

## Examining the Economic Value of Investing in Health

**Peixin WU**

*School of Economics and Management, University of Chinese Academy of Sciences, Beijing 100190, China; Peking Union Medical College Hospital, Chinese Academy of Medical Sciences, Beijing 100730, China*

**Shouyang WANG**

*School of Economics and Management, University of Chinese Academy of Sciences, Beijing 100190, China; Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100190, China; Center for Forecasting Science, Chinese Academy of Sciences, Beijing 100190, China*

**Abstract** This review article examines the relationship between health and economic development, highlighting the economic benefits of investing in health. The rise of non-communicable diseases (NCDs) and the COVID-19 pandemic have exposed high demand for increased investment in health as well as critical gaps in the global health system, particularly in low- and middle-income countries, where investments in primary healthcare and innovations in health technologies are lacking. The article emphasizes the importance of examining the economic impact of health, providing a summary of the different pathways through which health impacts the economy and reviewing various economic analyses, including a novel methodology called the health-augmented macroeconomic model (HMM) for evaluating the macroeconomic value of investing in health. The article suggests that reducing disease burdens can effectively generate sizable economic returns, and it is vital to integrate the concept of economic value in health policies and interventions.

**Keywords** investing in health; macroeconomic value; economic returns; health-augmented macroeconomic model

### 1 Introduction

Over the years, a bi-directional causal relationship between health and economic development has been clearly established. While health had traditionally been viewed as a consumption, concrete evidence has demonstrated the considerable economic value that can result from improved health. For instance, estimates of the return on investment for health in the United States show that the economic benefits of improved health exceed the corresponding health expenditures<sup>[1]</sup>. Health has also been identified as a crucial determinant of economic growth in Mexico<sup>[2]</sup>. Studies have also found that declining health brought by diseases such as the AIDS pandemic and maternal and child health conditions inhibit economic growth<sup>[3, 4]</sup>. It is thus important to raise awareness in viewing health as an investment rather than a cost.

The case for increased investment in health has been further substantiated by the highly prevalent rates of non-communicable diseases (NCDs)<sup>[5, 6]</sup> that accompanies the global demographic transition from younger populations to aging populations. NCDs are a set of chronic

conditions that are driven by behavioral, environmental, genetic, and physiological factors, and they often require long-term care and treatment<sup>[7]</sup>. Examples include cancer, diabetes, cardiovascular diseases, and more. In fact, in 2017, NCDs were reported to be responsible for over 70% of global mortality<sup>[8]</sup> and induce broad social and economic costs<sup>[9]</sup>. Bloom, et al.<sup>[10]</sup> showed that implementing World Health Organization's Best Buy interventions, which is a set of cost-effective interventions targeted at reducing NCD mortality and morbidity given the constraints in low- and middle-income countries (LMICs), could save 10%~15% of LMIC's economic costs from NCDs. In addition, the COVID-19 pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has led to almost 7 million deaths globally as of June 2023<sup>[11]</sup> and exposed critical gaps in the global health system, particularly in LMICs<sup>[12]</sup>. Specifically, lack of investments in primary healthcare and innovations in health technologies<sup>[12]</sup> is identified as a key restraint in global health crises. While there are several definitions of innovation, many focus on novel product or approaches that add social or economic value and brings significant and meaningful improvements<sup>[13]</sup>. Consequently, this could generate a negative feedback loop in which the health sector and the economy impede each other's development. In particular, the impact of health on the economy has been highlighted over the course of the pandemic<sup>[14]</sup>. Therefore, as society faces increasingly more health challenges, whether it be the currently rampaging COVID-19 pandemic, or the rising non-communicable disease burden, the importance of further integrating the notion of economic value into health interventions and policies has become urgently warranted. Both the economic benefits of improving health and healthcare<sup>[15]</sup> and the value of utilizing economic analyses should be taken into consideration when aiming towards this goal<sup>[16]</sup>.

