

ESCAPING THE HEALTH-POVERTY TRAP: PUBLIC HEALTH INVESTMENT AND ECONOMIC DEVELOPMENT

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We construct an endogenous growth model that addresses overpopulation and human capital deficiencies by incorporating public health into household intertemporal decision-making. In this framework, public health investments reduce infant mortality, lower fertility, and stimulate private investment in child quality through a quantity-quality trade-off, thereby accelerating long-term growth. Our main contribution is demonstrating that government policy can independently trigger a demographic transition without relying on autonomous income or technology shocks. Through numerical simulations and historical illustrations from the United Kingdom, United States, and China, we illustrate this theoretical mechanism, showing that public health improvement is a critical prerequisite for escaping the Health-Poverty Trap. Crucially, our simulation results reveal a non-linear policy threshold: while intermediate tax rates successfully finance public health and kick-start sustainable growth, extreme tax regimes fail to incentivize human capital accumulation. Prioritizing public health spending within an optimal range is thus a vital modern policy imperative.

Keywords: Public Health; Human Capital; Quantity-Quality Trade-Off; Economic Growth

JEL Classification: I18; O15; J13

1. INTRODUCTION

Before the 1800s, most parts of the world were poor and living conditions were unpleasant. From the 1800s, Western Europe pulled ahead economically, followed by the Industrial Revolution. Historians refer to this as the “Great Divergence”.¹

¹. According to Maddison (2001), a great divergence occurred in income per capita from 1820.

Economists debate its origins, with many emphasizing demographic transition as a key driver of development and the reversal of the Malthusian trap (Galor and Weil, 1999, 2000).

The role of demographic transition is almost universally regarded as being a key engine of economic development as well as the key factor of the reversal of the Malthusian relationship between income and population growth, the so-called Malthusian stagnation or poverty trap. The most classical examples of this relationship are several European countries in the late 18th century.

What, then, is the source of demographic transition? The majority of the literature puts emphasis on explaining the relationship between human capital accumulation and fertility choices. Becker and Lewis (1973) and Becker, Murphy, and Tamura (1992) argue that as income increases the opportunity cost of having a child and direct costs of raising and educating a child also increase, the substitution effect may dominate the income effect so that parents will choose to substitute quality for quantity by reducing the number of children and increasing investment spending on each child, the so-called quantity-quality trade-off hypothesis. This human capital-driven mechanism will enable the country to escape from the Malthusian trap. On the other hand, Galor and Weil (2000) and Galor and Moav (2002) suggested that the reason that parents switch out the quantity of children into quality was not triggered by an increase in income but rather by technological progress. This occurs because technological progress raises the return to human capital. As stated, both types of human capital growth models require a precondition, either an increase in income or an acceleration of technological progress.

Which of these explanations can explain a greater proportion of decline in fertility has yet to be settled. However, Caldwell (2001) states that for “all demographic transition theories it is the prior decline in mortality that in due course precipitates the fertility decline”. Galor and Weil (1999) also argue that the improvement in children survival can serve as a unified model that describes the complete transition from the Malthusian trap to an economic growth regime. That is to say, the decline in mortality rate should not be overlooked when investigating the source of demographic transition. Additionally, the decline in mortality rate is also an important factor for human capital accumulation. Ram and Schultz (1979) suggest that the changes in mortality have increased the motivation of human capital investment in any age. Lucas (2009) argues that knowledge accumulation occurs only when the longevity of human beings is sufficiently long.

Some literature attempts to link the relationship between mortality rate and fertility choice. Kalemli-Ozcan (2002) develops an overlapping generation (OLG) model and shows that there will be a hierarchy of children's needs when each child's survival is uncertain. Once such uncertainty falls, the hierarchy of needs decreases and gives rise to a quantity-quality trade off. Ehrlich and Lui (1991) viewed family as a mutual insurance mechanism that the younger generation provides the older generation support, and their model suggests that fertility will decline and schooling investment will increase via the improvement of longevity. Both models point out the importance of mortality rate, but

both of them assume that the survival rate is exogenous.

However, the decline of the mortality rate may not be brought about by accident. For example, Strulik (2004) emphasizes the decline of mortality of children can be affected by income rather than exogenous shocks.² In his model, the quantity-quality trade off occurs only when the mortality is sufficiently low, which could be triggered only when the initial income is sufficiently high. This perspective is in line with the theory of the Health-Poverty Trap, which states that poor economies are in poor health, and they are in poor health because they are poor. Sala-i-Martin (2005) gives reasons for the Health-Poverty Trap and suggests that an economy is impossible to experience economic growth without the improvement in health, while the economy is also impossible to have improvement in health without economic growth.

Recent scholarship continues to highlight the centrality of human capital in this process. Oltulular (2025) argues that sustainable economic growth in the twenty-first century depends primarily on human capital dynamics rather than physical investment, reinforcing the classical quantity–quality trade-off hypothesis (Becker and Lewis, 1973). Similarly, Wang et al. (2025) provide empirical evidence from Chinese cities showing that public health policies enhance innovation by mediating human capital accumulation. These findings suggest that public health improvement remains a critical precondition for demographic transition and growth, not only historically but also in contemporary economies.

