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公共衛生支出、人力資本與內生成長

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計 畫 主 持 人：莊奕琦

計畫參與人員：碩士班研究生-兼任助理人員：顧訓豪
碩士班研究生-兼任助理人員：李昕
博士後研究：顏扶昌

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中 文 摘 要 ： 本研究建構一理論模型，說明人力資本投資的內生成長之所以能成功的一先決條件是利用公共衛生支出的增加，大幅的降低嬰兒猝死率及生育率，從而帶來數量與質量抵換的人力資本投資誘因，進而促進經濟發展。本理論透過模擬數值分析獲得檢證，並由英國，美國及中國的歷史資料中獲得支持。本研究可供落後國家發展經濟的重要政策參考，即投入公共衛生支出將是一先決條件。

中文關鍵詞： 公共衛生。人力資本，數量與質量抵換，內生成長

英 文 摘 要 ： We construct a growth model by incorporating public health into household intertemporal decision making. Public health improvement significantly reduces death rate, especially infant mortality rate, which in turn reduces fertility rate and enhances private investment in both education and health, which further accelerate long-run growth of the economy. Without initial improvement in public health, the economy is likely stuck in stagnation. We calibrate the model using the U.K. historical data and simulation results confirm the hypothesis that increase in public health spending is a necessary condition for quantity-quality trade-off of human capital investment and subsequent economic growth. Additionally, we can also find the similar story in the case of USA and China. Our result has a strong policy implication that a developing country can create an environment which is conducive to private human capital investment by investing in public health first. That is, public health improvement can be the prerequisite for generating human capital-growth nexus.

英文關鍵詞： public health； human capital； quantity-quality trade off； endogenous growth

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□期中進度報告

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計畫參與人員：顧訓豪、李昕

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中　華　民　國　102　年　11　月　30　日

Public Health, Human Capital and Economic growth

Abstract

We construct a growth model by incorporating public health into household intertemporal decision making. Public health improvement significantly reduces death rate, especially infant mortality rate, which in turn reduces fertility rate and enhances private investment in both education and health, which further accelerate long-run growth of the economy. Without initial improvement in public health, the economy is likely stuck in stagnation. We calibrate the model using the U.K. historical data and simulation results confirm the hypothesis that increase in public health spending is a necessary condition for quantity-quality trade-off of human capital investment and subsequent economic growth. Additionally, we can also find the similar story in the case of USA and China. Our result has a strong policy implication that a developing country can create an environment which is conducive to private human capital investment by investing in public health first. That is, public health improvement can be the prerequisite for generating human capital-growth nexus.

JEL: I18, O15

Keywords: public health; human capital; quantity-quality trade off; endogenous growth

Correspondence to: Yih-chyi Chuang, Department of Economics, National Chengchi University, Taipei 116, Taiwan, ROC. Tel: 886-2-29387630; Fax: 886-2-29390344; E-mail: ycchuang03@gmail.com.

I. Introduction

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

There is an abundant literature studying the source of demographic transition. The majority of literature put emphasis on the explaining the relationship between human capital accumulation and fertility choice, Becker and Lewis (1973) and Becker, Murphy, and Tamura (1992) argue that as the income increase the opportunity cost of having a child and direct costs of raising and educating a child are also increased, and this substitution effect may dominate income effect such that parents will choose to substitute quantity for quality by reducing the number of children and increasing investment spending in 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 parents switch out the quantity of children into quality was not triggered by the increase of income but by the technological progress. Since the technological progress itself raise the return of human capital. As stated, both types of human capital growth model require a precondition either increase in income or acceleration of technological progress.

Which of these explanations can explain the most proportion of decline in fertility remains an issue to argue away. However, for Caldwell (2001), “all demographic transition theories it is the prior decline in mortality that in due to course precipitates the fertility decline”. Galor and Weil(1999) also argue that the improvements in mortality can serve for a unified model that describe the complete transition from the Malthusian trap to the economic growth regime. That is to say, the mortality rate should not keep silent when investigating the source of demographic transition. Additionally, the decline in mortality rate is also an important factor for the human capital accumulation. Ram and Schultz (1979) suggest that the changes in mortality have increased the motivation of human capital investment at any age. Lucas(2009) argue that the knowledge accumulation occurred only when the longevity of human is long enough.

Some literature attempt to link the relationship between mortality rate and fertility choice. Kalemli-Ozcan(2002) develop an OLG models and show that there will be a

hierarchy of children need when facing each child's survival is uncertain. As long as thus uncertainty falls, the hierarchy of needs decrease and give rise to a quantity-quality trade off. Ehrlich and Lui(1991) viewed family as a mutual insurance mechanism that young generation provide old generation support. Under the overlapping generation model, the fertility will decline and schooling investment will increase via the improvement of longevity. Both models point out the importance of mortality rate, but the both models assumed that the survival rate is exogenous.

However, the decline of mortality rate was not brought about by accident in the historical experience. Strulik(2004) view the mortality of children is affected by the income rather than an exogenous variable. In the model, the quantity-quality trade off occurs only under the mortality is sufficient low. However, if there is with no medical progress to improve the child mortality rate, or no technological progress to improve the economic condition, the decline in mortality rate occurs only when the initial income is sufficient high. This point of view is also corresponding with the theory of Health-Poverty Trap that is poor economies are in poor health, and they are poor health because they are poor. Sala-i-Martin (2005) give reason to the Health-Poverty Trap and suggest that the economy is impossible with economic growth without the improvement in health, and the economy is also impossible with the improvement in health without economic growth.