This review article aims to address the question of why the economic value of health needs to be rigorously examined as well as underscores the critical importance of examining the economic impact of health using economic analyses. This is accomplished by summarizing a range of pathways through which improved health can contribute to economic development and providing a comprehensive review of the different mechanisms through which health impacts the economy as well as various economic analyses, including a novel methodology in evaluating the macroeconomic value of investing in health. Moreover, this review article, for the first time, systematically reviews existing literature that utilizes the health-augmented macroeconomic model (HMM), bridging a knowledge gap related to HMM. This paper is organized as follows. First, it will summarize pathways through which health or healthcare interventions that reduce disease burdens contribute to economic growth. Second, it will summarize current methodologies in quantifying the economic value of reducing disease burdens as well as effective applications of them. Third, this article will introduce the health-augmented macroeconomic model. Lastly, it will conclude by discussing recommendations for future best practices.

## 2 Health Improvement and Economic Growth

There are several pathways through which improving health and reducing disease burdens can contribute to economic growth and development. First, reducing mortality rates can result in a larger labor force. When there is a decrease in the number of deaths, more individuals are available to participate in the workforce, thereby increasing the overall supply of labor<sup>[17]</sup>. This

can have a positive impact on the economy by increasing productivity and economic growth.

Second, eliminating diseases can also increase labor participation rates. Labor supply is found to be 19% below its potential in the presence of chronic conditions in Egypt<sup>[18]</sup>. By reducing the negative impact of illness on employment, the number of individuals who choose to participate in the workforce can increase significantly, in turn leading to an increase in the overall supply of labor and thus boosting productivity<sup>[17]</sup>.

Third, treatment costs can be reduced following improvements in health outcomes. Health shocks can be economically devastating for households in LMICs, according to Alam and Mahal<sup>[19]</sup>. For instance, a recent study found a strong association between medication costs of hypertension and diabetes and household catastrophic health expenditure in Pakistan and called for household protection from economic burden induced from NCD treatment<sup>[20]</sup>. When diseases are eliminated or their impact is alleviated, the resources, including household savings, which would have otherwise been used to treat these illnesses can be redirected towards other productive activities<sup>[17]</sup>. This can increase savings and investment, which in turn can boost the accumulation of physical capital and contribute to economic growth.

Fourth, reducing diseases allows healthier children to stay in school for longer periods of duration and reduce absenteeism<sup>[14]</sup>. This in turn is associated with better employment higher earnings later in life<sup>[4]</sup>. The resulting more positive educational outcomes would lead to larger human capital accumulation for societal benefits and economic growth.

Fifth, demographic dividends can be extracted from demographic transitions through improved health<sup>[21]</sup>. For example, a population with a greater proportion of older adults can provide accumulation of capital should longevity be enhanced<sup>[22]</sup>. Moreover, healthy aging for older adults can strengthen intergenerational benefits and societal wellbeing through continued work or volunteering from older adults, thereby contributing to economic growth<sup>[22]</sup>.

Sixth, health technology is another pathway through which improvements in health lead to economic growth and development. Health technologies can increase total factor productivity (TFP) in the healthcare sector, which can result in improved health outcomes, increased efficiency, and reduced costs, all of which can contribute to a more productive and competitive economy. By driving innovation and efficiency, health technologies can lead to the creation of new industries and jobs, and can also improve the productivity of other sectors by keeping the workforce healthy. Moreover, advances in health technologies can also have spillover effects into other sectors, such as information and communication technologies, and can promote the development of new products and services that can improve the quality of life for people around the world. Thus, health technologies can play a critical role in supporting sustainable economic growth and development.

The above explained pathways demonstrate the critical importance of health to the economy, showing how investing in health is essential for ensuring long-term economic growth and stability. The economic value of investing in health should be highly emphasized in future healthcare discussions. Policymakers, healthcare providers, and the private sectors should work together to ensure that investment in health is prioritized and properly funded, in order to support sustainable economic growth and development.

### 3 Methods in Quantifying the Economic Value of Health

Understanding the significance of health to the economy is not sufficient; there should also be more efforts being put into research that quantifies the economic value of reducing disease burdens. Common methods include cost-of-illness (COI), value of statistical life (VSL), economic growth regression, and macroeconomic models. These methods are introduced in detail below.

