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I. Здравоохранение, образование и благосостояние
I. Health, Education, and Welfare

НАКОПЛЕНИЕ И ЭФФЕКТИВНОЕ ИСПОЛЬЗОВАНИЕ КАПИТАЛА ЗДОРОВЬЯ: ТЕОРЕТИЧЕСКИЙ ПОДХОД НА ОСНОВЕ РАСШИРЕННОЙ ПРОИЗВОДСТВЕННОЙ ФУНКЦИИ КОББА – ДУГЛАСА

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Аннотация. На фоне реализации инициативы «Здоровый Китай» и трансформации демографического дивиденда здоровье, как форма капитала, выступает ключевым фактором национальной конкурентоспособности и долгосрочной устойчивости экономического развития. С опорой на данные Китайского статистического ежегодника, Национальной комиссии здравоохранения Китайской Народной Республики и демографических прогнозов ООН проанализированы современные тенденции в формировании капитала здоровья Китая и связанные с этим процессом структурные вызовы. На основе расширенной производственной функции Кобба – Дугласа разработан теоретический подход, интегрирующий капитал здоровья и выпуск продукции, что позволило предложить комплексный многомерный индекс капитала человеческого здоровья HHCI (*health human capital index*), включающий четыре ключевых параметра. Представленный авторский подход, охватывающий также жизненный цикл капитала здоровья и механизм многостороннего взаимодействия, позволил сформулировать практические рекомендации по накоплению и повышению эффективности использования капитала здоровья. Полученные результаты исследования закладывают прочную теоретическую и методическую основу для стимулирования качественного устойчивого экономического роста в условиях продолжающихся демографических и институциональных преобразований Китая.

Ключевые слова: капитал здоровья; накопление капитала здоровья; эффективность использования; расходы на здравоохранение; здравоохранение; инициатива «Здоровый Китай»; производственная функция Кобба – Дугласа; индекс капитала человеческого здоровья; HHCI.

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HEALTH CAPITAL ACCUMULATION AND EFFECTIVE UTILISATION: A THEORETICAL FRAMEWORK BASED ON AN EXTENDED COBB − DOUGLAS PRODUCTION FUNCTION

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Abstract. Against the backdrop of the initiative «Healthy China» and the transformation of the demographic dividend, health capital has emerged as a critical determinant of national competitiveness and the long-term sustainability of economic development. Based on data from the China Statistical Yearbook, the National Health Commission of the People's Republic of China, and United Nations World Population Prospects, this article analyses current trends in the formation of China's health capital and the structural challenges associated with this process. Building on an extended Cobb – Douglas production function, we propose a theoretical framework that integrates health capital into macroeconomic output analysis and introduce a comprehensive multidimensional health human capital index (HHCI) encompassing four key dimensions. Furthermore, we present an integrated policy framework grounded in a life-course approach to health capital and multi-stakeholder engagement, offering practical strategies to promote its accumulation and improve its utilisation efficiency. The findings provide a solid theoretical and methodological basis for fostering high-quality, sustainable economic growth amid China's ongoing demographic and institutional transformations.

Keywords: health capital; health capital accumulation; utilisation efficiency; health expenditure; healthcare; initiative «Healthy China»; Cobb – Douglas production function; health human capital index; HHCI.

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Introduction

Health, as a vital component of human capital, represents both a universal aspiration and a fundamental human need [1]. It is also a key factor in achieving economic growth and social development [2]. With the profound transformation of the global economic and social landscape, the critical role of health human capital in fostering economic growth, enhancing labour productivity, and improving the quality of human capital has drawn increasing attention [3; 4]. Since the launch of China's reform and opening-up, continuous economic development and significant improvements in living standards have led to a heightened public awareness of health issues. In the new era, the Chinese government has placed growing emphasis on the accumulation of health capital, recognising it as a cornerstone for promoting individual well-being and sustainable social prosperity.

Since 2013, when president Xi Jinping stated that «the health of the people is an essential component of building a moderately prosperous society in all respects»[1], the Chinese government has continuously elevated health to a national strategic priority. Following the formal launch of the strategy «Healthy China» in 2015, a series of major policy documents, including the planning outline «Healthy China 2030»[2], the 13th Five-Year Plan for Health and Wellness, and the initiative «Healthy China» for 2019–2030, have been issued to systematically advance the agenda of nationwide health promotion. These policies encompass a wide array of key areas such as health equity, basic medical security, public health services, health education, medical system reform, and population policy optimisation, collectively forming a relatively comprehensive framework for national health governance[3]. In recent years, the initiative «Healthy China» has been repeatedly incorporated

[1]Laying a solid health foundation for the great rejuvenation of the Chinese nation. A chronicle of the CPC Central Committee with Comrade Xi Jinping at its core accelerating the construction of a healthy China // Cyberspace Administration of China : website. URL: https://www.cac.gov.cn/2017-10/13/c_1121798758.htm (date of access: 12.02.2025).

[2]Ibid.

[3]Initiative «Healthy China» for 2019–2030 // The Central People's Government of the People's Republic of China : website. URL: https://www.gov.cn/xinwen/201907/15/content_5409694.-htm (date of access: 12.02.2025) (in Chin.) ; Outline of the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035 of the People's Republic of China // Ibid. URL: https://www.gov.cn/xinwen/2021-03/13/content_5592681.htm (date of access: 10.03.2025) (in Chin.) ; Report to the 20th National Congress of the Communist Party of China // Ibid. URL: https://www.gov.cn/xin-wen/2022-10/25/content5721685.htm (date of access: 10.02.2025) (in Chin.).

into medium- and long-term development plans, central political documents, and national economic work conferences, signifying that a health human capital-centered human capital strategy has risen to a top-tier national development priority[4] (fig. 1).

