{it} = \delta x_{it} + \alpha k_{it} + \gamma_i h_{it} + \lambda_i f_t + \mu_i + \varepsilon_{it} \quad (6)$$

Model (6) is a static single equation model, which cannot reflect the continuity and increasing property of individual health input[11], also cannot reflect the dynamic feedback mechanism among variables with the system. If the feedback mechanism among variables in the economic system is ignored, endogenous bias problem may happen, resulting unreliable estimated results [8]. Therefore, this paper constructs a panel data VAR structure system based on model (6) for the purpose of eliminating endogenous bias.

In order to express visually, here it views the heterogeneous elastic γ_i of different individual's economic growth to health input as homogeneous. Then how to process and grouping test the heterogeneity coefficient will be concretely discussed in the following part of this paper. Gives

$$BZ_{it} = \sum_{l=1}^{p} \phi_i Z_{i,t-1} + \Lambda_i F_t + \mu_i = \vartheta_{it} \quad (7)$$

where Z_{it} is the vector composed by four endogenous variables (x, k, h, y) in model (6). F_t is the vector composed by the common factor of each endogenous variable in period t. Λ_i represents the load vector of the common factor, reflecting the sensitivity of different individual i to the common factors. B is the matrix reflecting the homochromous relationship among variables. The parameter ϕ_l is the long-term correlation between the endogenous variables themselves and one another. Therefore, the structural impact among endogenous variables neither exist homochromous correlation nor long-term correlation. The variance-covariance matrix of ϑ_{it} is a diagonal matrix, which is denoted with Σ.

This paper aims at studying the health's impact on economic growth under the condition of unchanged medical health, thus the exogenous variable, neonatal mortality rate, is joined [12]. The World Health Organization (WHO) health survey data found that the neonatal mortality rate can better reflect the medical technology level. The equation after controlling the medical technology is written as

$$BZ_{it} = \sum_{l=1}^{p} \phi_l Z_{i,t-1} + \pi d_t + \Lambda_i F_t + \mu_i + \vartheta_{it} \quad (8)$$

where d is the neonatal mortality rate. The structural equation in equation (8) cannot be directly estimated. Its corresponding induction equation is

$$Z_{it} = \sum_{l=1}^{p} \Pi_l Z_{i,t-1} + \omega d_t + S_i f_t + b_i = \epsilon_{it} \quad (9)$$

where $\Pi_l = B^{-1}\phi_l, \omega = B^{-1}\pi, S_i = B^{-1}\Lambda_i, b_i = B^{-1}\mu_i, \epsilon_{it} = B^{-1}\vartheta_{it}$. As the induction coefficient does not reflect the spot relationship among the endogenous variables. Thus, the induced shock ϵ_{it} is correlated with each other, and its variance covariance matrix is be represented by Ω.

2.3 Health GDP Estimation

The variables in order to better describe each variable's impact on economic growth, we put the model into the panel structure VMA form.

$$z_{it} = c_i + \Psi_i f_t + W d_t + \sum_{p=0}^{\infty} \Theta_p \vartheta_{i,t-p} \quad (10)$$

$$= c_i + \sum_{p=0}^{\infty} \zeta_p d_{t-p} + \sum_{p=0}^{\infty} \Psi_{ip} \begin{pmatrix} f_{t-p}^x \\ f_{t-p}^k \\ f_{t-p}^h \\ f_{t-p}^y \end{pmatrix} + \sum_{p=0}^{\infty} \begin{pmatrix} \theta_{11p} & \theta_{12p} & \theta_{13p} & \theta_{14p} \\ \theta_{21p} & \theta_{22p} & \theta_{23p} & \theta_{24p} \\ \theta_{31p} & \theta_{32p} & \theta_{33p} & \theta_{34p} \\ \theta_{41p} & \theta_{42p} & \theta_{43p} & \theta_{44p} \end{pmatrix} \begin{pmatrix} \vartheta_{i,t-p}^x \\ \vartheta_{i,t-p}^k \\ \vartheta_{i,t-p}^h \\ \vartheta_{i,t-p}^y \end{pmatrix} \quad (11)$$

Where $c_i = \phi(1)^{-1} b_i$, $\Theta_p = \left(\sum_{j=1}^{p} \left(\Pi_j \phi_{p-j}\right)\right)$, $\Theta(L) = \sum_{p=0}^{\infty} \Theta_p L^p = \phi(L)^{-1} B^{-1}$, $\Theta(1) = \sum_{p=0}^{\infty} \Theta_p = \phi(1)^{-1} B^{-1}$. $\Theta(1)$ is the accumulative effect of each endogenous variable impact. $\sum_{p=0}^{\infty} \Psi_{ip}$ is the common factors' gross effect to province i, and Λ_i is its immediate effects.