#### 3.1 Cost of Illness (COI)

COI calculates the direct and indirect costs associated with a specific health burden<sup>[23]</sup>. In the 1960s, health economists such as Rice first elaborated on the calculations of the cost of illness<sup>[24]</sup>. A few years later, Hodgson and Meiners provided guidelines for those intending to conduct COI studies<sup>[25]</sup>. Afterwards, Byford<sup>[26]</sup> concludes that COI studies aim to identify and measure all the costs of a particular disease, including the direct, indirect, and intangible dimensions. Specifically, direct costs can be categorized into healthcare and non-healthcare costs. Healthcare costs refer to expenses associated with medical care services, including diagnosis, treatment, and rehabilitation<sup>[27]</sup>. Non-healthcare costs encompass the consumption of resources unrelated to direct medical care, such as transportation to and from healthcare facilities, specific household expenses, relocation costs, property damage, legal and court fees, and the cost of informal care provided by family members. Indirect costs relate to productivity loss, which includes mortality costs (i.e., the value of lost productivity due to premature death as a result of diseases) and morbidity costs (i.e., the value of lost productivity of persons unable to perform at full capacity due to illnesses)<sup>[27]</sup>. A common problem is that COI estimates vary widely between studies due to differences in cost inclusion and exclusion criteria, raising concerns about the validity of resulting estimates and methods used<sup>[28]</sup>.

#### 3.2 Value of Statistical Life (VSL)

VSL is an economic metric that gauges an individual's preference for reducing health risks over consuming other goods and services and is commonly employed in policy analysis<sup>[29]</sup>. Schelling introduced the VSL, marking the beginning of the transition to trade-offs between health risks and wealth as an appropriate economic tool for conceptualizing the valuation of mortality risk<sup>[30]</sup>. Early reliable estimates of VSL were developed through empirical surveys in the 1980s and subsequently used by US government agencies to assess changes in mortality risk<sup>[31]</sup>. After a while, the belief that age matters when calculating the VSL has led some to focus on simpler approaches, such as the 'value of a statistical life year' (or VS LY)<sup>[32]</sup>. Typically, this is obtained by dividing the VSL by the expected number of years of life remaining. In line with lifetime consumption, it is usually argued that the remaining years of life themselves should be discounted. However, when the beneficiaries of a risk reduction are different from the payers, the observed decision may differ substantially from a reasonable estimate of the VSL due to the difference in preference between these two groups.

#### 3.3 Economic Growth Regression

Economic growth regression, as indicated by its name, examines the impact of health indicators on economic growth<sup>[33]</sup>. The economic growth regression method is derived from the

field of research on the determinants of economic growth and is characterized by the use of health indicators as the key independent variables<sup>[34, 35]</sup>. Barro found a substantial positive effect of health (as assessed by life expectancy) on economic growth<sup>[35]</sup>. Bhargava, et al. used adult survival rates (i.e., effectively the inverse of adult mortality rates) between the ages of 15 and 60 as a health proxy to evaluate the impact of health on economic growth based on a global panel data set for the years 1965 to 1990<sup>[36]</sup>. Despite their advantages with regards to solid theoretical foundations, regressions can also have disadvantages and are often misused due to four main challenges: omitted variables, reverse causality, mismeasurement in an explanatory variable, and limited robustness in coefficient.

### 3.4 Macroeconomic Models

Macroeconomic models explore the dynamics of economic indicators affected by health indicators in an economy. Realizing the insufficiencies of the other methods, such as COI and VSL, in accounting for economic adjustment mechanisms, the World Health Organization developed the Economic Projections for Illness and Cost of treatment model (EPIC) to address this problem. Based on the Solow growth model<sup>[37]</sup>, the EPIC model was applied, during 2006, in the estimation of the economic impact of chronic noncommunicable diseases in nine countries<sup>[38]</sup>. The EPIC model has also been used to estimate the economic burden of chronic conditions in India, China, and Indonesia, as well as worldwide<sup>[10, 39, 40]</sup>. The advantage of EPIC is that it allows economic adjustment mechanisms and relates aggregate output (GDP) to labor and capital loss due to NCDs. The Pan American Health Organization and Harvard T.H. Chan School of Public Health then used a revised version of the EPIC model (EPIC-H Plus) to estimate the impact of NCDs on economic growth in Costa Rica, Jamaica, and Peru<sup>[41]</sup>. The EPIC-H Plus model extends the existing EPIC models by including morbidity-related reductions in labor supply and reductions in capital accumulation due to increased healthcare spending diverting from savings. Further noting the limitations of the EPIC-H Plus model, in 2018<sup>[42]</sup>, the health-augmented macroeconomic model (HMM), which was built on the Lucas production function<sup>[43]</sup>, contributes by allowing productivity loss to be stratified by education and experiences. HMM has been widely used in the economic evaluation of health indicators, mainly in the economic cost of diseases<sup>[42, 44, 45]</sup>, risk factors<sup>[17, 46]</sup>, and economic returns of health policies<sup>[15, 46]</sup>, such as the economic burden of tobacco use<sup>[46]</sup> and road injuries<sup>[45]</sup>. Due to its relevance and benefits to effective resource allocation, the HMM approach is highly valuable to the decision-making process in not only the public health field, but also the fields of management science and public policy.