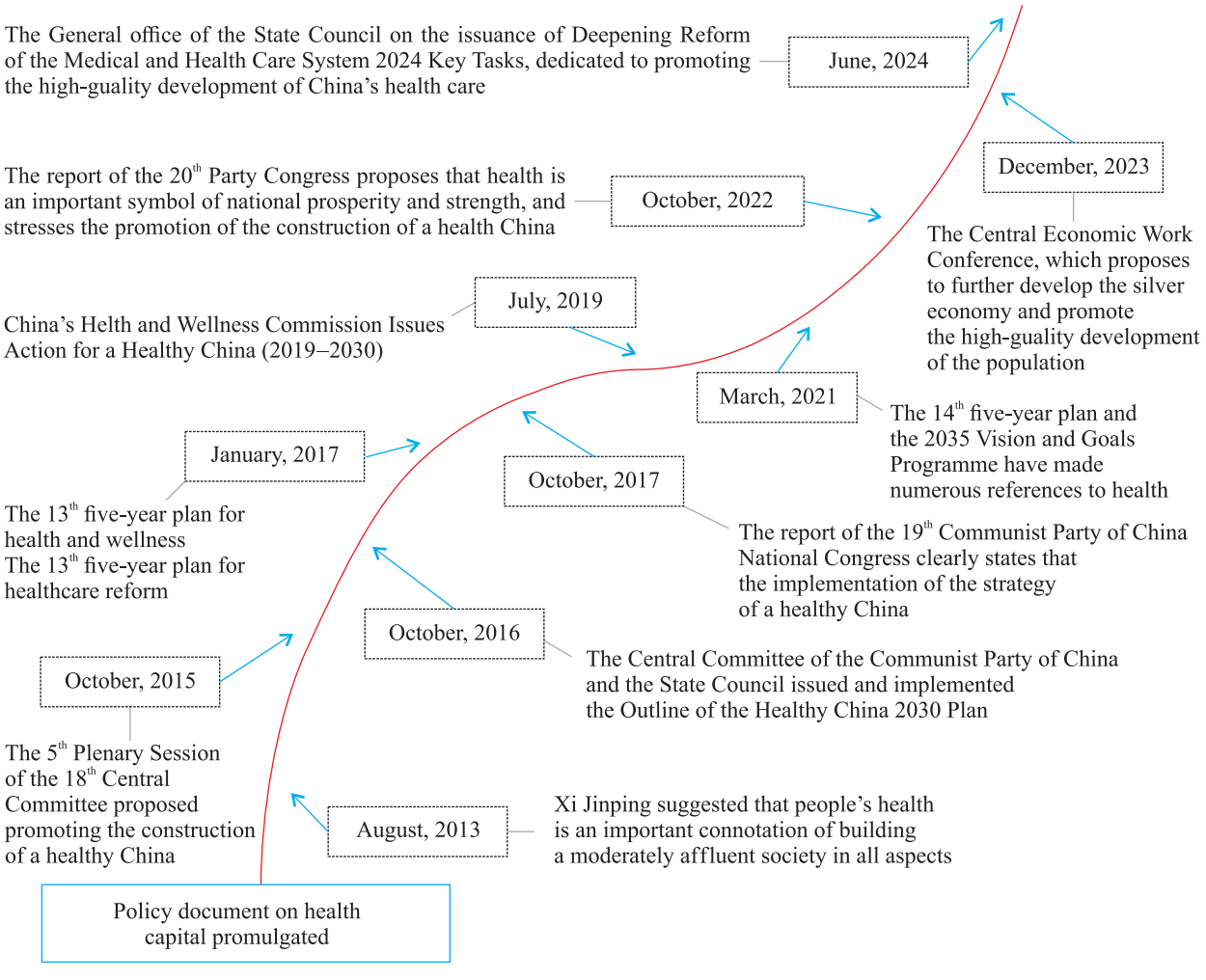

Fig. 1. Timeline of major policy documents related to health human capital in China

Since the founding of the People's Republic of China, and particularly since the beginning of the 21st century, the country has significantly increased its investment in health capital, leading to a progressively improved healthcare service system and markedly enhanced health governance capacity. On one hand, the overall scale of healthcare resources has expanded substantially. By the end of 2023, China had approximately 1.07 mln medical and health institutions and more than 10.17 mln hospital beds, representing 290.8-fold and 119.3-fold increases, respectively, compared to 1949. The number of hospital beds per 1000 population rose from 0.16 to 7.23. The primary healthcare network has been continuously strengthened, with primary institutions accounting for over 90 % of all medical facilities, effectively achieving near-universal coverage across urban and rural areas.

On the other hand, the health workforce has expanded steadily. As of 2023, the total number of health personnel nationwide reached 15.24 mln, nearly 27 times the figure in 1949. The number of licensed (assistant) physicians and registered nurses per 1000 people increased to 3.40 and 4.00, respectively, indicating a clear improvement in the level of professionalisation. Meanwhile, the healthcare insurance system and service delivery models have undergone significant optimisation. The number of individuals covered by basic medical insurance reached 1.33 bln, with coverage rates remaining above 95 % since 2018.

[4]Central Economic Work Conference 2024 [Electronic resourse] // Communist Party Member Network. URL: https://www.12371.cn/2024/12/12/ARTI173401163-6857721.shtml (date of access: 15.02.2025) (in Chin.) ; General Office of the State Council. Notice on the issuance of the 2024 Key Tasks for Deepening the Reform of the Medical and Healthcare System // The Central People's Government of the People's Republic of China : website. URL: https://www.gov.cn/zhengce/content/202406/content_6955904.htm. (date of access: 10.02.2025) (in Chin.).

The initiative «Internet Plus Healthcare» has accelerated, with telemedicine and appointment-based diagnosis and treatment widely adopted. As of 2023, more than 550 000 medical institutions were connected to the national cross-provincial settlement network. With institutional reforms and service capacity continuously improving, per capita total health expenditure has shown sustained growth, reaching 6425.3 yuan in 2023, an increase of 6.31 % year-on-year. The proportion of total health expenditure to GDP rose from 6.0 % in 2010 to 7.2 % in 2023, reflecting the government's growing commitment to health capital and the steady increase in fiscal support (table 1). Taken together, China has made substantial progress in strengthening the foundational conditions for health capital through increased resource input, institutional reform, and technological innovation providing a solid basis for the overall improvement of population health.

Table 1

National healthcare resources and health expenditures in China (2010–2023)

Year	Number of beds per 10 000	Increase over previous year, %	Total health costs per capita, yuan	Proportion of total health expenditure to GDP, %
2010	478.7	8.40	1440.3	5.15
2011	516.0	7.79	1643.2	4.98
2012	572.5	10.95	1807.0	5.15
2013	618.2	8.00	2326.8	5.57
2014	660.1	6.80	2586.5	5.56
2015	701.5	6.30	2952.0	6.00
2016	741.0	5.60	3351.7	6.20
2017	794.0	7.10	3712.2	6.36
2018	840.4	5.80	4148.1	6.40
2019	880.7	4.80	4656.7	6.50
2020	910.1	3.30	5146.4	7.12
2021	945.0	3.80	5348.1	6.50
2022	975.0	3.20	6010.0	7.00
2023	1017.4	4.35	6425.3	7.20

On the foundation of a continuously improving healthcare system and expanding medical resources, the overall health status of the Chinese population has witnessed a remarkable improvement. First, China's average life expectancy has increased significantly. Since the 1950s, data show a sustained upward trend in life expectancy among Chinese residents, reflecting substantial improvements in population health. As of 2024, the average life expectancy in China has reached 79 years, marking a 0.4-year increase from 2023. Among 53 upper-middle-income countries, China now ranks 4th, thus achieving the target set by the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035 of the People's Republic of China ahead of schedule (fig. 2).

Secondly, both the infant mortality rate (IMR) and the under-five mortality rate (U5MR) in China have continued to decline. These two indicators are internationally recognised as critical measures of population health. They not only reflect the health status of children but also serve as proxies for the overall quality of the healthcare system and the level of social development. The substantial reduction in early childhood mortality has directly improved the initial quality of human capital and enhanced the future health status of the labour force. As such, it has provided a foundational resource for long-term economic growth [5]. Since the 1950s, China has made internationally acclaimed progress in improving child health. In 2000, the IMR dropped to 27.9 per thousand (‰), and the U5MR reached 36 per thousand (‰). By 2023, the IMR had further declined to 5.1 ‰, and the U5MR to 7 ‰, representing reductions of approximately 96.0 % and 96.6 %, respectively, compared with 1950 levels. These achievements mark a historic leap forward in child health outcomes (fig. 3).