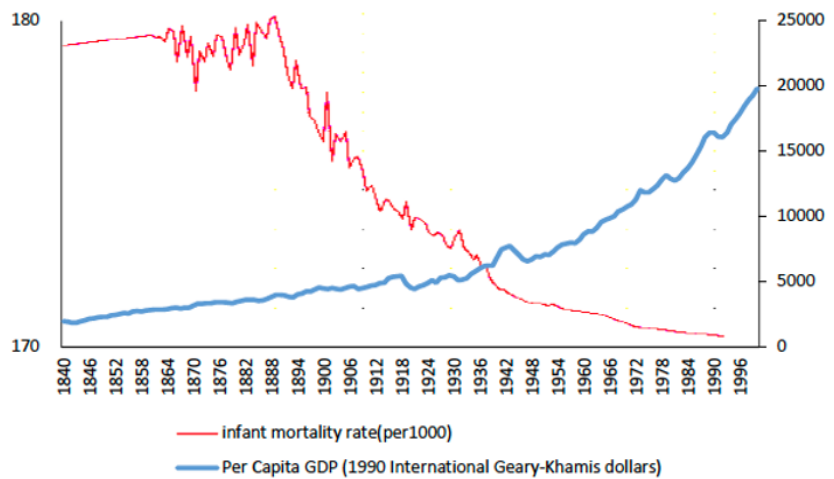
In this paper, we want to explore the solution to the Health-Poverty Trap for an economy which is stagnated in poor wealth and poor health. Empirically, it is widely accepted that the public health effort via a sanitary movement, developing an effective sewage system, and the requirement of pasteurized milk improve disease control in developed countries.³ Moreover, Anand and Ravallion (1993) claim that one third of life expectancy is explained by poverty and two thirds by public health spending. With this point of view in mind, our paper attempts to develop a model which argues that the economy might escape from the Malthusian trap and the Health-Poverty Trap via the improvement in public health, which is decided by a government's public policies.

Historical evidence suggests that many countries experience a sharp decline in birth rate and fertility rate before rapid economic growth, not the other way around as claimed by income or technology hypothesis in Becker and Lewis (1973) or Galor and Weil (2000). See, for example, the U.K. experience in the early 20th century. The U.K. experienced a sharp decline in the infant mortality rate and fertility rate between 1900 and 1920 (see Figure 1); however, U.K. per capita GDP did not start to increase

² Rather than by increased income, McKeown (1976) and followers argue that the mortality decline was mainly caused by improved (child) nutrition. In this strand of literature, it has been shown that due to the improvement in organization, technology, and transportation, the supply of food in England and Wales increased greatly during the 18th and 19th centuries. Furthermore, a better nutritional state is critical in improving children's response and survival to infectious diseases.

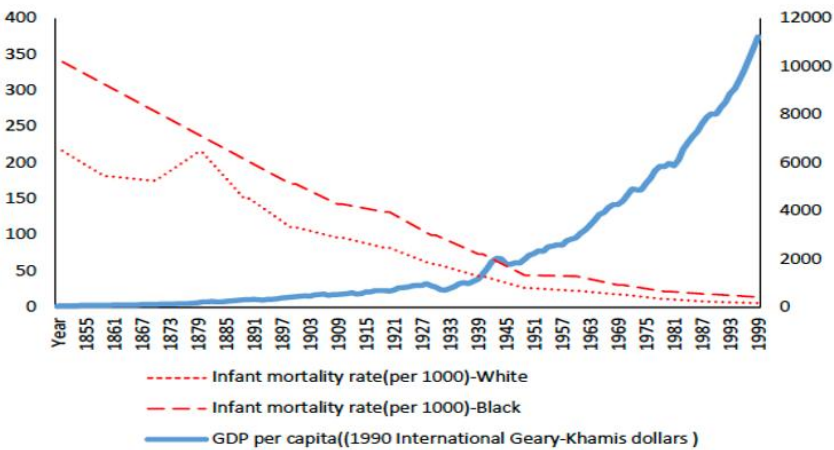
³ See Cutler and Miller (2005) and Caldwell (2001).

significantly until the 1930s.



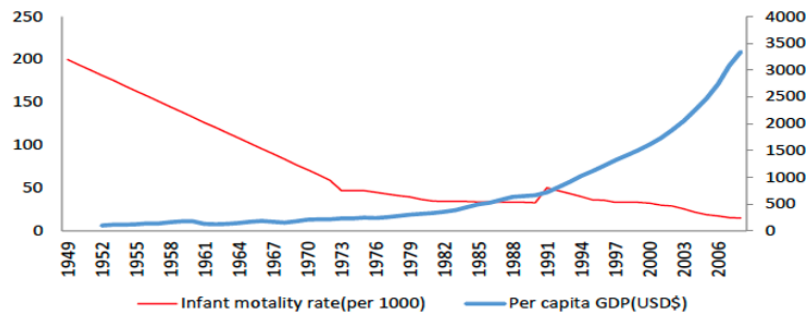
Source: University of Portsmouth, The World Economy: Historical Statistics (Angus Maddison)

Figure 1. Infant Mortality Rate and Per Capita GDP in the U.K.



Source: Michael Haines, Colgate University (infant mortality rate), The World Economy: Historical Statistics (Angus Maddison)

Figure 2. Infant Mortality Rate and Per Capita GDP in the USA



Source: China compendium of statistics, China population statistics yearbook

Figure 3. Infant Mortality Rate and Per Capita GDP in China

Similar examples can be found in the United States and China. From Figure 2, we observe that the infant mortality rate in the United States was as high as 216.8 per thousand babies born for whites and 340.0 for blacks in the 1850s. The United States infant mortality rate dropped to 110.8 for whites and 170.3 for blacks in the 1900s. The infant mortality rate dropped by half within 50 years in the United States. During the same period, the economy continued growing but with a low growth rate. Soon afterwards, however, even though the United States experienced the Great Depression and entered World War II, the U.S. economy began to boom with the fastest economic growth rates in the world. Figure 3 illustrates the Chinese experience. Again, we observe a rapid economic growth following an earlier steep decline in the infant mortality rate. Many economists attribute significant growth in China in the past 35 years to economic reforms and the one child policy which allows faster accumulation of physical capital; however, from Figure 3 we see that the first stage of Chinese demographic transition seems to be finished by 1978, two years before the one child policy had been formally introduced in 1980.

To be consistent with these historical facts, the main contribution of our paper is to construct a growth model by incorporating public health into household intertemporal decision making and prove that public health policy might play a key role to accelerate mortality decline, encourage private investment in health and education, and further allow the economy to escape from the Health-Poverty Trap.

This paper consists of four parts. Section 1 is the introduction. In Section 2, we construct a theoretical endogenous growth model by incorporating public health spending and private investment decisions in human capital accumulation. To evaluate the qualitative properties of the model, Section 3 provides a numerical simulation based on historical parameters, while Section 4 offers descriptive historical illustrations from

the United Kingdom, the United States, and China. These historical examples and simulations are intended to illustrate the theoretical mechanisms of the model rather than to serve as direct empirical validation of the propositions. Discussion and conclusions are offered in Section 5.

