Total health care expenditures in "perfect health service systems" and the GDP

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Abstract: Background The increasing total expenditure on health (TEH), as identified by the development of social economics, has consequently increased the pressure on the national health service systems (NHSSs) of several countries and regions. Methods The features of the TEH of a NHSS may be beneficial for dealing with this kind of pressure. The NHSS can be divided into the "public health" (PH), "basic health care" (BHC), and "enjoying health care" (EHC) systems. In this paper, we focused on the total EHC expenditure. A "perfect health service system" (PHSS) should have the following features: ① universal availability; ② capacity to address various patient needs; ③ reasonable resource allocation; and ④ efficient management. Mathematical models were constructed to calculate the total EHC expenditure in a PHSS. Results A specific relationship was found between the total EHC expenditure and the gross domestic product (GDP). The total EHC expenditure increases with the GDP. Furthermore, its growth rate is lower than that of the GDP in a PHSS. Conclusions The total EHC expenditure in a PHSS will not reduce the health security of the citizens, which makes it similar to the total PH and BHC expenditure. Efforts to improve an NHSS are important to have a PHSS and to distinguish EHC from PH and BHC.

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The German Bismarck government released the Disease Social Insurance Bill in 1883 (Felicia and Julio, 2005), which led to the first national social insurance system. Britain then officially released the National Health Service Act in 1948, after which the concept of a national health service system (NHSS) started to be used worldwide (Wikipedia, 2011). Henceforth, governments began to provide free basic medical service to their citizens. Several countries eventually realized that the formation, development, and improvement of their respective NHSS affected the development and stability of their national economy, population, culture, and political institutions. The involvement of the government propelled the development of the medical industry and improved the treatment of diseases, the health status, and the quality of life in these countries.

The total expenditure on health (TEH) of the NHSS provides the macroeconomic information of health and serves as an important standard for evaluating the national and regional health financing policies and health fund applications (ILO, 1959; ISSA, 1971; Murray et al, 1994). Under the guidance and support of the World Health Organization (WHO), each country has gradually focused on the establishment of TEH information systems. This action requires an improved approach towards studying national health accounts combined with the establishment of a stable information system of health service issuance. By combining data from the national health services with the national health service issuance system, the continuity and stability of TEH data information is improved. Furthermore, actual official data will be available for decisionmaking, reforming health systems, and comparing international organizations.

The International Labor Organization (ILO) calculated that in 1959, the medical expenses for social insurance and voluntary insurance in the USA; this was the first instance that a national health service was evaluated (ILO, 1959). Since the 1970s, WHO has given importance to studies of national health accounts and their results. Fifty years of research on TEHs has achieved outstanding achievements worldwide. Specifically, a standard system for national health accounts have been established, which has been applied by an increasing number of countries. With developments in their TEH research, 147 countries have used national health accounts to evaluate the national health expenses from 1985 to 2004, even though 94 of these countries are not members of the Organization for Economic Co-operation and Development (OECD) (Femando and Rannan-Eliya, 2005). WHO released the Guide to Producing National Health Accounts in 2003, which was taken as the theoretical basis to popularize and improve the accounting and operation principles that could guide the TEH of certain middle- and low-income countries.

The national health account employs the national economic accounting method and considers the entire health system as an accounting object. Moreover, the national health account establishes a standard accounting structure and studies the use of funds for a health system. The national health account is an important part of the national economic accounting system as an extension and application of national economic accounting in health systems (Chen and Luo, 2007). The national health account system of the countries in the OECD is a system of national health accounts, which has strict principles for economic classification and widespread data collection.

The ratio of the TEH to the GDP has been regarded as one of the comprehensive standards to measure the coordinated development between the population's health and the national economy because it reflects the different health investments of different countries and regions (Hu and Ye, 2003). Moreover, this ratio reflects the degree of support for health care and the general attitude of governments towards health. Monitoring the adaptation of health development to national economic growth is a standard practice. Each government can obtain related information from other countries as the basis of the formulation and improvement of their own developmental strategies and policies in the health industry. WHO (2001) announced the ratio of TEH to GDP and the internal composition of the member states for the first time in their 2000 World Health Report.