HMM considers several pathways when assessing the impact of diseases on the economy. Firstly, diseases reduce effective labor supply through mortality and morbidity, since fewer individuals would be available to work with mortality and morbidity leading to lower productivity and higher absenteeism. Secondly, households with family members affected by diseases use a portion of their savings to cover treatment costs, thereby reducing aggregate savings and investments and negatively affecting the accumulation of physical capital. The HMM model accounts for these pathways in a macroeconomic production framework. Further details on the comparisons of these mentioned methods can be found in Table 1.

**Table 1** Comparisons of common methods used in quantifying the economic value of healthcare

Methods	Definitions	Advantages	Limitations
Cost of illness (COI)	Summarizing the burden of a certain disease over a particular time in a single number; personal medical care costs (e.g., inpatient and outpatient hospital costs) plus non-personal costs (e.g., for research activities) plus loss of income (due to absenteeism, early retirement, or premature death)	The outcome is easily interpreted as the monetary value of the resources that could be saved by avoiding a specific disease	1. No economic adjustment mechanisms are considered (e.g., substitution of labor lost due to an illness by capital or other workers); 2. Disregard the effect of diseases on physical capital and human capital accumulation
Value of statistical life (VSL)	Estimating a person's willingness to accept premia for risky occupations via wage regressions; estimating a person's willingness to pay for the reduction of risks via hedonic price regressions	The value of statistical life, if multiplied by the number of cases, can be interpreted as the total statistical value of the loss due to an illness; it also considers the costs of pain and suffering	1. No economic adjustment mechanisms are considered; 2. The statistical loss due to an illness strongly depends on the age and the income level of workers
Economic growth regression	Regress the economic growth rate on the prevalence of the illness	Estimated growth effect is apparent; Approximately specified regression incorporates economic adjustment mechanisms	1. Requiring a wide range of precisely measured control variables for all countries in the sample; 2. Difficulty in detecting the significant effect for less severe diseases; 3. Endogeneity problem: reverse causality and omitted variable bias
Macroeconomic models	Extended model from EPIC model, allowing different age groups of workers to have different education levels and different levels of experience, addressing the lack of a morbidity mechanism by incorporating information on disease morbidity.	1. Accounts for the productivity loss among people with different education and experience levels; 2. Takes into account morbidity effect and treatment cost effect	1. Not a general equilibrium model; 2. Does not consider the impact of growth on health

While there exist limitations to each method used in quantifying the economic value of healthcare, as shown in Table 1, it is important to continue refining methodological approaches.