2. THE BASIC MODEL

2.1. Mortality Rate

In our model, the representative agent lives for three periods, childhood, young adulthood, and old adulthood. Before entering adulthood, there is a probability of childhood mortality, $(1-\pi)$, which depends on parents' proportion of income spent on children's health, d , and government's public health expenditures, g . We assume the survival rate by adulthood is determined by the following function:

$$\begin{aligned}\pi &= \bar{\pi} + \theta(g) + [1 - \bar{\pi} - \theta(g)]\lambda(g)d, \\ \theta(0) &= 0, \quad \theta'(g) > 0, \quad \theta''(g) < 0, \quad \lim_{g \rightarrow \infty} \theta'(g) = 0 \\ \lambda(0) &= \bar{\lambda} > 0, \quad \lambda'(g) > 0, \quad \lambda''(g) < 0, \quad \lim_{g \rightarrow \infty} \lambda'(g) = 0\end{aligned}\tag{1}$$

In equation (1), the survival rate π is determined by three terms. First, we use $\bar{\pi}$ to represent the natural survival rate. This refers to the survival rate of children until adulthood when there are no government interventions and no additional health spending (beyond necessity) by parents. Second, we allow the survival rate to depend directly on government's public health expenditures, with its effect given by $\theta(g)$. Third, parents' health expenditures also play a role, although the effectiveness also depends on government's public health expenditures. In particular, the larger is $\lambda(g)d$ (with maximum value, one), the higher is the third term in (1). Here, $\lambda(g)$ captures the idea that public health expenditures enhance the efficiency of private health spending.⁴ As a specific counterexample, suppose the government does not provide facilities to contain air pollution or water pollution, then regardless of the effort by private households, little can be gained in terms of survival rate. Private health expenditures become effective only when such public health facilities are in place.

⁴ We here assume that $\lambda(0) > 0$, suggesting that personal health expenditures always improve survival rate, though its effectiveness might be small.

2.2. The Representative Household

Insights from Barro and Becker (1989), Becker and Barro (1988), Ehrlich and Lui (1991), and Strulik (2004) suggest that intergenerational savings could occur not only through physical capital accumulation, but also through human capital accumulation. In our model, we assume a person lives for three periods: childhood, young adulthood, and adulthood. During childhood, the agent could not make any decisions, but his likelihood of survival and human capital could be improved through his parents' decisions on health and education spending. At the beginning of adulthood, the agent must decide his own consumption during young-age and old-age, c_1 and c_2 , the number of children to have, n , the health expenditure on children, d , and his children's quality, which is determined by his choice of education expenditure, q . In sum, we will consider the following utility maximization decision faced by the agent:

$$\begin{aligned} \max_{c_1, c_2, n, d, q} \quad & U = b_1 \ln(c_1) + b_2 \ln(c_2) + b_3 \ln(\pi n) + b_4 \ln(q + e); \quad b_3 > b_4 \\ \text{s.t.} \quad & c_1 + \frac{c_2}{1+r} + (d + q + e)n(1 - t)y + \bar{e}n = (1 - t)y \end{aligned} \quad (2)$$

In equation (2), we use y to represent per capita income, t to denote income tax rate, the private spending ratio on health (d), and education (q), while e and $\bar{e}$ are respectively the ratio of income needed and the fixed cost to physically raise a child. To simplify the analysis, we assume that the government uses all the taxes it collects on public health. Hence,

$$ty = g \quad (3)$$

From equations (1) to (3) we can solve for household optimal consumption in the two periods, c_1 and c_2 , the number of children born (n), and the private spending ratio on health (d), and education (q); this yields the interior solution:⁵

$$c_1 = \left(\frac{b_1}{b_1 + b_2 + b_3} \right) \cdot (y - g) \quad (4.1a)$$

$$c_2 = \left(\frac{b_2}{b_1 + b_2 + b_3} \right) \cdot (1 + r)(y - g) \quad (4.1b)$$

$$q = \frac{\pi + \theta(g)}{[1 - \pi - \theta(g)]\lambda(g)} - \frac{\bar{e}}{y - g} - e \quad (4.1c)$$

$$d = \left(\frac{b_3 - b_4}{b_4} \right) \cdot \frac{\pi + \theta(g)}{[1 - \pi - \theta(g)]\lambda(g)} - \left(\frac{b_3}{b_4} \right) \cdot \frac{\bar{e}}{y - g} \quad (4.1d)$$

$$n = \left(\frac{b_4}{b_1 + b_2 + b_3} \right) \cdot \frac{[1 + \pi - \theta(g)]\lambda(g)(y - g)}{[\pi + \theta(g)](y - g) - [1 - \pi - \theta(g)]\bar{e}\lambda(g)} \quad (4.1e)$$

⁵. See Appendix A for the discussion of the corner solution.

2.3. Firms and the Macroeconomy

We assume a representative firm who uses land, X , physical capital, K , and efficiency unit of labor HL , to produce final output, Y . Here, effective labor consists of two parts, where L represents the number of workers and H represents the human capital embodied in each worker. In this research, the number of workers is decided by the number of surviving children born, that is $L_t = \pi_{t-1} n_{t-1}$. Additionally, the amount of human capital embodied in each worker is decided by two sources: the education input received in his childhood and the human capital stock passed down through every generation. Thus, the human capital accumulation function can be written as:

$$H_t = \vartheta q_{t-1}^\zeta + H_{t-1} \quad (5)$$

In Equation (5), H_{t-1} denotes the human capital stock inherited from the previous generation, q_{t-1} denotes the education input provided by parents during childhood, while ϑ and ζ are just parameters indicating the effectiveness of education input in producing human capital.