More recently, society has given more attention to health and conflict between the healthservice demands and the scarce health resources, which have become more evident with the economic development of a country. The TEH growth rate in several countries is higher than their GDP growth. For example, in the USA, the ratio of TEH to GDP increased from 13.4% in 2000 to 15.7% in 2007 (WHO, 2010). In China, the average TEH growth rate from 2000 to 2008 was 15.5%, whereas the average GDP growth rate was 14.89% (China Health Economics Institute, 2009). Therefore, the TEH overgrowth may exert extra pressure on a country, its industries, and its citizens. This result may have a negative influence on the coordination and sustainable development of the nation and society, which consequently places much pressure on the NHSS. This problem has been a long-standing concern. Thus, the reasonable regulation of the TEH is important.

Most countries study the control of TEH based on the national conditions and then present a series of solutions (Dreger and Reimers, 2005; Erdil and Yetkiner, 2004). Examples of these solutions include an improved payment method for medical insurance, enhanced disease prevention and control, and strengthened monitoring of medical service suppliers. The composition of TEH can be determined using different methods. The most common method is based on the functions of each component. The said method is then used as the basis for describing a "perfect health service system" (PHSS). Mathematical models are then constructed to calculate for the total expenditure on health care in the PHSS.

Based on the different components of health services, medical services can be divided into three types: 1) "public health" (PH), which is invested by the government according to the design standard (Winslow, 1920); ⁽²⁾ "basic health care" (BHC), which strictly follows the rules and medical principles (Kruk and Freedman, 2008); ③ "enjoying health care" (EHC) with the service principle of "the patient comes first," which is based on the rules and regulations imposed by the market (Popenoe, 2000). Thus, TEH can be divided into the total expenditures for PH, BHC, and EHC (Lu and Liu, 2010). The present study quantitatively determines the total EHC expenditure using mathematical models which aim to reveal the features of an EHC in a PHSS, as described by Lu et al. (2010).

1. Materials and methods

1.1. Features of total EHC expenditure in the PHSS

First, we describe a "perfect NHSS" or PHSS. The following features should be in a PHSS: ① a universal basic health care system; ② efficient and flexible multi-purpose health services; ③ reasonable resource allocation; ④ efficient healthcare management; ⑤ a stable medical workforce; ⑥ low and reasonably achievable disease morbidity; and ⑦ widespread public health information.

1.2. Mathematical models

The mathematical models can be classified according to health service function. These models should calculate the actual total expenditure for health costs according to health resources used by the consumers, which is called the actual use method of the TEH.

When a country or a region has a PHSS, the total EHC expenditure is T_n in the year *n*. Given the actual use method of TEH, we define T_n , which includes five aspects: T_c (total construction expenditures of EHC institutions); P_n (total cost of EHC workers); W (total use of EHC medical treatments); M (total expenditure for EHC management); and L_n (investor profit from EHC), which are summarized in Table 1. Thus, we can build the following mathematical model:

$$T_n = T_c + P_n + W + M + L_n,$$
 [1]

$$T_c = H_c, \qquad [2]$$

$$P_n = mP_m, [3]$$

$$P_{rn} = \prod_{i=1}^{n} f_i (P_{b0} + P_{a0}), \qquad [4]$$

$$P_{n} = \prod_{i=1}^{n} f_{i} P_{0} = m H_{p} \prod_{i=1}^{n} f_{i} , \qquad [5]$$

$$W = NW_r, [6]$$

$$W_r = H_w,$$
^[7]

$$M = NM_r, \qquad [8]$$

$$M_r = H_m, [9]$$

$$L_n = \prod_{i=1}^n (z_i + 1) L_0 \,. \tag{10}$$

 T_c is defined as the total constructionrelated expenditure of an EHC institution. We set $T_c = H_c (1 + e^{E_c - t_c})$, where t_c is the evaluation coefficient of the total expenditures of constructing an EHC institution in the PHSS, E_c is the evaluation reference coefficient, and H_c is the total construction expenditure for the basic service agency in PHSS. Both E_c and H_c are constant. The evaluation coefficient of the EHC institution's total expenditure in the PHSS increases to $T_c = H_c$. This trend implies that when the total construction expenditure is constant at a certain level, the investment is mainly used for the specific planned updating and maintaining equipment and infrastructure.