The fourth equation in model (10) is the SMA form of economic growth, which can clearly reflect the dynamic effect of each variable's structured impact on economic growth. It can be expressed as

$$\begin{aligned} y_{it} = c_{i4} &+ \sum_{p=0}^{\infty} \Psi_{ip} f_{t-p}^y + \sum_{p=0}^{\infty} \theta_{41p} \vartheta_{i,t-p}^x \\ &+ \sum_{p=0}^{\infty} \theta_{42p} \vartheta_{i,t-p}^k + \sum_{p=0}^{\infty} \theta_{43p} \vartheta_{i,t-p}^h \\ &+ \sum_{p=0}^{\infty} \theta_{44p} \vartheta_{i,t-p}^y + \sum_{p=0}^{\infty} \zeta_{4p} d_{t-p} \end{aligned} \quad (12)$$

In equation (11), the following variables from left to right are respectively the cumulative effect of individual effect, the interaction effect between the common factors and individuals, the impact of industrial structure, capital, and health human capital input, inertial impact and the neonatal mortality rate on economic growth. Due to the endogenous shocks are mutually orthogonal and standardized, equation (11) shows the various concrete contribution of each impact source to economic growth, which accurately measuring the health human capital input and the dynamic mechanism of economic growth.

$\sum_{p=0}^{\infty} \theta_{41p}, \sum_{p=0}^{\infty} \theta_{42p}, \sum_{p=0}^{\infty} \theta_{43p}, \sum_{p=0}^{\infty} \theta_{44p}$ are the long-term effects of industrial structure impact, capital impact, the health impact of human capital and the inertial impact of economic growth. Correspondingly, $\theta_{41p}, \theta_{42p}, \theta_{43p}, \theta_{44p}$ are the dynamic responses of the lag p phase respectively. If the endogenous variables are stationary, the impulse response Θ_p will converge to zero, and the cumulative effect function $\Theta(1)$ will tend to be stable.

In statistical sense, we define the health GDP as the GDP value after eliminating the health input impact of the human capital[1]. Hereby, the proportion of economic growth brought by the health human capital input to income can be measured. As $\sum_{p=0}^{\infty} \theta_{43p}$ indicated the long-term effects of the health input on economic growth, and $\Sigma_{p=0}^{\infty} \theta_{43p} h_{i,t-p}$ denotes the per capita GDP increased by the health input lagged p period. So the human capital's health input cost of economic growth can be represented as

$$health_{it} = \frac{\sum_p (\theta_{43p} h_{i,t-p})}{y_{it}} \quad (13)$$

The greatest advantage of this method is to avoid subjective pricing towards residents' health loss, thus avoiding the arbitrariness of the calculation results because of the pricing factor, ensuring the objectivity of the healthy GDP results.

2.4 Group Testing of Marginal Effect of Health Input of Human Capital

When conducting the group testing of the marginal effect of the human capital's health input, the fourth equation in model (9) is extracted, and the coefficient of health input variable in the equation is turned heterogeneous. That is

$$\begin{aligned} y_{it} = \varphi_0 + \varphi_1 y_{i,t-1} + \varphi_2 x_{i,t-1} + \varphi_3 k_{i,t-1} + \varphi_4 d_t \\ + \varphi_{5i} h_{i,t-1} + g_i f_t + v_i + \xi_{it} \end{aligned} \quad (14)$$

where g_i is the factor loading coefficient for each region, v_i is the individual effects, φ_{5i} is the heterogeneous effect of different individuals' (provinces) health human capital input on economic growth, and ξ_{it} is the random error term.

According to the estimation method by Yang *et al.* [10], we can get $\varphi_{5i}, \varphi_0, \varphi_1, \varphi_2, \varphi_3, \varphi_4, g_i f_t$ and v_i through the estimation of equation (13). Sorting different provinces according to the arrangement of the value φ_{5i} in an ascending order of the ranks.