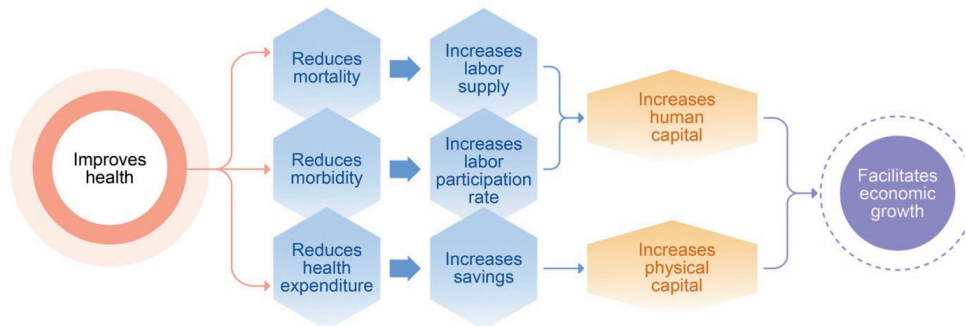
Main considerations should include indirect loss of productivity, ethical issues regarding subjective judgment of assigning value, comprehensiveness in accounting for different pathways through which health impacts the economy, and more. In addition, current literature examining economic analyses tend to focus on economic evaluations<sup>[47, 48]</sup>, such as cost-effectiveness analyses and cost-utility analyses<sup>[49]</sup>, which compares between different interventions rather than estimate the economic value of investing in health. By providing a review of common methods in evaluating economic value of healthcare as well as introducing a novel approach to measuring the macroeconomic value of investing in health, this review article promotes commitment to improved methods in examining the economic value of improving health.

## 4 Health-Augmented Macroeconomic Model (HMM)

### 4.1 Model Framework and Assumptions

*The HMM model is built on the Lucas production function.*

The HMM model is a novel approach to estimating the economic value of reducing disease burdens and health policies. HMM considers several factors when assessing the impact of health on the economy. It takes into account the effect of treatment costs on capital accumulation, the fact that diseases and health conditions can result in not just death, but also in reduced productivity and health, and the differences in human capital levels among workers of different age groups. HMM can be used to calculate the overall economic impact of diseases as well as estimate the economic benefits of reducing or eliminating diseases (Figure 1).



**Figure 1** HMM model framework. Adapted from Chen and Bloom<sup>[17]</sup>

Building upon Lucas<sup>[43]</sup>, the following production function is as follows for HMM:

$$Y_t = A_t K_t^\alpha H_t^{1-\alpha}, \quad (1)$$

where  $Y_t$  is aggregate output;  $A_t$  is the technological level at time  $t$ , which we assume evolves exogenously;  $K_t$  is the physical capital stock (i.e., machines, factory buildings, etc.); and  $H_t$  represents aggregate human capital. The parameter  $\alpha$  is the elasticity of final output with respect to physical capital. The aggregate production function recognizes that output is not only produced with physical capital and raw labor as in the Solow framework<sup>[50]</sup>, on which the WHO's original EPIC macroeconomic model is based<sup>[38]</sup>, but with *effective labor*, of which health is a crucial determinant. The effects of technological change are not included, which is a

limitation of HMM, but the changes in labor and physical capital due to diseases are provided as following.

*Impact of treatment cost on physical capital.*

Treatment cost for diseases is diverted from private and public savings as well as capital, reducing household and government reinvestment, and thus lowering long-term physical capital and impeding economic growth. Physical capital evolves according to

$$K_{t+1} = (1 - \delta)K_t + Y_t - C_t - TC_t = (1 - \delta)K_t + s_t Y_t, \quad (2)$$

where  $\delta$  refers to the depreciation rate,  $s_t$  refers to the saving rate,  $TC_t$  refers to the costs of ongoing treatment of diseases, and  $C_t$  refers to the amount of consumption. From Equation (2), it follows that the saving rate is defined as

$$s_t = 1 - \frac{C_t + TC_t}{Y_t}.$$

Note that aggregate output  $Y_t$  is used for three purposes: (i) to pay treatment costs  $TC_t$  (hospitalization, medication, etc.), (ii) to consume the amount  $C_t$ , and (iii) to save. The use of or preparation for the cost of treatment for diseases reduces the rate of savings and investment in total capital, thus impeding capital accumulation.