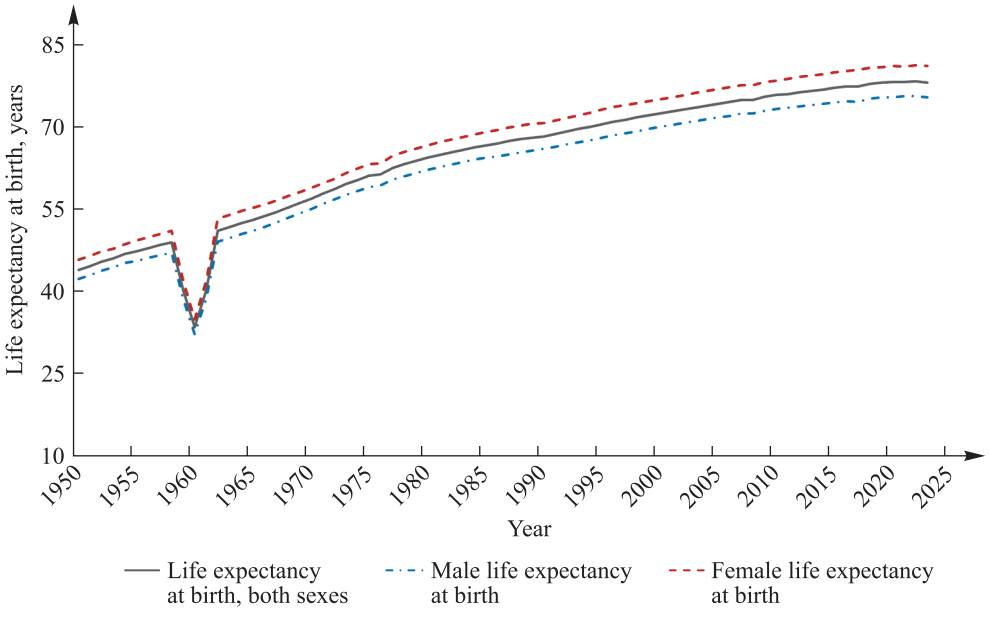

Fig. 2. Trends in life expectancy at birth in China (1950–2023).
Source: https://population.un.org/wpp/

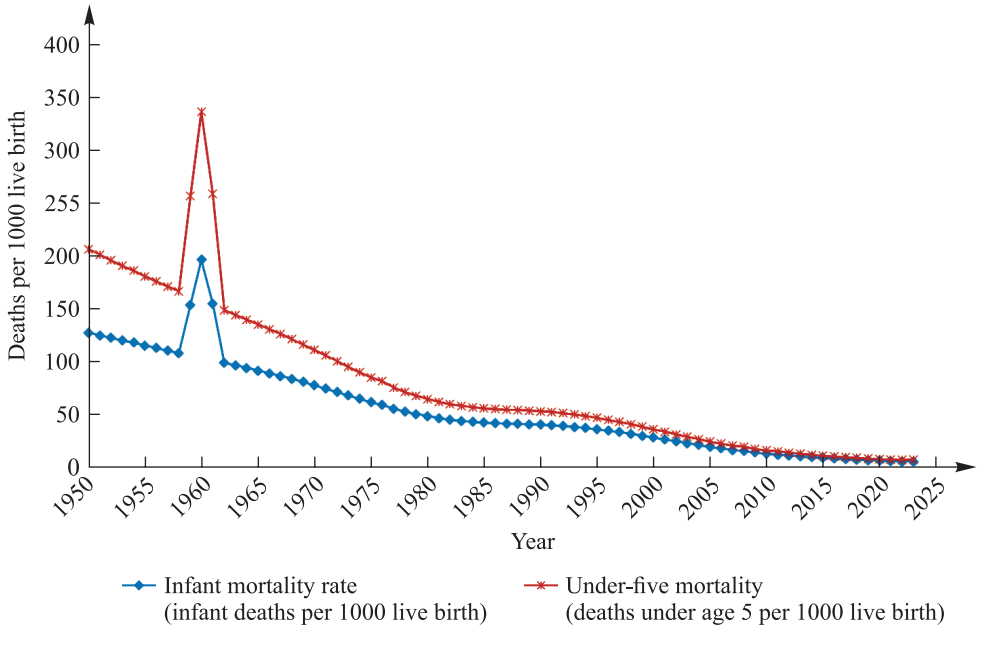

Fig. 3. Trends in mortality rate of infant and under-five in China (1950–2023).
Source: https://population.un.org/wpp/

Meanwhile, the continuous decline in birth rates, coupled with rising life expectancy, has accelerated the pace of population aging in China (fig. 4). As of 2024, individuals aged 65 and above account for 15.6 % of the total population, signifying China's entry into a deeply aged society. This demographic shift has not only heightened the overall disease burden but also intensified the risk of health capital depletion. Broadly speaking, the decline in the quality of health capital and the emergence of latent health risks are becoming increasingly intertwined. This trend reflects a structural shift from a visible burden of disease to invisible, systemic health vulnerabilities, posing a major constraint on sustainable social development. In recent years, academic research on health capital has deepened. Some scholars have examined the positive contribution of health capital to economic growth, focusing on the interplay between health and macroeconomic development [6]. Others have explored how factors such as education, income, and the supply of medical services influence health outcomes [7]. Despite this growing body of literature, there remains a lack of systematic analysis tailored to China's unique context of socioeconomic transition. Insufficient attention has been paid

to structural changes within health capital, the epidemiological shift toward chronic diseases, and the resulting economic and social consequences. These underexplored dimensions call for a comprehensive reassessment of China's health capital landscape.

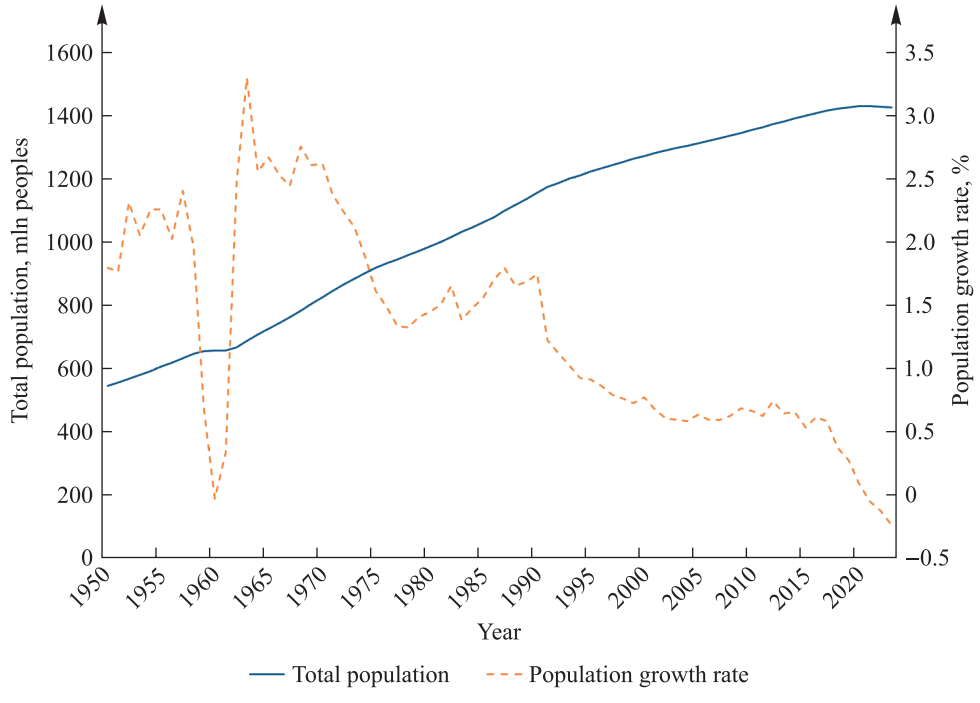

Fig. 4. Trends in mortality of infant and under-five in China (1950–2023).
Source: https://population.un.org/wpp/