As in Galor and Weil (1998), we assume the following production function:

$$Y_t = K_t^\beta (H_t L_t)^{\alpha(1-\beta)} X^{(1-\alpha)(1-\beta)} \quad (6)$$

Assuming the real interest rate, $r = \beta(Y_t/K_t)$, is fixed, we can rewrite equation (6) as follows:

$$Y_t = A_t (H_t L_t)^\alpha X^{(1-\alpha)}, A_t = (\beta/r)^{\beta/(1-\beta)} \quad (7)$$

Furthermore, as the factors are paid by their marginal products, we know that the real wage is given by:

$$w_t = \alpha(1-\beta) A_t H_t^\alpha L_t^{\alpha-1} X^{1-\alpha} = Y_t/L_t = y_t \quad (8)$$

Accordingly, from equation (8) we know that in equilibrium the growth rate of real wage (γ_w) and the output per capita (γ_y) will equal to:

$$\gamma_y = \gamma_w = \alpha\gamma_H - (1-\alpha)\gamma_L \quad (9)$$

where γ_H and γ_L are respectively the growth rate of human capital stock and the growth rate of labor input, which is also the growth rate of population. From the above setups we can arrive at two propositions discussing the preconditions that need to be satisfied for an economy to escape from the poverty trap and achieve a higher income level.

Proposition 1. *When the government is nonexistent, i.e. $t = 0$, and given a natural survival rate, $\bar{\pi}$, the economy could only grow through human capital accumulation if the initial income is sufficiently large. That is, a precondition for the economy to escape from poverty trap is to have $y_0 > \tilde{y}$.*

Proof. From (4.1c), we see that $q_0 = 0$ if $y_0 \leq \frac{[(1-\bar{\pi})\bar{\lambda}]}{[\bar{\pi}-(1-\bar{\pi})\bar{\lambda}e]} = \tilde{y}$, which in turns leads to $H=0$ as well as $\gamma_H=0$. The economy can experience growth only when the y_0 is large enough ($> \tilde{y}$) to trigger the parental investment in education q_0 , then $\gamma_H > 0$.

Proposition 2. *When the government is nonexistent, i.e., $t = 0$, and suppose that $y_0 < \tilde{y}$, then the economy could escape from the poverty trap through human capital accumulation only when the children's survival rates are raised exogenously to $\tilde{\pi} > \bar{\pi}$.*

Proof. From (4.1c), we see that $q_0 = 0$ if $\pi \leq \tilde{\pi} = \bar{\lambda}(\bar{e} + ey)/[\bar{\lambda}(\bar{e} + ey) + y]$, which in turns leads to $H=0$ as well as $\gamma_H=0$. The economy can grow only when the π is large enough ($> \tilde{\pi}$) to trigger parental investment in education q_0 , then $\gamma_H > 0$.

From propositions 1 and 2 we know that when the government is nonexistent, there are only two paths to escape from the poverty trap. First, the economy needs some exogenous shocks to raise the initial income level. Second, the children's survival rate is exogenously increased. However, past research often finds the first path to be unsuccessful in explaining an economy's escape from the poverty trap. For example, Aiyar et al. (2006) use an overlapping generation model and argue that the technological increase and the improvement in land productivity during 1-1500 A.D. only changed population density but not income levels. In a similar vein, Ashraf and Galor (2011) also empirically demonstrate that the productivity growth in the pre-Industrial Revolution only contributes to a larger population. These results suggest that it is more important to look at ways that could improve survival rates. While most previous studies assume it to be decided exogenously, we argue that government policies can play an important role as in proposition 3.

Proposition 3. *For any set of preference parameters and decreasing return continuous functions $\theta(g)$ and $\lambda(g)$, there exists a tax rate $\hat{t}$ where $\underline{t} \leq \hat{t} \leq \bar{t}$, that is sufficient to guarantee the private spending on children's quality.*

As we have discussed before, if the economy is in stagnation and the tax rate is too low (i.e. $t \leq \underline{t}$) for government to improve the sanitation environment, there are no incentives for parents to invest in education since the infant mortality is high. On the other hand, if the economy is in stagnation and the tax rate is too high (i.e. $t \geq \bar{t}$) for parents to live without being on the bread line, there is also no reason for parents to invest in education. Therefore, only through an appropriate tax rate (i.e. $\underline{t} \leq \hat{t} \leq \bar{t}$) can an economy simultaneously improve public health as well as maintain the basic needs for a family, giving the parents incentives to invest in their children's quality so that the economy can eventually escape from poverty.

Proposition 3 has a very important economic policy implication. That is,

government's intervention can transform the economy from stagnation to a growth regime without any exogenous shocks. Moreover, since human capital is the main engine of our setting, the more educational inputs parents give to their children, the earlier the economy can enter into the growth regime.⁶

Propositions 1 - 3 can give us a concrete explanation of how the "Great Divergence" occurred in the 1800s. Taking England as an example, England started their industrial revolution in the early 1700s. However, in the early industrial revolution period, England did not enjoy high income growth. Rather, the extremely poor sanitary conditions caused widespread infectious diseases and very high infant mortality rates, especially in the urban areas where most vibrant economic activities occur. It is only after the control of infectious diseases that one finds a decrease in the mortality rate. In the literature, most attribute this improvement of a better public health system, especially the establishment of sewage disposal, increased provision of public sanitary facilities, and policies aimed to contain population densities during the 19th century.

Thus, the improvement of public health seems to be a good conduit to generate private human capital investment. In the following section, we will use numerical analysis to simulate the model developed in this section to test if initial improvement in public health may trigger a growth trajectory to escape from the poverty trap and preconditions for economic take-off.

3. SIMULATION

3.1. Numerical Setting

The United Kingdom, the first country to escape from the poverty trap, was also the first to complete a demographic transition. Hence, in this study we simulate the model according to U.K. historical records.

The model is calibrated using historical records from the United Kingdom alongside standard parameters from the existing growth literature. Table 1 summarizes the baseline parameter values, operational assumptions, and their primary sources.