Assuming $r_{it} = y_{it} - \hat{\varphi}_0 - \hat{\varphi}_1 y_{i,t-1} - \hat{\varphi}_2 x_{i,t-1} - \hat{\varphi}_3 k_{i,t-1} - \hat{\varphi}_4 d_t - \hat{g}_i \hat{f}_t - \hat{v}_t$, the constraint model is given

$$r_{it} = \varphi_5 h_{i,t-1} + \xi_{rit} \quad (15)$$

Then, we first divide the individuals into two groups, setting $l = 1 \sim (N-1)$, $O = 1 \sim l$, $P = (l+1) \sim N$, O and P respectively represent the individual serial number contained in group 1 and group 2 with different l, and the elasticity

[1] In the economic sense, health GDP means the GDP level after eliminating the contribution margin of health human capital input.

of economic growth to the health loss of human capital in each group is homogeneous, namely $\tau_1 = \varphi_{51} = \varphi_{52} = \cdots = \varphi_{5l}$, $\tau_2 = \varphi_{5(l+1)} = \varphi_{5(l+2)} = \cdots = \varphi_{5N}$. Equation (14) is transferred into a semi constrained model (inter-group homogeneity and intra-group heterogeneity), showed as followed

$$r_{it} = \left[\tau_1 h_{O,t-1}, \tau_2 h_{P,t-1}\right] + \xi_{urit} \tag{16}$$

RSS can be estimated with LSDV method through model (14) and (15). The value of l ranges from 1 to $N-1$, and correspondingly $N-1$ sets of RSS value can be obtained. *SupF* therefore can be calculated as

$$SupF = \max_{l \in [1, N-1]} F_1 \tag{17}$$

where $F_l = \frac{(RSS_{rit} - RSS_{urit})/q}{RSS_{urit}/(n-k)} \sim F(q, n-k)$, RSS_{rit} and RSS_{urit} are from equation(14) and (15) respectively. q is the number of constraints for the constrained model, and $q = 2^2$, which means that, at the moment, the differences between the constrained model and semi constrained model is the largest, this paper therefore temporarily divides from here into two groups. Assuming the first group is individual $1 \sim M$, and the second group is individual $(M+1) \sim M$. Then it continues to grouping with the same method described above to individual $1 \sim M$ and $(M+1) \sim N$. All the calculated F-statistics are less than the given critical value regardless of where to divide the intra-group individual of each group into two groups until the end of the grouping.

3. SYSTEM ESTIMATION, IDENTIFICATION AND SAMPLE DATA

3.1 Estimation of IEPSVAR System

Existing SVAR and PSVAR estimation methods cannot realize the estimation of the Interaction Effect Panel Structural Vector Autoregressive model (IEPSVAR). This paper conducts GMM and iterative estimation of principal component analysis based on Bai[13]'s thought.

The basic idea is, firstly ignoring the common factors, employing the Generalized Method of Moments (GMM) estimation to obtain the initial value model coefficients, then the principal component analysis is carried out on the residual to get the common factors and load coefficient estimates. Secondly, defining the projection matrix to eliminate the common factor, and turning the model into PSVAR model. Using GMM method to estimate the residual, and employing the principal component analysis to analyze the residuals, thus the induced parameter estimators $\hat{\Pi}_L$, $\hat{\omega}$, $\hat{S}_i$ and the common factor $\hat{f}_t$ can be obtained by iterating to convergence.

According to the corresponding relationship between the induced errors and structure errors $\in_{it} = \mathrm{B}^{-1}\vartheta_{it}$, and its variance matrixes Σ and Ω have following relations

$$\Omega = B^{-1}\Sigma B^{-1} \tag{18}$$

[2] In order to keep the mean of the covariance to be zero and the F-statistics' theoretical distribution, the intercept term is added into equation (14) and (15).

Immediate parameter matrix B has 16 unknown parameters, and Σ has 4 unknown parameters, but there are only 10 induced parameter estimation in $\hat{\Omega}$. We cannot estimate B and Σ through equation (17) if the constraints are not imposed. First of all, Σ should be set as the unit matrix, which means to make the random shock standardized, and its dimension is set to be one standard deviation. At this time, 6 constraints also need to be applied to make the model exactly to be identified.

3.2 Identification of IEPSVAR System

3.2.1 Current Effects of Capital Stock, Health Human Capital Input, and Income on Industrial Structure

First of all, current capital input will not have an immediate effect on the current industrial structure, but affect the industrial structure in the lag phase. Second, capital accumulation can promote technical progress. Enterprises adjust its competition strategies in the market by imitating and learning the advanced technology, and gradually formed a new industrial structure. While the process takes time to complete, there exits lag effect of the adjustment of capital on industrial structure[14]. The two aspects all indicate that capital stoke does not affect the current industrial structure, namely, $b_{12} = 0$ exists in the current parameter matrix B.