In summary, although existing studies have made meaningful progress in identifying the relationship between health capital and economic growth, most of the literature remains concentrated at the micro level, focusing on the link between individual health, labour supply, and firm-level productivity. However, there is a lack of theoretical inquiry and pathway analysis that integrates health capital into macroeconomic growth models. Moreover, there is an urgent need to establish a multi-actor, systematically coordinated policy toolkit to support health capital development. In response to these gaps, this paper centers on the mechanisms through which health capital contributes to macroeconomic output. It develops a theoretical framework by extending the Cobb – Douglas production function, aiming to systematically explain how health capital promotes economic growth by enhancing effective labour efficiency and total factor productivity. Building on this foundation, and in line with the strategic goals of the initiative «Healthy China» as well as international best practices, the study proposes a policy evaluation index for health capital. It further puts forward a systematic policy pathway characterised by a «life-cycle perspective» and «multi-actor collaboration». The goal of this paper is to provide theoretical support and practical tool for the institutional design and strategic deployment necessary to enhance China's health capital.

Health capital and macroeconomic output development trends of health capital in China: theoretical framework

As early as 1909, American economist I. Fisher articulated the economic losses caused by illness, including lost working time, the net present value of future earnings lost due to premature death, and direct medical expenditures. In 1962, S. J. Mushkin introduced the concept of health investment into the human capital framework, positioning health alongside education as one of the two core components of human capital. This study elaborated on the interactive relationship between health and education and proposed that health constitutes a distinct yet equally important form of human capital, separate from education [8]. Subsequently, G. S. Becker (1964) and V. R. Fuchs (1972) further provided empirical evidence underscoring the irreplaceable role of health in shaping individual human capital [9; 10].

It was not until 1972 that M. Grossman formally incorporated health capital into the analytical framework of human capital. In his model, health is treated as an accumulable capital stock, whose depreciation rate and investment level jointly determine an individual's health status, which in turn affects productive capacity

through «effective labour» [3]. Health capital thus possesses dual attributes: it serves both as a consumption good and as an investment good.

Researcher M. Grossman integrated health capital with the concept of the life cycle. From birth, everyone is endowed with an initial stock of health capital, which typically depreciates with age. On the other hand, health investments, such as proper nutrition, preventive care, and medical expenditures, can prolong working life and enhance productivity. Therefore, health capital functions as a long-term variable that influences the potential output level.

The Cobb – Douglas production function, a classical model used to describe the quantitative relationship between output and production inputs, is typically expressed as:

$$Q = AK^{\alpha}L^{\beta}.$$

In the standard formulation, Q denotes total output, A represents total factor productivity, typically proxied by GDP, K and L are the inputs of capital and labour, respectively, while α and β are the output elasticities of capital and labour, capturing their respective marginal contributions. The Cobb – Douglas model rests on several core assumptions: perfect substitutability of production inputs, diminishing marginal returns, and constant returns to scale. Additionally, its log-linear form facilitates empirical estimation, making it a widely adopted tool in macroeconomic growth models, development economics, and production efficiency analysis. Given these strengths, this study incorporates health capital into an extended Cobb – Douglas production function, a modification that is both theoretically consistent and empirically tractable. From an economic perspective, health capital primarily affects «effective labour», that is, labour input should not be measured solely by the number of workers or hours worked but must also account for how health conditions influence labour efficiency. In this context, the original labour input L is adjusted to incorporate the impact of population health through a health-adjusted labour factor, expressed as aL, where $a \in (0, 1]$ represents the health efficiency coefficient of the labour force. For example:

$$a = 1 - \frac{t}{d},$$

where t denotes the average number of workdays lost due to health-related reasons per employed person during the reference period (for example, a calendar year, including certified sick leave, injury recovery, and other health-related absences), and d denotes the benchmark number of scheduled working days per worker in the same period, excluding weekends and official public holidays in accordance with the national labour calendar. Both variables are measured in the same time units (days or, where applicable, hours). Accordingly, aL represents effective labour input adjusted for productivity losses due to health-related work absences.

Beyond its indirect influence on labour productivity, health capital (H) can also be treated as an independent production input. While its effect on total factor productivity may exhibit a lag, it is typically long-lasting and cumulative. Sustained investment in health not only enhances the immediate efficiency of labor but also expands the broader productive capacity of the economy over time.

Based on this rationale, the Cobb – Douglas production function can be extended to incorporate both channels of influence as follows:

$$Y = AK^{\alpha}(aL)^{\beta}H^{\gamma}. \quad (1)$$

In equation (1), H denotes the stock of health capital, γ is its output elasticity, capturing the marginal contribution of health capital to output.

Building on the strategic framework of the initiative «Healthy China», this study further specifies the extended Cobb – Douglas production function in time-indeX ED form:

$$Y_t = A_t K_t^{\alpha}(a_t L_t)^{\beta}H_t^{\gamma}.$$

Here, H_t is defined as the aggregate stock of health human capital in period t, understood as the population-weighted stock of productive health capacity. In the empirical analysis, H_t is proxied by the dimensionless, normalised composite health human capital index (HHCI) developed in next section (table 3), which covers four dimensions: health status (H1), health behaviour (H2), health environment (H3), and health investment (H4). The index is normalised to a 0–100 scale with the base year set to 100, and in the log-linear specification we use $\ln H_t$, allowing γ to be interpreted as the output elasticity with respect to health capital.

This specification captures the integrated role of health capital in macroeconomic output by embedding both its direct contribution as a production factor and its indirect effect via health-adjusted labour productivity. It provides a theoretically consistent and empirically operational framework for analysing the contribution of health investments to economic growth under China's ongoing demographic and institutional transitions.

By taking the natural logarithm of both sides, the model can be transformed into a log-linear form suitable for empirical estimation, as shown in equation

$$\ln Y_t = \ln A_t \cdot \alpha \ln K_t \cdot \beta \ln\left(a_t L_t\right) \cdot \gamma \ln H_t + \varepsilon_t. \quad (2)$$

In equation (2), Y_t denotes the macroeconomic output indicator, such as real GDP or per capita GNI; K_t represents physical capital input, typically measured by fiX ED asset investment; L_t is the labour force size, and a_t is the health-adjusted labour efficiency coefficient, reflecting the impact of population health on labour productivity; H_t is the composite health capital index. The parameters α, β and γ represent the output elasticities of capital, labour, and health capital, respectively; ε_t is the error term. Equation (2) thus provides both a theoretical foundation for identifying the role of health capital in promoting macroeconomic growth and a quantitative basis for evaluating policy outcomes under the strategy «Healthy China». Based on this, the study will further quantify health capital and construct a comprehensive health human capital index.

Constructing a multidimensional human capital index in the healthcare sector

Enhancing health capital is not solely the responsibility of the healthcare sector; it is also a critical pillar in the modernisation of national governance capacity. A scientifically grounded and operational measurement framework is essential for the targeted formulation and effective implementation of health policies. As the well-known maxim states, «What cannot be measured cannot be managed». Without a unified, practical, and methodologically rigorous framework, health human capital, the measurable embodiment of the broader concept of health capital, cannot be accurately quantified for purposes such as resource allocation, performance evaluation, or integration into broader economic and social development strategies.