⁶ Equation (5) implies this model is an exogenous growth model with zero human capital growth rate in the long-run steady state ($\lim_{t \rightarrow \infty} \gamma_H = \frac{\vartheta \tilde{q}^\zeta}{H_{t-1}} = 0$, where $\tilde{q}$ is the constant education input in the long-run steady state). By equation (9) we know that the long run economic growth is closely related to the human capital accumulation. Therefore even if we assume the human capital accumulation function as $H_t = (1 + \vartheta q_{t-1}^\zeta) * H_{t-1}$ that represents this is an endogenous growth model with positive human capital accumulation growth rate in the long run ($\lim_{t \rightarrow \infty} \widehat{\gamma}_H = \vartheta \tilde{q}^\zeta$), propositions 1-3 still hold since the key engine for an economy to escape from stagnation is human capital.

Table 1. Baseline Model Calibration Parameters and Sources

Parameter	Description	Baseline Value	Source / Justification
y_0	Initial per capita income	700	Maddison (2003) international dollars
$\bar{\pi}$	Natural child survival rate	0.33	Historical baseline assumption
b_1	Utility weight: young consumption	0.40	Standard preferences configuration
b_2	Utility weight: old consumption	0.03	Standard preferences configuration
b_3	Utility weight: surviving children	0.22	Baseline preference alignment
b_4	Utility weight: child quality	0.15	Assumes $b_3 > b_4$ preference restriction
e	Fixed cost of child rearing	7.00	Calibration for baseline stagnation
$\bar{e}$	Variable child rearing cost factor	0.0435	Calibration for baseline stagnation
m	Public health efficiency index	0.435	Hyperbolic tangent scaling factor
a	Public health convergence speed	0.005	Diminishing marginal returns control
$\bar{\lambda}$	Baseline private efficiency index	12	Minimum effectiveness of private inputs
x	Private spending multiplier scaling	12	Hyperbolic tangent scaling factor
b	Private efficiency convergence speed	0.0025	Diminishing marginal returns control
θ	Human capital production multiplier	10.00	Strulik (2004) baseline framework
ς	Human capital return elasticity	0.30	Strulik (2004) baseline framework

Firstly, we assume that the human capital in the current period within the economy comes from both the human capital stock inherited and the private education expenditure on households' offspring in the previous period.

Secondly, according to Maddison (2003), the per capita income of the Kingdom in 1500 was 762 international Geary-Khamis dollars, and therefore the initial income was set at 700 in the simulation. Due to missing cost information of raising children, the fixed cost was assumed to be $e=7$ while the coefficient of the variable part with income was $\bar{e}=0.0435$. In addition, $b_1 = 0.4$, $b_2 = 0.03$, $b_3 = 0.22$ and $b_4 = 0.15$ in the utility setting.⁷

According to equation (1), the survival rate consists of three parts, including natural survival rate $\bar{\pi}$, government expenditure on public health $\theta(g)$, which increases the survival rate, and parents' health expenditure on children d , which also increases the survival rate. As mentioned before, we define $\bar{\pi}$ as the natural survival rate of children until adulthood when there are no government interventions and no additional health

⁷ From the model in section 2.2, the saving rate can be expressed by $s = b_2/b_1+b_2+b_3$. Though 1500-1700 saving rates were not available, Crafts (1985) documented that the investment to GDP ratio was 0.05 in the United Kingdom during the 1700s. Based on this information and our model setting, the initial saving rate of households is 0.046 in the simulation.

spending beyond necessity by parents. Though an accurate natural survival rate is not documented, we assume $\bar{\pi}=1/3$ in the simulation.⁸

The public health expenditure has two effects on the survival rate: direct effect $\theta(g)$ and indirect effect $\lambda(g)$, both of which are increasing but converge in g to capture the diminishing marginal return of the government expenditure on public health. To restrict the range of the survival rate to be between 0 and 1, we assume both $\theta(g)$ and $\lambda(g)$ both of hyperbolic tangent functional forms. Let $\theta(g)$ be $m \cdot [\exp(ag) - 1] / [\exp(ag) + 1]$, where m represents the efficiency of the survival rate increase through public health expenditure and we set $m=0.435$. Moreover, parameter a is used to measure the convergence of this hyperbolic tangent function and $a=0.005$. Similar to the setting of $\theta(g)$, indirect effect $\lambda(g)$ is defined as $\lambda = \bar{\lambda} + \{x \cdot [\exp(bg) - 1] / [\exp(bg) + 1]\}$, where $\bar{\lambda} = 12$, $x = 12$, and $b = 0.0025$.⁹

Finally, following Strulik (2004), the flow term of the human capital accumulation ($\vartheta q_{t-1}^{\varsigma}$) is set as $\vartheta=10$ and $\varsigma=0.3$.

3.2. Simulation Result

In this paper, human capital (H) accumulation, which is determined by parents' decision to give their children education (q), is the main engine of growth. Therefore, if the initial survival rate or the initial income is too low to motivate the parents to invest in education for their children, the economy will always stay in stagnation. Under this circumstance, public health expenditure plays an important role as it provides a stimulus for growth even when an economy has no medical or technological progress. In order to stress this point, we simulate several key variables, including real income per capita (y), human capital accumulation (H), survival rate (π), number of children born (n), number of surviving children (πn), private spending ratio on health (d) and education (q) under different tax rates of 0%, 5%, 10%, 60%, and 70% for 500 years.¹⁰ The simulation results are given in Table 2 as well as Figures 4(a) - 4(f).

First, we start with a scenario where there exists no tax and thus no public health expenditure. As shown from Table 2, in this scenario, the real income per capita stays at 700, the number of children born is 7.58, and the number of surviving children is 2.53. Because of the high mortality rate, parents are unlikely to invest in any education or health resources for their children. The income growth rate remains zero and the

⁸ There is an old Chinese saying that "having one child is inadequate to say one has one offspring and having two children can be just counted as having a half offspring, while having three children then one can treat it as having one offspring." This implies that the average survival rate was 1/3 in ancient China. Hence, $\bar{\pi}=1/3$ is assumed in the simulation.