The relationship between the health human capital input and the industrial structure are linked mainly through economic growth. Schultz [1] argues that the improvement of health level promotes the population growth, which increases the amount of future human resources. And labor nutritional supplement and housing conditions improvement etc., also improve the quality of human resources, providing a driving force for industrial structure upgrading. But the cultivation process of healthy human capital is slow, which cannot directly bring rapid impact on industrial structure adjustment. Thereby, we can get $b_{13} = 0$.

The gross economic growth will promote the industrial structure changes, and timely industrial structure adjustment drives the economy to achieve new increase, and thus the industrial structure must adapt to the current economic development level. Economic growth breaks the original equilibrium when the economy grows to a certain degree, which inevitably leading to corresponding changes in industrial structure [15]. The industrial structure change caused by economic growth is a gradual process, which cannot be achieved overnight. Hence, we believe that economic growth has no impact on the industrial structure adjustment in the current, that is $b_{14} = 0$.

3.2.2 Current Effects of Health Human Capital Input, Economic Growth on Capital Stock

In the process of economic development, as a result of personal input in health has continuity in time, the health human capital stock will increase. So when the aggregate input is fixed, the health human capital input can produce crowding out effect on physical capital accumulation [7]. But changes in the health level directly affect human capital rather the capital stock of the current period. Therefore, $b_{23} = 0$.

Economic growth is income growth, and the saving rate is proportional to the economic growth rate in the steady growth of economy [16]. The income growth in the current period will increase the saving in the next period, which rises the capital supply. When the supply exceeds the demand, capital market interest rate falls, the investment cost reduces correspondingly, and stimulates the growth of the investment demand. Thus increasing the investment in the next period, the capital stock will change accordingly, but has no effect on the current capital stock, so $b_24 = 0$.

3.2.3 Current Effects of Economic Growth on Health Human Capital Input

Although the rapid economic growth has provided the necessary financial support for increasing residents' health input and improving the quality of people's material life, the high intensive work pressure also increases the likelihood of contracting some diseases, which, on the contrary, is bad for residents' health[8]. The impact of economic growth on health is a long and slow process, so it can be assumed that the economic growth has no effect on the current human capital input in health, as reflected in the model $b_{34} = 0$.

3.3 Group Testing Model Estimation

In the estimation of model (13), first of all, the common factor f_t and factor loading coefficient g_i is ignored, and all coefficients are as heterogeneous, that is

$$y_{it} = \varphi_{0i} + \varphi_{1i} y_{i,t-1} + \varphi_{2i} x_{i,t-1} + \varphi_{3i} k_{i,t-1} + \varphi_{4i} d_t + \varphi_{5i} h_{i,t-1} + v_i + \xi_{it} \tag{19}$$

The initial value of health input coefficient $\tilde{\varphi}_{5i}$ can be calculated through equation (18) with the time series estimation method. Then, we assume that only the health input coefficient is heterogeneous, the other coefficients are homogeneous, and model can be transferred as

$$y_{it} - \tilde{\varphi}_{5i} h_{i,t-1} = \varphi_0 + \varphi_1 y_{i,t-1} + \varphi_2 x_{i,t-1} + \varphi_3 k_{i,t-1} + \varphi_4 d_t + v_i + \xi_{it} \tag{20}$$

Level or system GMM method cannot be directly adopted to estimate equation (19) as the dependent variable at this moment differs from the original dependent variable y_{it} and $y_{i,t-1}$ is no longer the lag value of the dependent variable at this time. However, as a special kind of GMM method, Two-stage Least Squares (2SLS) regression can be used to get the consistent estimators of model (19). The initial values of f_t and g_i can be obtained by carrying out the principal component analysis on the residual error ξ_{it} after working out the initial values as well as the residual errors of each coefficient. Further, all the coefficients in equation (13) can be estimated using the iterative estimation method mentioned above, and the group testing is accomplished.