*Impact of mortality and morbidity on human capital.*

Mortality and morbidity reduce effective labor supply by reducing total labor population and labor participation rate. Individuals of age group  $a$  are endowed with  $h_t^{(a)}$  units of human capital and supply  $l_t^{(a)}$  units of labor from age 15 up to their retirement at age  $R$ , i.e., for  $a \in [15, R]$ . Children below the age of 15 and retirees above the age of  $R$  do not work.  $R$  varies by country and could correspond to a high age (e.g., some people older than 80 could also be working). In the theoretical derivations,  $R$  indicates the upper bound of the summation. Labor projections data from the International Labour Organization where positive values for the labor force exist for cohorts above the age of 65 is used. Aggregate human capital in the production function (1) is then defined as the sum over the age-specific effective labor supply of each age group:

$$H_t = \sum_{a=15}^R h_t^{(a)} l_t^{(a)} N_t^{(a)}, \quad (3)$$

where  $N_t^a$  denotes the number of individuals in age group  $a$ . Note that aggregate human capital increases with the number of working-age individuals who live in the economy (i.e., with a higher  $N_t = \sum_{a=15}^R N_t^{(a)}$ , with individual human capital endowment (i.e., with a higher  $h_t^{(a)}$  for at least one  $a$ ), and with labor supply (i.e., with a higher  $l_t^{(a)}$  for at least one  $a$ ). The reduction of the labor participation rate  $l_t^{(a)}$  captures the morbidity effect because people with an illness typically reduce their labor supply, either by reducing working hours or by leaving the workforce. Furthermore, both mortality and morbidity reduce effective labor supply. The reduction of the population size  $N_t^{(a)}$  thus captures the mortality effect.

We consider differences in labor force level across different educated or trained populations by the Mincer equation<sup>[51]</sup>. The average human capital of the cohort aged  $a$  based on an

exponential function of education and work experience is constructed:

$$h_t^{(a)} = \exp[\eta_1(ys_t^{(a)}) + \eta_2(a - ys_t^{(a)} - 5) + \eta_3(a - ys_t^{(a)} - 5)^2], \quad (4)$$

where  $\eta_1$  is the semi-elasticity of human capital with respect to average years of education as given by  $ys_t^{(a)}$ , and  $\eta_2$  and  $\eta_3$  are the semi-elasticities of human capital with respect to the experience of the workforce  $(a - ys_t^{(a)} - 5)$  and the experience of the workforce squared  $(a - ys_t^{(a)} - 5)^2$ , respectively. A school entry age of 5 years is assumed throughout.

*Cornerstone, limitations, and applications of HMM.*

The cornerstone of HMM, encompassing both the Lucas production function and the Mincer equation, finds validation in empirical studies. In particular, HMM is well-suited under the context of chronic diseases and related risk factors<sup>[41]</sup>, and it has been applied to several countries, including China<sup>[52]</sup>, the United States<sup>[53]</sup>, and more. Empirical analyses of cross-country data attest to the significance of human capital in economic progress<sup>[54]</sup>. Typically, human capital's output elasticity ranges between 0.3 and 0.8, while physical capital oscillates between 0.2 and 0.6, supporting the contribution of both human and physical capital to economic growth, which lends credibility to the Lucas function<sup>[55–57]</sup>. However, the evidence for human capital externalities in the Lucas function is rather limited<sup>[58]</sup>. To accurately portray labor force changes, we analyze the effect of education on workforce dynamics using the Mincer equation, which is confirmed by empirical studies of the beneficial effect of education on wages<sup>[59, 60]</sup> and the nonlinear effect of work experience<sup>[61, 62]</sup>. Still, challenges remain, highlighted by Moretti's observation of the positive externalities of higher education levels for society at large, which suggests potential underestimations when applying Mincer's equation on the macroeconomic level<sup>[63]</sup>. In sum, the foundational principles of the Lucas function and the Mincer equation are empirically robust, and HMM is a well-grounded model to capture the economic outcomes of changes in investment, labor force size, and labor participation rate due to diseases. However, the disease impact shifts with regards to medical technology investments, and overall technological productivity remains unaddressed.

There is growing literature in the application of the model. Health literature fields in which the HMM is applied include the macroeconomic impact of NCDs in the United States<sup>[42]</sup>, the macroeconomic impact of NCDs attributable to air pollution in China<sup>[17]</sup>, the global macroeconomic impact of road traffic accidents<sup>[45]</sup>, and the macroeconomic impact of tobacco and tobacco control policies in China<sup>[46]</sup>. This approach allows policymakers to determine the regions and countries that are most affected by the economic burden of diseases. Furthermore, the economic values of implementing health policies to tackle specific diseases and risk factors can be effectively estimated. Consequently, resources can be directed toward disease areas and interventions that provide the greatest economic returns, resulting in a more efficient allocation of resources.