⁹ Based on 2001 U.S. data, Strulik (2004) assumes a constant indirect effect and sets $\lambda = 25$. The maximal number of $\lambda(g)$ in our setting is compatible with Strulik (2004).

¹⁰ Because the economy remains in a steady state with zero per capita output growth over 500 years, we calibrate the model for this period.

economy stays in the Malthusian trap with the dual features of low income and high fertility rate.

Table 2. Simulation Results under Different Tax Rates

	t=0	t=0.05	t=0.1	t=0.6	t=0.7
Output per capita (y)	700.00	708.10	29971.18	30415.74	777.37
Survival rate (π)	0.33	0.37	0.99	0.99	0.70
Number of children (n)	7.58	6.32	1.84	1.84	2.51
Number of surviving children (L)	2.53	2.34	1.83	1.83	1.77
Education input ratio (q)	0.00	0.00	0.13	0.13	0.00
Human capital accumulation (h)	10.00	10.00	2440.90	2495.66	10.00
Health input ratio (d)	0.00	0.00	0.04	0.04	0.00

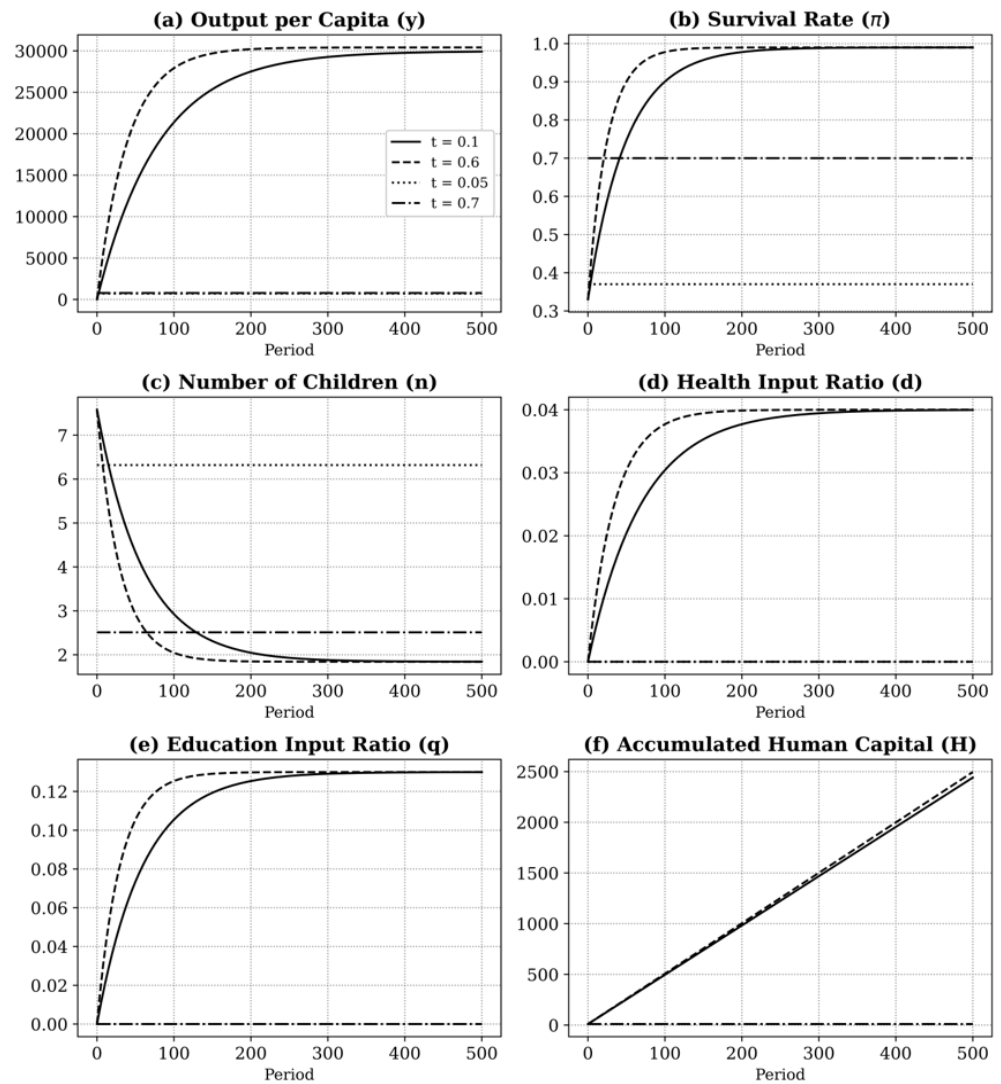
Note: When $t=0.1$ or 0.6 , the economy converges towards a steady state with zero growth rate around the 500th period. Therefore, the simulation results show the outcome of all variables in the 500th period.

To correctly interpret the dynamic pathways illustrated in Figure 4, a crucial analytical clarification regarding the overlapping trajectories is warranted. In panels (a), (d), (e), and (f), certain simulation curves appear to be missing; however, this visual phenomenon is natively driven by the economic optimization behavior of the household under extreme policy regimes. Specifically, under the zero-tax benchmark $t=0$, the low-tax regime $t=0.05$, and the excessively high-tax regime $t=0.70$, the economy is firmly locked in a Malthusian stagnation or a Health-Poverty Trap. Under these three distinct scenarios, the optimal choices for private spending ratio on child health d and education q collapse entirely to the zero corner solution $d = 0, q = 0$.

Consequently, as shown in panels (d) and (e), the trajectories for $t=0, t=0.05$, and $t=0.70$ perfectly overlay each other along the horizontal axis at the zero floor. Because parental investment in education is nonexistent $q=0$, the human capital accumulation function defined in Equation (5) yields zero endogenous growth, causing the accumulated human capital stock H for these three regimes to remain at its baseline parameter value $H=10$. This structural lock-in forces the three curves in panel (f) to perfectly coincide as a single flat line. Finally, for panel (a), although per capita output under $t=0.05$ ($y=708.10$) is marginally higher than that under $t=0$ ($y=700.00$), this minor baseline discrepancy is visually compressed into a single overlapping trajectory when scaled against the modern growth regimes ($t=0.1$ and $t=0.6$), where per capita income converges toward approximately 30,000.