3.4 Sample Data and Variable Declaration

This article selects the annual data of 29 provinces and municipalities in China from 2001 to 2018 as the research sample. Tibet Autonomous Region and Chongqing municipality are excluded because of the data availability. Sample data are collected from *China City Statistical Yearbook* and *China Statistical Yearbook.*

Quantifiable technical progress (*x*) The industrial structure index is used as the proxy indicator of the quantifiable technology progress, which are represented by the proportion of Urban tertiary industry and rural tertiary industry respectively. Compared with the primary industry, the proportion of the secondary industry and the tertiary industry to GDP in our country currently are high, but the industrial wastes emissions, including the exhaust gas,waste water and solid wastes, have brought great pressure on the environment, which have obvious effects on residents' health[17]. On the contrary, the tertiary industry has little effects on residents' health. Besides, the tertiary industry contains the high-tech industries, which is able to better reflect the quantifiable technological progress level.

Capital (*k*) It can be measured by the per capita capital stock through the formula $K_{it} = K_{i,t-1}(1 - \rho_{it}) + I_{it}$, where K_{it} is the current capital stock, $K_{i,t-1}$ stands for the capital stock in the last period, ρ_{it} represents the depreciation rate that is normally set as 9.6%, I_{it} denotes the current gross fixed asset investment. This paper chooses the year of 2000 as the base year to deflate the fix assets investment. As the urban and rural stock of capital data in the base year are not available, the urban stock of capital in the base year in this paper is calculated by the stock of capital of each province in the base year times the ratio of the province's urban GDP to gross GDP. So does the the rural stock of capital in the base year. Finally, per capita human stock of capital is measured by dividing by the population.

Health human capital input (*h*) Because the health input is embodied in the cost of seeing doctors, seeking medical care, spending on medical products and improving nutrition [12]. This paper adopts urban and rural per capita health care expenditure as the proxy indicator of the health the human capital input h and deflated by the fixed base price index in 2000. It is important to note that the health care expenditure actually contain two forms, namely the medical expenses for disease and the preventive health care input caused by improved health consciousness. The health expenditure in this paper mainly refers to the former. But the problem is that the second kind of expenditure cannot be directly separated out from the existing statistical data. However, the health-conscious change has the characteristic of social group. It is a common factor for individuals. So the health consciousness effect is included in the common factor f_t. In this paper, the introduction of the common factor f_t, in fact, is equivalent to only regressing the remaining items after removing the effects of f_t in all variables, which is the basic property of the partialling effect of multiple regression. Therefore, the introduction of the factor f_t is helpful to separating the effects of preventive health care expenditure determined by the health consciousness out from the medical care expenditure, and the

Table 1 Group Testing Results in Urban Areas.

Group 1	Guizhou, Qinghai, Gansu, Guangxi, Shanxi, Heilongjiang, Ningxia
Group 2	Jilin, Henan, Anhui, Jiangxi, Liaoning, Hebei, Yunnan, Xinjiang, Inner Mongolia, Hubei
Group 3	Shanghai, Beijing, Jiangsu, Tianjin, Hunan, Sichuan, Zhejiang, Fujian, Shandong, Hainan, Shaanxi[3], Guangdong

Table 2 Cumulative Effect of Health Human Capital Input's Impact on Income in Urban Areas[4].

Variable Impact	Group 1	Group 2	Group 3
Health Input's Impact of Human Capital	−0.398	−0.196	0.053
	(−5.234)	(−3.538)	(5.471)

partialling effect of this variable is actually the marginal effect of the health care expenditure.

Income level (*y*) It is measured by urban per capita disposable income (per capita net income represents rural residents' income level), using 2000 as the base year to deflate.

Neonatal mortality rate (*d*) It is measured by urban and rural neonatal mortality rate.

In order to directly measuring the elasticity among variables, capital stock, human capital input in health, income level three variables are taken the natural logarithm. Before modeling, the stationarity test is performed in order to avoiding the emergence of spurious regression, the panel unit root test shows that the four variables $(x_{it}, k_{it}, h_{it}, y_{it})$ are stationary[3].

4. RESULTS ESTIMATION AND DISCUSSION

4.1 Contribution Margin of Health Human Capital Input in Urban Areas

4.1.1 Dynamic Response Mechanism of Economic growth on Health Human Capital Input

Based on the group testing described earlier, the urban areas of 29 provinces and municipalities can be divided into three groups (see tab. 1) under the 1% significant level. Obviously, group 1 and 2 mainly contain the Midwest provinces, such as Jiangxi, Henan, Anhui, Guangxi, Yunnan and Qinghai, etc. While the eastern regions are mostly classified as group 3, such as Beijing, Shanghai, Guangdong and so on.