 P_{rn} represents the per capita payments; P_{b0} is the reference value of per capita wages and welfare; P_{a0} is the reference value of per capita bonus; f_n represents the variation coefficient of per capita payments; $H_p = P_{b0} + P_{a0}$ represents the per capita payments to EHC staff from the first year. The ratio of *m* (quantity of EHC workers) to *N* (total population) is invariant. The per capita payments (H_p) include P_{b0} (reference value of per capita wages and welfare) and P_{a0} (reference value of per capita bonus). Given t_w (evaluation coefficient of medical treatment's per capita cost in the PHSS), E_w is the evaluation reference coefficient and H_w is the standard per capita health care consumption in PHSS. Both E_w and H_w are constant. Suppose $W_r = H_w$ and both are constant, W_r (per capita health care consumption) can achieve the constant in a period of time. Theoretically, EHC follows a positive cycle, and the disease occurrence is maintained at a certain level. W (total health care consumption) of EHC) is only affected by N (total population) and W_r (per capita medical consumption) to satisfy equation [6].

Given t_m (evaluation coefficient of per capita administrative cost in PHSS), E_m is reference evaluation coefficient and H_m is the standard per capita administrative cost in PHSS. Both E_m and H_m are constants. Suppose $M_r = H_m(1 + e^{E_m - t_m})$, the management method is advanced and workflow is optimal as t_m increases to PHSS. $M_r = H_m$ is constant, which implies that the per capita administrative cost (M_r) can similarly be reduced to a constant.

 L_0 is the profit of standard EHC service agents in a PHSS. L_n is the profit of EHC. Suppose the profit growth of EHC is $z_n = (L_n - L_{n-1})/L_{n-1}$, then $L_n = \prod_{i=1}^n (z_i + 1)L_0$ to satisfy equation [10].

1.3. Mathematical model calculation 1.3.1 Relationship between the coefficient of variation per capita and the GDP growth rate

Let the GDP growth rate be x_n , then

$$\overline{f} = \sqrt[n]{\frac{P_n}{P_0}}, \quad \frac{1}{x} = \sqrt[n]{\frac{G_n}{G_0}},$$
 [11]

where
$$f > 0$$
 , $x > 0$, and $x_n = (G_n - G_{n-1})/G_{n-1}$. That is,

$$G_n = \prod_{i=1}^n (x_i + 1)G_0.$$
 [12]

 G_n is the GDP in the year *n*; x_n is the growth rate of G_n ; \overline{x} is the average growth rate of GDP; f_n is the variation coefficient of per capita

payment; \overline{f} is the average growth rate of per capita payment.

Let $\overline{f} > \overline{x}$ and $G_n = P_n$ in the year *n*. From equation [11], we obtain

$$G_0 \overline{x}^n = P_0 \overline{f}^n.$$
^[13]

Taking the logarithm from both sides of equation [13] produces

$$\ln G_0 + n \ln x = \ln P_0 + n \ln f .$$
 [14]

That is,

$$n = \frac{\ln \frac{P_0}{G_0}}{\ln \frac{\overline{x}}{\overline{f}}}.$$
[15]

 $P_0 < G_0$ and n > 0 . All values are natural numbers. Thus, equation [15] should fulfill:

$$\ln \frac{x}{\overline{f}} < 0 \text{ and } \overline{f} > \overline{x}.$$
 [16]

Therefore, when $\overline{f} > \overline{x}$ in the year *n*, then

 $G_n = P_n$. Theoretically, $G_n \ll P_n$. Thus, $\overline{f} > \overline{x}$ is not available.