## 4.2 Macroeconomic Value of Reducing Disease Burdens

Following the HMM model, past literature has demonstrated the macroeconomic value of reducing diseases and injuries, as shown below in Table 2<sup>[17, 41, 42, 45, 46, 53, 64, 65]</sup>. The main findings provide the economic costs of diseases and risk factors, which would translate into saved opportunity costs should these diseases and risk factors be reduced, and thus demonstrate the

significant economic values of reducing NCDs, improving mental health conditions, mitigating COVID-19, reducing tobacco use and cigarette smoking, reducing road injuries, and reducing cancers.

**Table 2** Review of existing literature using HMM

Author, Year, Title	Published journal	Topic	Main findings
Chen, et al. (2023), Estimates and Projections of the Global Economic Cost of 29 Cancers in 204 Countries and Territories From 2020 to 2050 <sup>[65]</sup>	<i>JAMA Oncology</i>	Cancers, 204 countries	The global economic cost of cancers from 2020 to 2050 was estimated to be \$25.2 trillion (in international dollars at constant 2017 prices). The economic burden and the health burden were distributed unequally across countries, world regions, and country income groups.
Nargis, et al. (2022), Economic loss attributable to cigarette smoking in the USA: An economic modelling study <sup>[53]</sup>	<i>The Lancet Public Health</i>	Smoking, NCD, U.S.	The annual combined loss of income and unpaid household production at the national level was \$436.7 billion (equivalent to 2.1% of US gross domestic product [GDP] in 2020). The cumulative loss of income and unpaid household production was \$864.5 billion (equivalent to 4.3% of US GDP in 2020).
Chen, et al. (2019), The global macroeconomic burden of road injuries: estimates and projections for 166 countries <sup>[45]</sup>	<i>The Lancet Planetary Health</i>	Road injury, 166 countries	Road injuries will cost the world economy US\$1.8 trillion (constant 2010 US\$) in 2015–30, which is equivalent to an annual tax of 0.12% on global gross domestic product.
Chen, et al. (2019), Noncommunicable Diseases Attributable To Tobacco Use in China: Macroeconomic Burden and Tobacco Control Policies <sup>[46]</sup>	<i>Health Affairs</i>	Tobacco use, NCD, China	Tobacco-attributable NCDs affect China's productive capacity and estimated that these diseases would impose a total cost of 16.7 trillion yuan (US\$2.3 trillion, in constant 2018 prices) in the period 2015–30, which corresponds to an annual tax of 0.9 percent on aggregate income. If China raised the tax on cigarettes to 75 percent of their retail price and implemented wide-ranging tobacco-control policies, the Chinese economy could save 7.1 trillion yuan (US\$1.0 trillion) for 2015–30 — The equivalent of adding a 0.4 percent dividend annually.

**Table 2** (Continued)

Author, Year, Title	Published journal	Topic	Main findings
Chen, et al. (2021), The economic burden of COVID-19 in the United States: Estimates and projections under an infection-based herd immunity approach <sup>[64]</sup>	<i>Journal of the Economics of Ageing</i>	COVID-19, U.S.	GDP loss associated with unmitigated COVID-19 would amount to a cumulative US\$1.4 trillion by 2030 assuming that 60 percent of the population is infected over three years. This is equivalent to around 7.7 percent of GDP in 2019 (in constant 2010 US\$) or an average tax on yearly output of 0.6 percent.
Chen, et al. (2018), The macroeconomic burden of noncommunicable diseases in the United States: Estimates and projections <sup>[42]</sup>	<i>PLOS One</i>	NCD, mental health, U.S.	A total loss of USD94.9 trillion (in constant 2010 USD) due to all NCDs in the U.S. over the period 2015–2050, roughly corresponds to an annual tax rate of 10.8% on aggregate income.
Bloom, et al. (2020), The economic burden of chronic diseases: Estimates and projections for, China, Japan, and South Korea <sup>[52]</sup>	<i>Journal of the Economics of Ageing</i>	NCD, mental health, Asia	Total losses associated with NCDs over the period 2010–2030 are (measured in real USD with the base year 2010) estimated to be \$7.7 trillion for China, \$3.5 trillion for Japan, and \$1 trillion for South Korea.
Chen and Bloom (2019), The macroeconomic burden of noncommunicable diseases associated with air pollution in China <sup>[17]</sup>	<i>PLOS One</i>	Air pollution, NCD, China	Total losses from NCDs associated with air pollution in China in 1990–2030 are estimated to be \$1,137 billion (constant 2010 USD) and in 2015–2030 are estimated to be \$499 billion (constant 2010 USD). Cardiovascular diseases account for the highest burden, followed by chronic respiratory diseases, diabetes, and cancer.