The line 4 of Θ_p in equation (10) reflects the cumulative effect of each endogenous variable on one standard deviation impact of economic growth, dividing the estimates of the cumulative effect by the standard deviation of corresponding variable's structural random impact to measure the accumulative effect of one unit impact. The specific results are shown in table 2.

The accumulative effect of the health human capital input of group 1 and 2 contained more central and western provinces are −0.398 and −0.196 respectively, suggesting that the health human capital input in these regions actually hold back the economic growth.

This is due to the fact that the less occupancy volume of physical capital, unreasonable industrial structure, imbalance production factors ratio and insufficient input of other factors in the Midwestern urban regions result in relatively excessive residents' health input, and the marginal effect continues to decrease and eventually become negative.

First of all, due to the lack of capital formation, the economic development of the central and western regions has been strongly constrained by capital sources. Secondly, the central and western regions were deeply influenced by the planned economy system in the past developing process, which the industrial structure need to be upgraded and adjusted comprehensively. The lack of physical capital and unreasonable industrial structure leading to the economic growth in these areas rely too much on the health input of the human capital, while the health input is restricted by other factors, which cannot promote economic growth, and even impede the economic development.

The accumulation effect of health human capital impact on income in group 3 is 0.053, suggesting that the health human capital input in these regions promote the economic growth.

Due to geographical advantages with the adoption of China's reform and opening-up policy for a long time, China's eastern urban areas have formed regional resources agglomeration effect. In the aspect of economic development structure, the tertiary industry are dominant in the eastern urban areas, and the industrial structure upgrading and adjustment have been basically completed. Adequate physical capital and industrial structure optimization and upgrading have made the factors allocation more reasonable in the eastern urban areas. With the economic foundation, the health the human capital input can play a certain role in promoting the economy.

4.1.2 Cost Analysis of Health Human Capital Input

The health GDP in this paper is defined as the GDP level eliminating the contribution margin of residents' health input, and the gap between the GDP and the health GDP reflects the health input costs of human capital. Based on equation (12), the proportion of corresponding GDP of health input impact

[3]Unit root test for endogenous variables (p values are showed in the brackets/bracketed values are p values)

Variable	*str*	*cap*	*med*	*inc*
Urban data	−5.0298	−4.1532	−8.7583	−8.6348
LLC Test	(0.0000)	(0.0019)	(0.0001)	(0.0000)
Rural data	−2.8953	−6.2596	−5.5727	−6.2109
LLC Test	(0.0026)	(0.0000)	(0.0001)	(0.0000)

[4]The t statistical value in the brackets are obtained by bootstrapping for 300 times, the same below.

Table 3 The proportion of health human capital input in GDP in urban regional provinces.

Group 1		Group 2		Group 3	
Guizhou	−7.34%	Jilin	−3.55%	Shanghai	0.87%
Qinghai	−6.88%	Henan	−3.31%	Beijing	1.03%
Gansu	−6.46%	Anhui	−3.18%	Jiangsu	1.32%
Guangxi	−5.79%	Jiangxi	−2.97%	Tianjin	1.47%
Shanxi	−5.33%	Liaoning	−2.66%	Hunan	1.59%
Heilongjiang	−4.78%	Hebei	−2.25%	Sichuan	1.65%
Ningxia	−4.26%	Yunnan	−1.88%	Zhejiang	1.72%
		Xinjiang	−1.85%	Fujian	1.95%
		Inner Mongolia	−1.60%	Shandong	2.14%
		Hubei	−0.83%	Hainan	2.22%
				Shaanxi	2.35%
				Guangdong	2.46%

Table 4 Group testing results in rural areas.

Group 1	Gansu, Shanxi, Qinghai, Jiangsu, Zhejiang, Shanghai
Group 2	Guangdong, Shandong, Fujian, Beijing, Ningxia, Hainan, Hebei, Guangxi, Xinjiang
Group 3	Hunan, Heilongjiang, Liaoning, Henan, Hubei, Jiangxi, Inner Mongolia, Sichuan, Jilin
Group 4	Guizhou, Anhui, Shaanxi, Yunnan, Tianjin

Table 5 Cumulative effect of human health capital input on income in rural areas

Impact variables	Group 1	Group 2	Group 3	Group 4
Health input impact of human capital	−0.078	−0.043	0.029	0.076
	(−4.975)	(−3.788)	(2.562)	(6.351)

to the real GDP are used to measure the gap between the GDP and the real GDP, the average from 2009 to 2018 reflects the ratio of gross health input to GDP level, and the results are shown in table 3.