From a methodological perspective, research on health human capital measurement has traditionally followed two main approaches: macro-level and micro-level. At the macro level, studies utilise national or regional data and rely on indicators such as mortality rates, morbidity rates, disease prevalence, and life expectancy. For example, T. P. Schultz and A. Tansel (1993) analysed the effects of illness and disability on labour income [11]; A. Bhargava and co-authors (2001) provided empirical evidence that survival rates significantly contribute to economic growth in low-income countries [12]; D. E. Bloom and co-authors (2001) constructed a health capital measurement framework based on life expectancy, mortality rates, and the ratio of health expenditure to GDP [13]. A. Aguayo-Rico and I. A. Guerra-Turrubiates (2005) developed a multidimensional health indicator system covering healthcare services, socioeconomic conditions, lifestyle, and environmental factors [14], offering a comprehensive approach to health capital assessment. L. Gong and co-authors (2012), by contrast, used public health expenditure as a proxy variable for health capital and established a model linking health capital accumulation to economic growth [15].

At the micro level, the focus shifts to individuals or households, emphasising the direct and indirect effects of health status on labour participation and income. Individual health is commonly measured using anthropometric indicators such as height, weight, and body mass index, as well as self-assessed health status and quality of life scales. J. Strauss and D. Thomas (1998) analysed data from household budget surveys to explore the relationship between nutrition intake, physical health indicators, and income [16]. J. P. Smith (2009) used self-rated health as a core variable to examine the link between childhood health and socioeconomic status in adulthood [17]; M. Balaj and co-authors (2017), drawing on European Social Survey data, investigated how behaviour, occupational characteristics, and living conditions jointly influence self-perceived health outcomes [18].

Some studies have employed composite scales to provide a more nuanced depiction of individual quality of life. Commonly used instruments include the Sickness Impact Profile[5], Nottingham Health Profile[6], EuroQol Five-Dimension Scale[7], World Health Organization Quality of Life (WHOQOL)[8], and the Medical Outcomes Study 36-Item Short-Form Health Survey[9] (table 2). These tools capture multiple dimensions of physical and mental health, offering rich information and comprehensive item coverage. Although the WHOQOL extends its scope to include social relationships and environmental factors, it remains primarily a tool for assessing overall quality of life rather than a strict measure of health capital in the economic sense.

[5]The Medical Outcomes Study 36-Item Short-Form Health Survey developed by J. E. Ware and co-authors in 1992 based on the Medical Outcomes Study conducted by RAND, this scale assesses eight dimensions of health.

[6]Nottingham Health Profile initiated in 1975 by the department of community health at the University of Nottingham; this instrument consists of two parts: the first part includes 38 items focused on health status, and the second part includes 7 items assessing the impact on daily life.

[7]EuroQol Five-Dimension Scale developed by the EuroQol Group in 1990, this instrument measures health-related quality of life across five dimensions.

[8]WHOQOL launched by the World Health Organization in the mid-1990s, the original WHOQOL-100 was later shortened to WHOQOL-BREF. It covers five broad domains.

[9]The Medical Outcomes Study 36-Item Short-Form Health Survey developed by J. E. Ware and co-authors in 1992 based on the Medical Outcomes Study conducted by RAND, this scale assesses eight dimensions of health.

Table 2

Commonly used scales and dimensions of health human capital

Name of health scale	Core measurement dimensions
Sickness Impact Profile	Sleep and rest, eating, work, home management, recreation and pastimes, ambulation, mobility, body care and movement, social interaction, alertness behaviour, emotional behaviour, and communication
Nottingham Health Profile	Sleep, physical mobility, energy, pain, emotional reactions, and social isolation
EuroQol Five-Dimension Scale	Mobility, self-care, usual activities, pain (discomfort), and anxiety (depression)
WHOQOL	Physical health, psychological well-being, social relationships, environmental context, and spirituality (personal beliefs)
MOS 36-Item Short-Form Health Survey	Physical functioning, role limitations due to physical health, bodily pain, general health perceptions, vitality (energy or fatigue), social functioning, role limitations due to emotional problems, mental health

The measurement of health human capital in China has largely followed two analytical perspectives: the macro-level and the micro-level approaches. At the macro level, commonly used indicators include the proportion of health expenditure in GDP [19], healthy life expectancy, healthcare expenditures in government public spending, and total health expenditures [20], as well as hospital beds per 10 000 people [21]. Some studies have also constructed comprehensive indicator systems to measure health capital [22; 23]. At the micro level, self-rated health indicators [24], physical health, and cognitive function [25] are widely used. In addition, some researchers have developed micro-level health human capital indices using standardised health measurement scales [26–28].

Overall, the methods for measuring health human capital, whether from a macro- or micro-level perspective, have been evolving, gradually shifting from reliance on single-variable indicators toward multidimensional frameworks. In China, micro-level studies on health capital are largely empirical in nature, relying on classical econometric models to refine variable construction, with diverse data sources. However, there remains a lack of in-depth exploration into the fundamental connotations and structural dimensions of health capital.

Building a scientifically sound and systematic evaluation of health human capital is crucial for advancing the strategy «Healthy China» and supporting high-quality development. Based on macroeconomic mechanism identification and empirical feasibility, this study constructs a multidimensional HHCI encompassing four dimensions (table 3). As shown in table 3, this study attempts to comprehensively assess the formation and accumulation of health human capital across four dimensions: stock, behaviour, environment, and investment.

Table 3

Construction of a four-dimensional HHCI

Health dimension	Secondary indicators	Measurement content
H1	Physical health	Incidence of illness, pain or discomfort
		Chronic diseases
		Body mass index
		Sleep quality
	Mental health	Depression tendency (CES-D Score)
		Self-rated mental status
		Anxiety score (e. g., GAD-7)
H2	Healthy lifestyle habits	Average sleep duration
		Daily fruit and vegetable intake
		Frequency of smoking (drinking)
	Health knowledge	Health literacy score
		Awareness of vaccines (infections)

Ending of the table 3

Health dimension	Secondary indicators	Measurement content
H3	Access to medical care	Health technicians per district
		Health insurance coverage rate
		Number of beds per district
	Living environment quality	Air pollution (e. g., PM2.5)
		Drinking water sanitation
		Residential density
		Safety perception
H4	Education and health investment	Years of schooling
		Share of preventive health expenditure
		Child vaccination rate
		Physical exam frequency
	Public health financing	Per capita public health expenditure
		Ratio of primary healthcare workforce
		Coverage of health promotion programmes

Note. To avoid any confusion with «system», we consistently refer to HHCI as an index rather than a «system», while acknowledging its multidimensional structure.

This framework is characterised by a clear horizontal structure and strong vertical operability. In terms of weighting methodology, to minimise the potential bias introduced by subjective judgment, this paper employs a combination of the analytic hierarchy process and the entropy weight method. The analytic hierarchy process involves soliciting evaluations from experts in health economics, public health, and statistics to assess the relative importance of secondary and tertiary indicators. A judgment matrix is then constructed, and a consistency index is calculated to ensure coherence in expert evaluations. Meanwhile, the entropy weight method assigns objective weights based on the degree of variation in indicators derived from large-scale survey data or health statistics. The smaller the entropy value of an indicator, the more information it provides, and the higher its assigned weight. This method emphasises the discriminatory power of each indicator and helps reduce the influence of subjective bias. Based on this dual-method approach, we calculate the composite weights for the health capital index as follows:

$$w_j = \alpha w_j^E + (1-\alpha) w_j^A,\ \alpha \in [0,1]. \tag{3}$$

In equation (3), we assume that the entropy-based weight for the j-th indicator is denoted as w_j^E, and the expert-based (analytic hierarchy process) weight is w_j^A. The parameter α represents the relative importance of the entropy weight in the combined weighting scheme. Based on the standardised and weighted aggregation of health capital indicators using equation (3), we construct a composite HHCI, which serves as a macro-level measure of a population's overall health capital status. The construction of the HHCI follows several key steps.