If
$$0 < \overline{f} < \overline{x}$$
 is available, that is,
 $0 < \overline{f} < \overline{x}$, we obtain

$$0 < \sqrt{\frac{P_n}{P_0}} \le \sqrt{\frac{G_n}{G_0}} .$$
[17]

Applying equations [5] and [12] to equation [17] produces

$$0 < \sqrt[n]{\prod_{i=1}^{n} f_i} \le \sqrt[n]{\prod_{i=1}^{n} (1+x_i)}$$
 [18]
That is

That is,

$$0 < f_n \le \prod_{i=1}^{n-1} \frac{(1+x_i)}{f_i} (1+x_n) .$$
 [19]

1.3.2 Relationship between the EHC profit and the GDP growth rate

In PHSS, the profit growth rate of EHC (z_n) and the GDP growth rate (x_n) have the following relationship:

$$z_n = \alpha x_n.$$
[20]

 α can be constant or a function that implies specific relationships between z_n and x_n .

Calculation of the total EHC expenditure

 (T_n)

By combining equation [2], as well as

equations [5] to [10], into equation [1], we obtain

$$T_n = H_c + \prod_{i=1}^n f_i P_0 + NW_r + NH_m + \prod_{i=1}^n (\alpha x_i + 1)L_0$$
[21]

When $H_c = a$ and $W_r + H_m = b$, where a and b are positive constants (a, b > 0), equation [21] becomes

$$T_n = a + bN + \prod_{i=1}^n f_i P_0 + \prod_{i=1}^n (\alpha x_i + 1)L_0$$
 [22]
That is,

$$T_n = a + bN + \prod_{i=1}^{n-1} f_i f_n P_0 + \prod_{i=1}^n (\alpha x_i + 1)L_0.$$
 [23]

By combining equation [19] with equation [23], we obtain

$$a+bN+\prod_{i=1}^{n}(\alpha x_{i}+1)L_{0} < T_{n} \le a+bN+\prod_{i=1}^{n-1}f_{i}\prod_{i=1}^{n-1}\frac{(1+x_{i})}{f_{i}}(1+x_{n})P_{0}+\prod_{i=1}^{n}(\alpha x_{i}+1)L_{0}$$
[24]
That is,

$$a + bN + \prod_{i=1}^{n} (\alpha x_i + 1)L_0 < T_n \le a + bN + \prod_{i=1}^{n} (1 + x_n)P_0 + \prod_{i=1}^{n} (\alpha x_i + 1)L_0$$
. [25]

Calculation of the EHC growth rate (y_n)

Consider the ratio of the total EHC staff to the total population i in a PHSS, such that i = m/N. Let a + bN = d, $P_0 = mH_p = c$, and $B = \prod_{i=1}^{n} (\alpha x_i + 1)L_0$, where d, c, and B are positive constants (d, c, B > 0; when N is invariant). From equation [25], we obtain

$$d + B < T_n \le d + B + c \prod_{i=1}^n (1 + x_i)$$
[26]

The annual growth rate of the EHC total cost \mathbf{y}_n is

$$y_{n} = (T_{n} - T_{n-1})/T_{n-1}.$$
[27]
If $T_{n} = d + B + c \prod_{i=1}^{n} (1 + x_{i}),$
then $T_{n-1} = d + B + c \prod_{i=1}^{n-1} (1 + x_{i})$ and $A = \prod_{i=1}^{n-1} (1 + x_{i}).$
Thus, $T_{n} = d + B + cA(1 + x_{n})$ and
 $T_{n-1} = d + B + cA.$
[28]

$$T_{n-1} = d + B + cA$$
. [28]
Given equation [27], we obtain

$$y_n = cAx_n / (d + B + cA).$$
 [29]
That is,

$$y_n = c \prod_{i=1}^{n-1} (1+x_i) x_n \bigg/ \bigg| d + \prod_{i=1}^n (a x_i + 1) L_0 + c \prod_{i=1}^{n-1} (1+x_i) \bigg|$$
[30]