In terms of group 1 and 2 contained more central and western provinces, the health the human capital input holds back economic progress. If these areas increase physical capital investment, optimize the industrial structure, and do not at the expense of residents' health as the cost of economic development, the GDP can rise 4.3%–7.3%, 0.8%–3.6% respectively from the point of view of the long-term equilibrium. For group 3 contained most eastern provinces, residents' health costs of per capita GDP are around 0.9%–2.5%. From another perspective, the gross economy will decrease in proportion if there is no health human capital input, which is not reasonable to measuring the income level with per capita GDP ignoring residents' health loss.

4.2 Contribution Margin of Health Human Capital Input in Rural Areas

4.2.1 Dynamic Response Mechanism of Economic growth on Health Human Capital Input

The rural areas can be divided into 4 groups by provinces with the same grouping method of urban areas, as seen in table 4. Group 1 and group 2 are mostly western and eastern provinces, and group 3 and 4 are mainly the provinces in the middle of China.

Table 5 is the cumulative effects of human capital health input on economic growth in the rural areas. The cumulative effect of one unit health input impact of human capital on income in group 1 and 2 are negative, and in group 3 and 4 are positive, which indicate that health human capital loss in the eastern and western rural regions are actually hinder the economic growth, while the residents' health input in the central rural regions promote the economic growth.

The industrial structure in the western rural areas is single and aging, the industry has just started, and the service industry is even not yet in its infancy, along with the ambiguous delimitation of property rights of the existing agricultural management system, farmers lack the enthusiasm of farming and investment. The capital investment in the western rural areas is gravely insufficient, and the human capital health input are relatively surplus, resulting in the marginal effect of the health input is negative.

The economy has been on a rapid growth trajectory in eastern rural regions in recent years, but this kind of growth is at the cost of consuming the scarce natural resources and polluting the ecological environment, which will not be able to achieve sustainable development. Therefore, unlike the western rural areas, the negative effects of the health loss in the eastern rural regions not only have the problem of excessive input of human capital, but also the invalid health loss caused by environmental pollution.

The rural areas in the middle of China have been a major agricultural areas and important commodity grain base. In recent years, the central rural areas focus on developing agricultural circular economy and agricultural

Table 6 The percentage of health human capital input in GDP in rural provinces (Unit: %).

Group 1		Group 2		Group 3		Group 4	
Gansu	−5.34	Guangdong	−2.15	Hunan	0.74	Guizhou	3.44
Shanxi	−4.69	Shandong	−2.08	Heilongjiang	0.68	Anhui	3.58
Qinghai	−4.33	Fujian	−2.01	Liaoning	0.93	Shaanxi	3.70
Jiangsu	−4.17	Beijing	−1.76	Henan	1.25	Yunnan	3.91
Zhejiang	−3.78	Ningxia	−1.73	Hubei	1.44	Tianjin	4.15
Shanghai	−3.66	Hainan	−1.52	Jiangxi	1.59		
		Hebei	−1.33	Inner Mongolia	1.72		
		Guangxi	−1.19	Sichuan	2.06		
		Xinjiang	−0.64	Jilin	2.27		

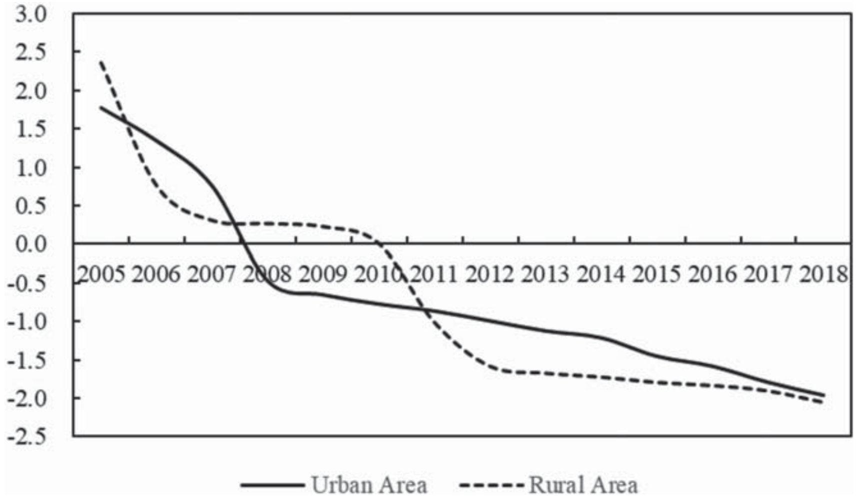

Figure 1 Dynamic changing trend of institutional factor dominating health human capital input.

products intensive processing industry, actively promoting the production and quality of the agricultural products, increasing the agricultural economic benefit, and providing material basis for economic development, which have achieved remarkable success. Therefore, as a result of the upgrading and optimization of the first industry as well as the general equilibrium of the factor allocation, the labor input and corresponding health input play a positive effect on the economic growth.