Step 1. Due to the heterogeneity in units and scales across indicators, it is necessary to normalise the raw data before aggregation. For positively oriented indicators (i. e., higher values indicate better health outcomes), we adopt the range standardisation method, defined as

$$X'_{ij} = \frac{X_{ij} - \min\left(X_j\right)}{\max\left(X_j\right) - \min\left(X_j\right)}, \tag{4}$$

where X_{ij} is the original value of indicator j for observation i, and X'_{ij} is the standardised value. For negatively oriented indicators in equation (4), that is, indicators where higher values reflect worse health outcomes.

Step 2. The standardisation is adjusted accordingly as follows:

$$X'_{ij} = \frac{\max\left(X_j\right) - X_{ij}}{\max\left(X_j\right) - \min\left(X_j\right)}.$$

Step 3. The standardised indicator values are multiplied by their corresponding weights and aggregated to construct the HHCI, which serves as a core metric for assessing the level of health capital across regions or population groups. The HHCI for the *i*-th observation unit (individual or city) can thus be expressed as

$$HHCI_i = \sum_{j=1}^{n} \omega_j X'_{ij},$$

where $HHCI_i$ represents the HHCI for the *i*-th observation unit (individual or city), ω_j denotes the composite weight of the *j*-th indicator, and X'_{ij} is the standardised value of that indicator. In summary, the constructed HHCI not only provides a practical and quantifiable foundation for the variables used in the theoretical model, but also serves as a valuable tool for subsequent policy evaluation and dynamic monitoring.

Efficient use of health capital: a life-course and multi-stakeholder strategy

Based on the constructed four-dimensional health capital index, this paper further explores strategic pathways for enhancing health capital through a life-cycle approach and multi-stakeholder collaboration.

Life-cycle-oriented strategy: stage-specific approaches to health human capital accumulation. Individual health capital evolves in distinct phases throughout the life course. At different life stages, health needs, risk exposures, behavioural patterns, and policy response mechanisms vary significantly. Accordingly, it is essential to develop targeted health policy instruments and support mechanisms based on life-cycle segmentation (table 4).

Table 4

Characteristics of health risk and policy mechanisms

Life-cycle stage	Health risk characteristics	Priority policy mechanisms
Infancy and early childhood (0–3 years)	Underdeveloped physiological systems, weak immunity, highly sensitive to nutrition and environmental factors	Strengthen maternal and child health services, improve vaccination coverage and precision in early nutrition interventions
Childhood and adolescence (3–18 years)	Rapid physical and mental development, initial behavioural formation, notable emotional volatility	Promote school-based health education, adolescent mental health interventions, and healthy behaviour development programmes
Working age (18–60 years)	Dual pressure from work and family, increased risk of chronic diseases, fluctuating health behaviours	Establish workplace-based health promotion systems , develop occupational health services and chronic disease screening for middle-aged individuals
Old age (60 years and above)	Coexistence of multiple illnesses, significant functional decline, increased dependence on care	Develop policies for healthy aging, promote long-term care insurance and integrated community-based eldercare services

As shown in table 4, infancy and early childhood represent the starting point of health capital accumulation and serve as a critical window for later physical and cognitive development. At this stage, the immature immune system makes infants highly vulnerable to malnutrition, infectious diseases, and environmental pollution. These factors can lead to insufficient health reserves or even adverse outcomes in early life development. To ensure a strong foundation for individual health capital, it is essential to expand the coverage of maternal and child health services, increase access to and uptake of vaccinations, and strengthen early nutrition interventions.

Childhood and adolescence constitute periods of rapid growth during which individuals begin to form behavioural habits, health awareness, and psychological structures. If health education is lacking or if unhealthy lifestyles are adopted during this stage, long-term negative consequences such as obesity, depression, and addiction may arise. Policy responses should emphasise the standardisation of health education in schools, the integration of mental health services into the school system, and the promotion of healthy habits related to diet, physical activity, and sleep. This approach helps to build a comprehensive and early-stage mechanism for health cultivation.

The working-age period is a critical phase for both the accumulation and return on health human capital. It is also the period with the highest risk of chronic diseases. Stress from work, a fast-paced lifestyle, and unhealthy eating habits can trigger metabolic and cardiovascular conditions. It is necessary to establish a health security system that emphasises proactive screening, early intervention, and personal responsibility. This includes implementing occupational health standards, encouraging regular health check-ups through workplace incentives, and developing health-promoting work environments to improve both healthy life expectancy and labour productivity.

In older adulthood, health human capital tends to decline more rapidly due to the coexistence of multiple chronic conditions, functional impairments, and reduced capacity for social participation. There is a significantly

increased reliance on care services. Policy efforts should shift focus from treatment-oriented systems to care-oriented frameworks. This involves improving long-term care insurance programmes, strengthening community-based rehabilitation and eldercare networks, and promoting in-home aging support and adaptation services. These measures are essential to ensuring a basic quality of life and dignity for older populations.

A life-cycle-based strategy relies on a progressive logic of early prevention, midlife intervention, and later-stage care. By identifying key population groups in advance and applying precise management, this approach makes it possible to shift the focus of disease control to earlier stages, reduce the long-term cost of health maintenance, and enhance the overall efficiency of health capital accumulation. Structuring the pathway to enhance health capital from a life-cycle perspective improves policy precision, promotes efficient allocation of resources, and supports sustained health interventions. This is a critical component in advancing the strategy «Healthy China» to a more comprehensive and sustainable level.

Multi-stakeholder synergy mechanisms: advancing policy implementation and systemic integration. The formation and enhancement of health capital do not rely solely on the healthcare system itself, but rather constitute a systemic endeavor that spans multiple sectors and engages a wide array of stakeholders. Based on this understanding, this paper categorises the pathways for improving health capital into four core intervention mechanisms: government intervention, social support, corporate responsibility, and individual agency (fig. 5).

This multi-stakeholder coordination framework provides both a governance foundation and practical pathways for addressing the structural bottlenecks, institutional barriers, and behavioural inertia that often hinder the accumulation of health capital. Firstly, the government intervention mechanism. The government serves as the core actor in institutional provision and macro-level guidance, playing a dual role as both the designer of institutions and allocator of resources in the formation of health capital. It holds an irreplaceable leadership position particularly in the provision of fundamental public services, industrial policy orientation, and environmental governance. Governmental policy interventions not only directly improve health outcomes through service provision but also shape health-related behaviours of other actors via institutional regulations and fiscal incentives, thereby establishing a foundational institutional framework for the accumulation of health capital.

Secondly, the social support mechanism. The active participation of social organisations and social capital helps to fill the gaps in government resources and information, playing unique roles in health promotion, coverage of vulnerable groups, and dissemination of health-related values. The key to the social support mechanism lies in stimulating «collaborative externalities» and achieving «social embedding» in health governance, which enhances the equity and cultural adaptability of interventions.