If $T_n = d$, then $T_{n-1} = d$. Combined with equation [27], we obtain

$$y_n = 0.$$
 [31]

From equations [26], [27], and [31], we obtain

$$0 < y_n \le c \prod_{i=1}^{n-1} (1+x_i) x_n \bigg/ \bigg| d + \prod_{i=1}^n (\alpha x_i + 1) L_0 + c \prod_{i=1}^{n-1} (1+x_i) \bigg|$$
[32]

1.3.3 Relationship between growth rates of the total EHC cost and the GDP

Let the ratio of EHC total costs annual growth rate (y_n) to GDP growth rate (x_n) be g_0 , such that

$$g_0 = y_n / x_n \,. \tag{33}$$

Combining equations [20] and [32] with equation [33] produces

$$0 < g_0 < cA/(d + B + cA)$$
. [34]

Given that
$$cA > 0$$
, $B > 0$, and $d > 0$, then
 $0 < g_0 < 1$. [35]

2. Results

2.1. Relationships between parameters of the EHC total expenditures and the GDP growth rate

A PHSS was defined to have the following properties: the total construction expenditures for the EHC service agency, the per capita health care consumption of the EHC, and the per capita administrative expenditure for the EHC. These conditions can be achieved or approximated as constant values through several methods. Therefore, relationships between the parameters of the EHC total expenditures and the GDP growth rate are described by the mathematical models in several equations. Equation [19] is the relationship expression of the per capita payment variation coefficient in the year n and the GDP growth rate. Equation [25] shows that the total EHC expenditure is affected by the total population and the GDP growth rate in the year *n*. Meanwhile, the total EHC expenditure has a positive correlation with total population. Moreover, we can determine that the total EHC expenditure will theoretically increase with the increasing GDP, as shown by equations [32] and [35]. However, the growth rate of the total EHC expenditure is lower than that of the GDP (Figure 1).



Figure 1: Growth trends of G_n and T_n , per country or region

3. Discussion

The total EHC expenditure in a PHSS will increase as the society develops, but the EHC growth rate (y_n) is usually lower than the GDP growth rate.

Moreover, we can determine that the range of y_n is

$$0 < y_n \le c \prod_{i=1}^{n-1} (1+x_i) x_n / \left| d + \prod_{i=1}^n (\alpha x_i + 1) L_0 + c \prod_{i=1}^{n-1} (1+x_i) \right|$$

from equation [32]. PH, BHC, and EHC in the PHSS will not severely affect a country or a region nor reduce the health security of its citizens. Thus, a country or a region should target the establishment of a PHSS for the improvement of its NHSS. To date, the most important issue is to distinguish EHC from PH and BHC.

Although the results of this paper are based on several hypotheses, the obtained formula brings new research opportunities on TEH. The estimation and combination of the total expenditures for PH and BHC, as well as the relevant parameters in the total expenditures for EHC, can be achieved by means of historical data. The ideal conditions may be difficult to achieve, but they provide a perfect benchmark for the management and control of the NHSS.

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Table 1: Index system table of medical consumption classified by service function and production

Classification	Items of TEH actual use method	EHC Items
Individual EHC Expenditure	Individual medical expenses spent in the EHC service. Includes: expenses of outpatient service, hospitalization, retail medicine and medical derivatives.	Total expenditures of EHC (W) and total payment of health workers (P_n) .
EHC Development Expenditure	Resource consumption of EHC health development. Includes: EHC research expenses and fixed assets added value.	Total construction expenses of EHC institutions (T _c).
Other EHC Expenditure	Mainly includes administrative management expenses.	Total management expenditure M (staff cost belongs to P_n).
EHC profit		investor Profit (L _n).

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