4.2.2 Cost Analysis of Health Human Capital Input

Table 6 shows the average for 10 years of data by region of the amount of corresponding GDP of the health impact on the real GDP in rural areas from 2009 to 2018.

Groups 1 and 2 mainly comprise western and eastern provinces, the health input cost of the human capital is about −5.3% – −0.6%. The health GDP path in the east and west are higher than the real path. However, in order to achieve a potential development path, it is necessary to expand the fixed assets input in the western rural areas, while the eastern rural areas need to focus on environmental improvement.

Groups 3 and 4 mainly consist of provinces in the central region, where the marginal effect of h human health capital input is positive, contributing to the local economy growth by 0.7%–4.2%.

4.3 Response characteristic and regional discrepancy of health human capital input on non-quantification factors

f_t^{med} represents the impact of non-quantitative technological and institutional factors on different regions in addition to the industrial structure, capital stock, economic growth, and its inertia and other quantitative factors, capturing the variation trend due to technological progress and institutional change and their impact on the contribution of human health capital.

In order to reflect the main characteristics of the non-quantitative technical and institutional factors' impact on the variation trend, this paper extracts only the maximum common factor of the eigenvalue. According to the results of the principal component analysis, the corresponding f_t^{med} of the maximum eigenvalue in the urban and rural regions can explain 98% and 96% changes of regional health input common factors respectively. This factor basically captures the principal trend features of the regional human capital health input changes impacted by the common institutional and policy trends. Figure 1 shows the estimates of the dynamic change trends of the health human capital input decided by the non-quantitative institutional factors.

The estimated results of the common factors in Figure 1 show that technological and institutional factors continue to improve public health in the urban areas after removing the impact of the quantitative economic factors such as economic growth and industrial structural improvements since 2005.

However, the trend in the rural areas is obviously different from that of the urban areas. In particular, technological and institutional factors significantly improved the health of rural residents from 2005 to 2007. However, this trend remained at a standstill from 2007 to 2010. Since 2010, the technical and institutional factors have again decreased residents' health input, which may due to the reform of the rural medical system.

Importantly, the estimated results of common factors show that the institutional factor appears to be less important to improving social health in the urban regions, while the institutional factors' effect on the improvement of the rural social health is more apparent. Conversely, when the common factors in urban areas decrease quickly, the common factors in rural areas fall relatively slowly. The estimated results of the common factors, therefore, provide us with a very meaningful conclusion: the positive role played by the institutional factors in social health is significantly different between the urban and rural areas.

5. CONCLUSION

For some time, China's extensive and rapid economic development has placed huge pressure on residents' health as well as on the resources and environment. When calculating the GDP, the explicit cost of the resources should not be the only thing to consider; the implicit cost of people's health should also be taken into account.

This paper constructs a group panel structural VAR system containing a non-quantitative interaction effect based on Chinese provincial panel data from 2001 to 2018. Given the huge differences between the urban and rural areas in China in terms of economic and social progress, the group testing method was adopted to measure the contribution made by human health capital to economic growth in urban and rural regions, and the variables affecting the non-quantitative social environment factors such as culture, institution and social consciousness, etc., on residents' health. The main conclusions are given below.

Firstly, in terms of the contribution made by human health capital to economic growth, it is mainly negative in the central and western regions. Their health GDP path is usually about 3.82% higher than the real GDP path, and about 7% higher in a few provinces. The effect on most eastern regions is positive since the proportion of the health costs to the real GDP is about 1.73%.

Secondly, in terms of the contribution of rural human health capital input to economic growth, it is mainly negative in the western and eastern regions. Their health GDP path is usually about 2.69% higher than the real GDP path, and a few provinces are over 5%. The marginal effect of most middle regions is positive since the proportion of the health costs to the real GDP is about 2.25%.

Thirdly, institutional and technological factors played a continuous and significant role in reducing the health input in economic activities during the sample period. However, the role of institutional environment factors shows some discrepancies between urban and rural areas, especially before the year 2010.

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