Now suppose that the government imposes a tax rate, 5%, and tax revenues are all used as public health expenditure. As we can see from each left panel of Figures 4(a) - 4(f), when the tax rate is 5% and the public health spending is positive, the survival rate increases by 4% (from 33% to 37%, Table 2). Such an increase, however, is too little to stimulate education spending due to a highly uncertain survival. As a result, the individual's optimal choice is to raise children without any education or health

expenditures. Because of zero education spending, the human capital does not accumulate and the economy remains stagnant. That is, this economy is still trapped in a Malthusian sense.



Notes: The figures plot the 500-period dynamic trajectories of key macroeconomic and household variables. In panels (a), (d), (e), and (f), trajectories for $t=0$, $t=0.05$, and $t=0.70$ visually overlap due to identical zero corner solutions $d=0$, $q=0$ and Malthusian stagnation.

Figure 4. Simulation Results under Different Tax Rates

However, if the government increases the tax rate to 10%, the results are totally different. According to Figure 4(b), the survival rate has a big increase even in the early stage of economic development. A sharp increase in survival rate allows individuals to raise fewer children (Figure 4(c)) and spend more on children's health (Figure 4(d)) and education (Figure 4(e)). A higher level of education accelerates the accumulation of human capital (Figure 4(f)), and thus promotes economic growth, which in turn helps the government collect more tax revenues and spend more on public health. Over time individuals choose to raise fewer and fewer children, but allocate more and more health and education resources to children, and as a result the survival rate and the accumulation of human capital also keep increasing. From Figure 4(a), we can see that the per capita income is constantly increasing. We also depicted the case of the 60% tax rate, where the results are similar to those of the 10% tax rate except for a higher speed of convergence in the case of the 60% tax rate.

In addition, we simulated the case with a 70% tax rate. Although the survival rate rises from 33% to 70% (Table 2), low disposable income leaves individuals with little incentive to invest in children's education and health, so the economic growth rate remains stagnant.

To summarize, as shown in Table 2, using zero tax rate scenario as the benchmark model, we find there is a jump in per capita income for the economies with 5% or 70% tax rates. However, a one-time jump in income level due to a too low or a too high tax rate does not induce a sustainable economic growth due to lack of incentives on increasing children's education and health spending. On the other hand, when the tax rate is set at an intermediate level such as 10% or 60%, our results indicate that households will continue spending out of their disposable income on children's education and health, and thus human capital accumulation will occur and per capita income continue growing.

4. HISTORICAL ILLUSTRATIONS AND DISCUSSION

The numerical simulations presented in the previous section demonstrate that the demographic transition and sustainable economic takeoff rely heavily on public health investment financed within an appropriate range of tax rates. To complement these numerical insights and illustrate the underlying theoretical mechanisms of the model, this section provides qualitative historical reviews from the United Kingdom, the United States, and China. Rather than serving as direct empirical validation of the theoretical propositions, these diverse country examples are presented as historical illustrations of how government-led improvements in public health can operate as a primary conduit to trigger the quantity-quality trade-off and resolve overpopulation and human capital deficiencies.

4.1. United Kingdom

The historical trajectory of the United Kingdom provides a clear qualitative counterpart to the mechanism modeled in our framework. During the Middle Ages (5th - 15th centuries), most European economies were in the form of feudal systems that relied mainly on agriculture. Feudal societies were organized around manorialism, in which tenant farmers cultivated and resided on land owned by a feudal leader. The power of the feudal leader came from the ownership of land.¹¹ Under the feudal system the central government did not directly rule the state and therefore it resulted in political power fragmentation or decentralization. This is one of the reasons for the low government expenditure to GNP ratio at that time.¹² After the mid-15th century, the British agricultural economy started to decline due to the rise of an enclosure movement motivated by the flourish of international trade, and therefore manorialism started to shrink.

During the period of 1600-1688, the U.K. government expenditure to GNP ratio remained as low as 2.2 percent. However, the enclosure movement and the King's poll tax policy caused more and more riots and, as a result, the Glorious Revolution took place in 1688. Soon after the revolution, the Bill of rights was introduced and became a law in 1689. The Bill mainly consisted of (1) prohibiting the King from taking property or imposing taxes without the approval of the Great Council and (2) forcing the King to use the tax revenue fairly. Some historians view the Glorious Revolution as a start of constitutional monarchy, and it granted the efficient use of the central government tax revenue. At the same time, the tax revenue increased and the central government became more and more powerful because of the decline of the feudal system. It turned out that the government expenditure to GNP ratio had kept increasing since 1688 with a mean of 14 percent during 1689-1800.

In British history, the Glorious Revolution promoted a reasonable tax rate and the Industrial Revolution boosted production technology. While the subsequent Industrial Revolution accelerated production technology, rapid urbanization initially worsened sanitary environments, inducing widespread infectious diseases and severe infant mortality, particularly in economically vibrant urban centers. It was the subsequent institutional expansion of public health infrastructure in the mid-to-late nineteenth century—notably through centralized sewage disposal, water purification systems, and urban density controls—that precipitated the sharp decline in mortality. As illustrated in Figure 1, the U.K. experienced a precipitous drop in infant mortality and fertility between 1850 and 1930, whereas significant acceleration in per capita GDP growth did not materialize until the 1940s. This sequence cleanly illustrates our theoretical proposition that public health intervention acts as a historical prerequisite for the

¹¹ Cameron (1989) described the feudal system as follows: “no land without a lord, no lord without land.”

¹² The average ratio of British government expenditure to GDP is approximately 1.5 percent before the 16th century.

demographic transition, preventing technological progress from being entirely diluted by population growth.

4.2. United States

The demographic transition of the United States between 1800 and 1940 offers another institutional illustration of the model's public health transmission channel. Despite experiencing massive waves of net in-migration from 1840 to 1920, the destructive disruptions of the Civil War (1861 - 1865), and shifting baseline population demographics, the United States witnessed a remarkable, sustained decline in infant mortality beginning in the 1870s (Figure 2). Prior to this pivotal period, macroeconomic stability was routinely threatened by periodic epidemics of cholera, yellow fever, and dysentery.