## 5 Discussion

This article provides a review of the various pathways through which health impacts the economy and different methodologies in quantifying the macroeconomic value of reducing disease burdens and risk factors, in particular introducing the HMM model and its applications. This review article presents an overview of existing literature that have demonstrated how reducing disease burdens can effectively generate sizable economic returns. For instance, through applying the HMM approach, it is estimated that the total macroeconomic value of reducing tobacco-related non-communicable diseases in China will be 16.7 trillion yuan from 2015 to 2030. This amount is equivalent to a 0.9 percent annual tax on the country's total income<sup>[46]</sup>. Additionally, it is estimated that reducing secondhand smoke exposure will contribute 14 percent to the overall macroeconomic value of 16.7 trillion yuan. Moreover, the economic value

of addressing road injuries globally is estimated to be \$1.797 trillion from 2015 to 2030, which is equivalent to a 0.12% annual tax on the world's total output<sup>[12]</sup>. Another study finds that in light of the recent pandemic, vaccination has been shown to be not only the most effective mechanism for alleviating health burdens, but also the most effective approach to limiting economic burdens of the pandemic<sup>[66]</sup>. These findings imply that targeted public health policies that can reduce specific disease burdens may contribute to facilitating economic growth.

The economic impacts of specific health and healthcare interventions have also been thoroughly examined in existing literature. For example, investment in collaborative care, which involves a trained individual who not only facilitates coordination between different health professionals but also delivers psychological interventions, generates a return of 1.52 pound for each pound invested by the second year of implementation, demonstrating the high cost-effectiveness of this health service<sup>[9, 67]</sup>. Another study found that a community-based screening program for fracture risk in older women in the United Kingdom is very cost-effective<sup>[68]</sup>. However, not all studies have shown positive economic impacts of health and healthcare interventions, and this could be attributed to differences in study design<sup>[9, 69]</sup>. Therefore, it is important for future research to investigate the standardization and comparability of different approaches to measuring economic benefits from health investments so as to better elucidate health areas that requires increases in investment as well as the magnitude of health investments.

Although several efforts have been made to stress the importance of increasing investment in healthcare from the perspective of facilitating economic growth and development, Chen, et al.<sup>[15]</sup> found severe underinvestment in health in India, China, and the Russian Federation, as well as underspending in 15 economies except for the United States. Health investment increases are found to be crucial to achieve the welfare-maximizing level of health expenditure<sup>[15]</sup>. However, health expenditures have traditionally been seen as a cost rather than an investment with significant returns<sup>[14]</sup>. Therefore, the transition from viewing health as a cost to an investment needs to be further promoted in order to reach optimal investment levels in health.

It is also worth noting that economic benefits are only one advantage of investing in healthcare. Besides economic values, it is also pertinent to consider social values from investing in healthcare. Examples of potential social benefits include societal gains in education, gender equality, the environment, human rights<sup>[70]</sup>, and more, as well as accrued knowledge and wisdom from older adults who experience better health and increased longevity<sup>[22]</sup>. Returns from investing in healthcare could be further increased if social benefits are realized. Future research should place more focus on both the economic and social values of investing in healthcare and developing relevant policies.

It is vital that calls to increase investment in healthcare be addressed. Health is a critical indicator of economic growth and development, and considering the multiple pathways and mechanisms through which health is closely associated with the economy, it is important to integrate the concept of economic value, such as in the form of productivity and workforce participation, in health policies and interventions. At the same time, conducting high-quality economic analyses can provide valuable information about the costs and benefits of different policies and interventions, helping policymakers to make informed decisions about where to allocate resources for the greatest impact.

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