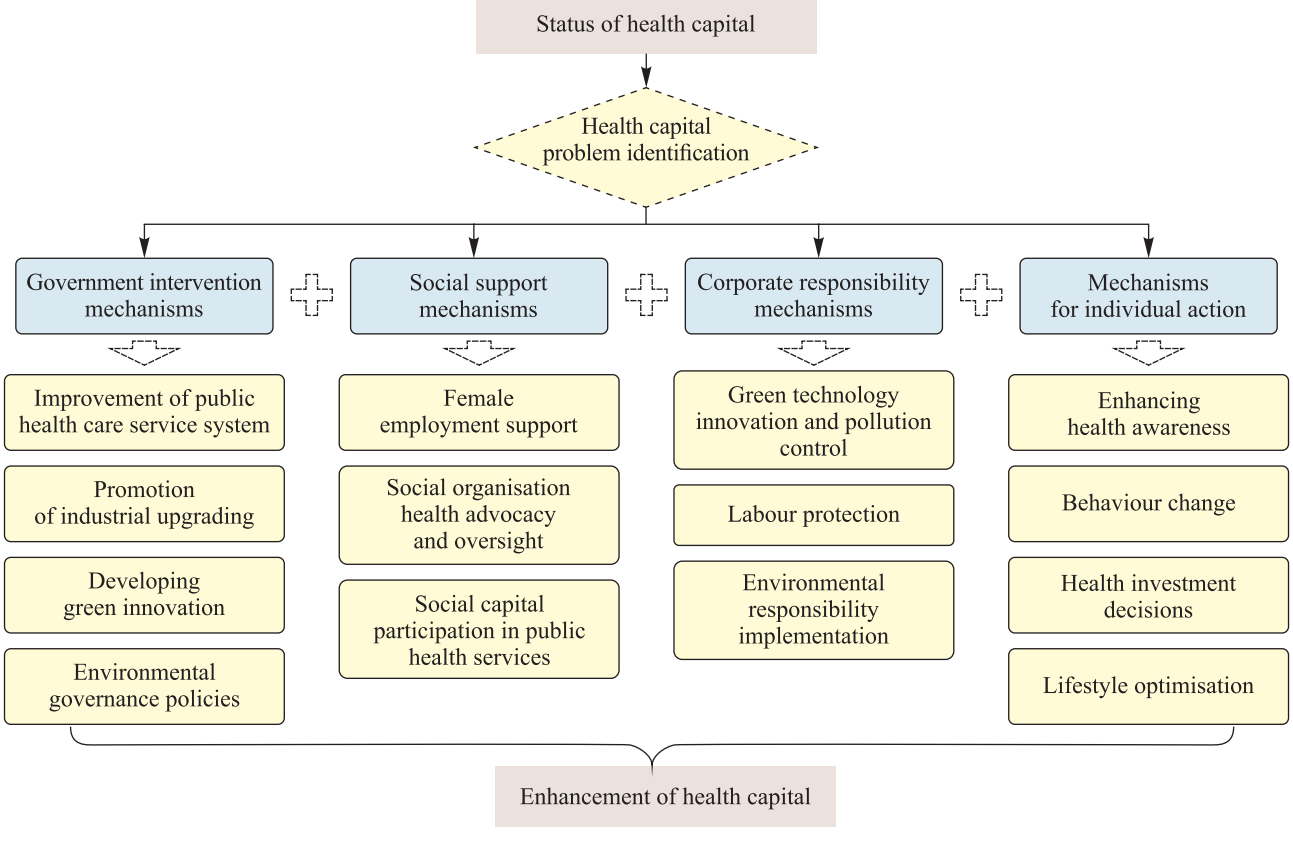

Fig. 5. A multi-actor strategic framework for enhancing health capital

Thirdly, the corporate responsibility mechanism. As the core entity of labour organisation and technology provision, enterprises not only directly affect the health status of their employees but also indirectly influence societal health levels through their production processes, environmental emissions, and resource allocation. Enterprises are not only controllers of healthy production conditions but should also act as collaborators in realising the value of health capital. Institutionalising corporate responsibility mechanisms provides a market foundation for promoting sustainable health development.

Finally, the individual action mechanism. Individuals are the ultimate bearers of health capital, and their behavioural choices directly impact the efficiency of health capital accumulation and depletion. Individual behaviour is the ultimate carrier for the implementation of multi-level interventions. Effective health governance must pay attention to the incentive structures and support conditions for behavioural transformation to achieve the «last mile» closure from cognitive awareness to behavioural execution.

In summary, the essence of the multi-stakeholder coordination mechanism lies in embedding health capital enhancement within a nested system of institutions, society, markets, and individuals. By clearly delineating roles, strengthening linkages, and sharing responsibilities among these mechanisms, health policies can shift from fragmented provisions to systematic collaboration, thus enabling the effective transformation of health capital from an «individual condition» into an «economic resource». The framework illustrated in fig. 5 offers logical support and practical pathways for constructing a new governance synergy pattern under the strategy «Healthy China».

Conclusions

National health, as a vital part of the sustainable and harmonious development of the country and society, is a fundamental need of the people and a crucial foundation for socioeconomic development. It holds strategic significance in advancing China's path of modernisation with Chinese characteristics. Under the strategy «Healthy China», health capital, as a core driver of high-quality development, has attracted increasing attention regarding its economic value, institutional foundations, and policy pathways. Based on a systematic review of the current development status of health capital in China, this paper identifies the existing challenges and bottlenecks in the sustainable growth of health capital. Employing an extended Cobb – Douglas production function, we formally incorporate health capital into the production framework, revealing its deep mechanisms of influence on macroeconomic growth by enhancing labour efficiency and total factor productivity. Furthermore, we construct a four-dimensional health capital index and a composite health capital index, providing a quantitative foundation for policy analysis and dynamic monitoring. To promote the sustainable and high-quality development of health capital, this paper proposes a systemic optimisation pathway centered on the concepts of the «full life cycle» and «multi-stakeholder collaboration». This approach designs staged intervention mechanisms assigning responsibilities across government, society, enterprises, and individuals. Based on the above, the following policy recommendations are put forward.

1. Strengthen foundational investments in health capital. Increase government fiscal input in basic medical and health services, especially targeting rural areas, severely aging regions, and less developed central and western provinces. Promote balanced deployment of medical infrastructure and public health systems. According to World Bank data, medical and health investment in low-income countries accounts for less than 3 % of GDP, while high-income countries generally exceed 8 %. China still has room for improvement.

2. Establish a nationwide health promotion system to enhance individual health capital reserves. First, formulate and implement a national-level action plan for health promotion, formally integrating health capital into the macro policy framework and fiscal evaluation systems to elevate its priority in resource allocation. Second, strengthen health behaviour interventions and mental health development, particularly focusing on youth and working-age populations, promoting integrated development of health education and medical services. Third, leverage platform «Internet Plus Healthcare» to expand online health management, chronic disease follow-ups, and preventive services, improving accessibility and convenience of health promotion.

3. Improve elderly health protection systems to actively address population aging challenges. On one hand, accelerate the establishment of community-based elderly health service networks and promote the development of integrated medical and elderly care institutions to realise seamless «medical-rehabilitation-nursing-elderly care» services. On the other hand, advance pilot programmes and national rollout of long-term care insurance systems to alleviate family caregiving burdens and enhance health capital maintenance for disabled and semi-disabled elderly. According to data from the China Insurance Industry Association, by 2050 the number of disabled elderly will exceed 90 mln, underscoring the urgent growth in long-term care demand. Additionally, promote the smart elderly care industry by applying intelligent monitoring, telemedicine, and big data management to improve elderly health management and service efficiency.