The post-1870s mortality decline was directly driven by extensive municipal and state-level public health interventions alongside complementary medical innovations. Large-scale public investment in urban sewer networks, water filtration, and chlorination systematically eliminated pathogen-producing environments. Simultaneously, institutionalized vaccine rollouts, including the introduction of cholera vaccines in 1879 and plague vaccines in 1897, effectively contained epidemic transmission. This historical process exemplifies how public investments reduce natural child mortality risk, thereby fostering a more predictable environment that encourages long-term human capital investments..

4.3. China

The contemporary economic development of China further illustrates that state-led public health efforts can induce a demographic transition and lift an economy out of a low-health, low-wealth trap. Following decades of civil conflict, China in the early 1950s suffered from acute deficiencies in environmental hygiene, with homebirth infections, pneumonia, and preventable epidemics driving infant mortality to approximately 200 per thousand births. Concurrently, per capita income remained severely constrained during the initial fifteen years of the People's Republic of China (1949 - 1964).

Despite severe economic constraints, the state implemented aggressive public health policies to improve birth outcomes and suppress infant mortality. These interventions included the establishment of a centralized nationwide epidemic prevention system, a universal maternal and child health-care network¹³, and the institutionalization of the

¹³. During the 1950s, it was widely considered shameful for a woman to give birth in China. Some pregnant women would be hounded out of the house to give birth in a cattle pen or sheep pen. Moreover, some midwives were seriously lacking medical and health knowledge to provide an adequate way to help a mother give birth. According to an approximate estimate, two hundred thousand pregnant women and one

rural "barefoot doctor" scheme by 1970¹⁴. Consequently, major infectious diseases were contained, and maternal and infant mortality rates dropped sharply. Crucially, as shown in Figure 3, the first stage of the Chinese demographic transition was largely accomplished by 1978. This timeline precedes both the market-oriented economic reforms of late 1978 and the formal implementation of the one-child policy in 1980.

The Chinese experience illustrates our theoretical mechanism: proactive public health policies can independently drive down mortality and fertility, setting the necessary baseline conditions for subsequent human capital accumulation and rapid economic growth.

4.4. Synthesis

A comparative synthesis of the United Kingdom, the United States, and China reveals consistent qualitative regularities that echo our model's core hypothesis. Although these three economies commenced their modern growth phases in entirely different eras and under divergent institutional frameworks, each experienced a structural decline in infant mortality and fertility prior to the onset of rapid, sustained economic expansion. This historical ordering contradicts hypotheses that view demographic transition purely as a passive consequence of rising income or autonomous technological progress. Instead, these historical episodes illustrate that public health investment operates as a foundational engine of development. By simultaneously mitigating overpopulation pressures and increasing the expected return to human capital, public health improvements establish the critical precondition required to break out of the Health-Poverty Trap.

5. CONCLUDING REMARKS

This paper tries to provide a rationale to understand what causes the human capital-growth nexus. We construct a growth model by incorporating public health into household intertemporal decision making. In the model, public health improvement significantly reduces death rate, especially the infant mortality rate, which in turn reduces fertility rate and enhances private investment in both education and health,

million newborns died from inappropriate methods of delivery. The most important reform of the maternal and child health-care system in the 1950s in China was to promote nationwide the correct methods of delivery to decrease the death rate of newborns and their mothers.

¹⁴. Barefoot doctors are the doctor who received basic medical and paramedical training and provide the basic health care service in rural area. The main task of barefoot doctors is to halt epidemic diseases and improve birth outcomes.

which further accelerates long-term growth of the economy. Without initial improvement in public health, the economy is likely to be stuck in stagnation. We simulate the model using U.K. historical records and our simulation results confirm the hypothesis that under a reasonable tax rate to finance public health, the increase in public health spending is a necessary condition to kick-start the quantity-quality trade-off of human capital investment and thus stimulate subsequent long-term economic growth. However, the scenarios of a too low or a too high tax rate will not generate beneficial results leading to sustainable long-term growth. Additionally, we compare the economic development experience among the UK, the US and China, and we observe that government intervention in public health did play a role in all three countries' initial stages of growth.

Our results have a strong policy implication for a developing country to escape from the Health-Poverty Trap and accelerate the human capital investment by first investing in public health financed through a reasonable tax rate. That is, public health improvement is a prerequisite for generating the human capital-growth nexus. By reducing mortality and fertility, it encourages private investment in education and health, enabling economies to escape the Health-Poverty Trap. Historical evidence from the United Kingdom, the United States, and China demonstrates that mortality decline preceded rapid economic expansion.

Recent studies confirm that this mechanism remains relevant today. Oltulular (2025) emphasizes that human capital is the key source of future economic value, while Wang et al. (2025) show that "Health in All Policies" initiatives foster innovation through human capital accumulation. Contemporary theoretical analyses (Abrha and Weldeyohans, 2025) further extend the demographic transition framework by integrating modern dimensions such as digital literacy and health resilience. Together, these insights highlight that prioritizing public health is not only a historical necessity but also a modern policy imperative for sustainable development.

APPENDIX

Proof that $(d=0, q=0)$ is the only feasible corner solution when an economy has the mechanisms of endogenous growth factor in our setting. The conditions for corner solution can be rewritten below:

i) Suppose that $d = 0$ and $q > 0$. Then $b_3 = b_4 + [b_4\bar{e}/(e + q)y]$, that is $q = [b_4\bar{e} - (b_3 - b_4)ye]/[(b_3 - b_4)y]$ under our calibration setting, which is not fulfilled for $q > 0$.

ii) Suppose that $d > 0$ and $q = 0$. Then $\pi = [\lambda(ey + \bar{e} + yd)]/[y + \lambda ey + \lambda \bar{e}]$. However, the economy will never experience an endogenous economic growth under.

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Received March 28, 2026, Accepted September 03, 2026.