4. Build multi-department coordination mechanisms and cross-stakeholder collaboration platforms to integrate government, enterprises, social organisations, and research institutions in modernising health governance. First, strengthen the concept «Health in All Policies» by embedding health objectives into policymaking and implementation across urban planning, transportation, education, environmental protection, employment, and other sectors. Second, establish a national-level system «Health Impact Assessment» to conduct health impact analyses prior to major policies and projects, ensuring cross-sectoral coordination in promoting national health. Third, improve comprehensive chronic disease prevention and control strategies by addressing rising incidence and obesity rates through integrated initiatives such as tobacco and alcohol control, nutritional interventions, and physical activity promotion, fostering a multi-sector joint effort and population-wide participation environment for health support.

5. As a foundational and long-term capital for national development, the systematic accumulation and efficient governance of health capital will be key supports for China's sustainable socioeconomic progress. The theoretical construction, indicator measurement, and policy innovation related to health capital bear significant theoretical and practical importance.

It should be noted that despite the systematic exploration in theoretical modelling and policy design, limitations remain. First, constrained by data availability and methodological frameworks, this paper has not conducted large-sample empirical estimation or regional heterogeneity analysis of the HHCI. Second, the model assumes structural stability and does not fully consider short-term disturbances to health capital caused by shocks such as pandemics or institutional reforms. Third, corporate-level investment behaviour mechanisms in health capital still require further micro-level modelling and validation.

Future research will focus on empirically testing the impact of health capital on individual income and returns to human capital based on microdata; analysing health capital accumulation pathways and policy effects across regions at different development stages considering regional heterogeneity; exploring applications of artificial intelligence, big data, and other technologies in monitoring, forecasting, and governance of health capital to promote the construction of an intelligent health capital system.

References

1. Marmot M. Achieving health equity: from root causes to fair outcomes. *Lancet.* 2007;370(9593):1153–1163. DOI: 10.1016/S0140-6736(07)61385-3.

2. Bloom DE, Canning D. The health and wealth of nations. *Science.* 2000;287(5456):1207–1209. DOI: 10.1126/science.287.5456.1207.

3. Grossman M. On the concept of health capital and the demand for health. *Journal of Political Economy.* 1972;80(2):223–255.

4. Becker GS. *Human capital: a theoretical and empirical analysis with special reference to education.* New York: Columbia University Press; 1975. 390 p.

5. Heckman JJ. The economics, technology, and neuroscience of human capability formation. *PNAS.* 2007;104(33):13250–13255. DOI: 10.1073/pnas.0701362104.

6. Well DN. Accounting for the effect of health on economic growth. *Quarterly Journal of Economics.* 2007;122(3):1265–1306. DOI: 10.1162/qjec.122.3.1265.

7. Cutler DM, Lleras-Muney A. Education and health: evaluating theories and evidence. In: House JS, Schoeni RF, Kaplan GA, Pollack H, editors. *Making Americans healthier: social and economic policy as health policy*. New York: Russell Sage Foundation; 2006. p. 29–60. DOI: 10.3386/w12352.

8. Becker GS. *Human capital: a theoretical and empirical analysis with special reference to education.* New York: National Bureau of Economic Research; 1964. 187 p. DOI: 10.1177/000271626536000153.

9. Mushkin SJ. Health as an investment. *Journal of Political Economy.* 1962;70(5):129–157. DOI: 10.1086/258730.

10. Fuchs VR. *Economic aspects of health.* Chicago: University of Chicago Press; 1982. 344 p. (NBER conference report).

11. Schultz TP, Tansel A. *Measurement of returns to adult health: morbidity effects on wage rates in Côte d'Ivoire and Ghana.* New Haven: Yale University; 1992. 56 p.

12. Bhargava A, Jamison DT, Lau LJ, Murray CJL. Modeling the effects of health on economic growth. *Journal of Health Economics.* 2001;20(3):423–440. DOI: 10.1016/S0167-6296(01)00073-X.

13. Bloom DE, Canning D, Sevilla JP. *The effect of health on economic growth: theory and evidence.* Cambridge: National Bureau of Economic Research; 2001. 29 p. (NBER working paper; no. 8587). DOI: 10.3386/w8587.

14. Aguayo-Rico A, Guerra-Turrubiates IA, de Oca-Hernández RM. Empirical evidence of the impact of health on economic growth [Internet]. *Issues in Political Economy.* 2005;14 [cited 2025 February 12]. Avalaible from: https://blogs.elon.edu/wp-content/blogs.dir/456/files/2021/02/v14-aguayorico-final.pdf.

15. Gong L, Li H, Wang D. Health investment, physical capital accumulation, and economic growth. *China Economic Review.* 2012;23(4):1104–1119. DOI: 10.1016/j.chieco.2012.07.002.

16. Strauss J, Thomas D. Health, nutrition, and economic development. *Journal of Economic Literature.* 1998;36(2):766–817.

17. Smith JP. The impact of childhood health on adult labor market outcomes. *Review of Economics and Statistics.* 2009;91(3):478–489. DOI: 10.1162/rest.91.3.478.

18. Balaj M, McNamara CL, Eikemo TA, Bambra C. The social determinants of inequalities in self-reported health in Europe: findings from the European Social Survey (2014) special module on the social determinants of health. *European Journal of Public Health.* 2017;27(1):107–114. DOI: 10.1093/eurpub/ckw217.

19. Wang D, Li X, Huang L. How does health investment affect economic growth? Based on a cross country panel data analysis. *Economic Science.* 2019;1:5–17. Chinese.

20. Hao F, Zhang Y. Measuring health capital of Chinese residents: from the perspective of «Healthy China». *Population and Economy.* 2019;1:14–30. Chinese.

21. Xie Z, Yang J. Government health care expenditures, healthy human capital, and China's rural economic growth. *Statistics and Decision.* 2020;36(7):41–45. DOI: 10. 13546/j.cnki.tjyjc.2020.07.009. Chinese.

22. Wang H, Zhang J, Wu Z, Li H. Research on health human capital index system. *Shanghai Management Science*. 2017;39(4): 30–34. Chinese.

23. Zhang H. *Study of impact of health on China's economic growth* [dissertation]. Beijing: Capital University of Economics and Business; 2018. 138 p. Chinese.

24. Wang H, Zhu X. The influencing factors on health inequality on the middle-aged and elderly. *Chinese Journal of Population Science.* 2018;3:109–120. Chinese.

25. Liu Y. Does the lifestyle affect the health of the elderly? Evidence from older people in China. *Population and Development.* 2018;24(4):77–86. Chinese.

26. Bian H, Cui J, Tang D. Health status and policy implications for left-behind children in underdeveloped rural areas of China. *Social Science Research.* 2018;2:114–124. Chinese.

27. Bai X, Zhu Y, Qu B. Application of the Nottingham Health Profile in evaluating life quality of medical students. *Chinese Journal of Health Statistics*. 2019;36(1):103–105. Chinese.

28. Xiao J. *Health human capital. Concept, measurement, and its impact on job performance and well-being* [dissertation]. Chengdu: Southwestern University of Finance and Economics; 2020. 218 p. Chinese.

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