In this paper, we want to explore the solution of Health-Poverty Trap under the economy is in a stagnation and in a poor health. Empirically, it is wildly accepted that the public health effort via sanitary movement, developing effective sewage system and the requiring pasteurized milk improve in the disease control in the developed country.[1]Anand and Ravallion(1993) also claim that one third of life expectancy is explained by a poverty and two thirds by public health spending. With the point of view, our paper attempt to develop a model to describe that the economy might escape from the Malthusian trap and Health-Poverty Trap via the improvement in the public health which decided by the public policy of government. The main contribution of our paper is we prove that the public health policy might play a key role in the acceleration of mortality decline and further cause the economy escape from Health-Poverty Trap.

In history many countries experience sharp decline in birth rate and fertility rate before rapid economic growth. See, for example, the U.K. in the early 18th century before significant economic growth after 1930s The U.K. experienced a sharp decline in infant

[1] See Cutler & Miller(2005) and Caldwell(2001)

mortality rate and fertility rate from 1900 to 1920 (see Figure1), however per capita GDP of the U.K. started to increase significantly not until 1930s.

The similar story can be found in United States and China. From figure 2, we can observe that infant mortality rate in United States was as high as 216.8 per thousand babies born for whites and 340.0 for blacks in 1850s. The United States infant mortality rate drop to 110.8 for whites and 170.3 for blacks in 1900s. Infant mortality rate drop half in 50 years in United States. At the same period, the economic continued increasing but with low growth rate. Soon afterwards, US entered World War One in 1917, experienced the Great Depression in 1929, and entered World War II in 1941. After the World War II, United States just began to boom, with the fastest economic growth rates in the world.

Additionally, Figure 3 also shows that a rapid China's economic growth follows an earlier steep decline in infant mortality rate. However, Chin's government officials still worried about the annual growth of the population. Therefore, one child policy had been implemented in 1978. Nevertheless, the first stage of Chinese demographic transition seems done by 1978.

To be consistent with these historical facts, we construct a growth model by incorporating public health into household intertemporal decision making via the endogenous mortality rate of children and endogenous fertility rate. This paper consists four parts. Section I is introduction. In section II, we construct a theoretical endogenous growth model by incorporating public health spending and private investment decision in human capital accumulation. In section III, we further use numerical analysis to calibrate the model using the U.K. historical records in 1500-1700. With appropriate parameters consistent to real world estimation, we find a growth trajectory for a poor economy to converge to a wealthy economy within a finite time frame. Discussion and conclusion are followed in section IV.

II. The Basic Model

2.1 Mortality Rate

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

$$\pi = \bar{\pi} + \theta(g) + [1 - \bar{\pi} - \theta(g)]\lambda(g)d,\ \theta'(0) = 0,\ \theta'(g)>0,\ \ \theta''(g)<0,\ \theta(g) = 0$$
$$\lambda'(0) = 0,\ \lambda'(g)>0,\ \ \theta\lambda''(g)<0,\ \lambda(g) = 0 \qquad (1)$$

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 expenditure, with its effect given by $\theta(g)$.Third, parents' health expenditure also plays a role, although its effectiveness also depends on government's public health expenditure. In particular, the larger is $\lambda(g)d$ (with maximum value, one), the higher is the third term in (1). Here, we use $\lambda(g)$ to capture the notion that government's public health expenditure will improve the efficiency of private health expenditure. 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. Only when these public health facilities are in place could private health expenditures become real effective.

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 two periods: childhood and adulthood, in which the latter can be further distinguished into prime-age and old age periods. 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 prime-age and old-age, c_1 and c_2, the number of children to have, n, 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:

$$\max U = b_1 lnc_1 + b_2 lnc_2 + b_3 ln(\pi n) + \mathrm{b}_4 ln(q + e);\ b_3 > b_4 \qquad (2)$$
$$\text{s.t. } c_1 + \frac{c_2}{1+r} + (d + q + e)n(1 - t)y + \bar{e}n = (1 - t)y$$

In equation (2), we use y to represent household income, t to denote income tax rate,

while e and $\bar{e}$ are respectively the fixed cost and the ratio of income needed to physically raise a child.[2] In order to simplify the analysis, we assume that the government uses all the taxes it collects on public health. Hence,

$$ty = g \tag{3}$$

From equations (1) to (3) we can solve for the 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:

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

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

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

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

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

2.3 Firms and the Macroeconomy

We assume a representative firm who uses land, *X*, physical capital, *K*, and effective labor *HL*, to produce final output, *Y*. Here, effective labor consists of two parts, with *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 survived children born, that is $L_t = \pi_{t-1} n_{t-1}$. Additionally, similar to van Zon and Muysken (2001), our model views education input as the main source of human capital. Therefore, the human capital of worker in the initial period can only be accumulated by parental investment in education. Furthermore, human capital of the last period is one component of the stock of human capital. Thus, the human capital accumulation function can be written as:

$$H_t = V {q_{t-1}}^f + H_{t-1} \tag{5}$$

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

[2] Here, *e* does not need to have an economical meaning. The main reason for setting *e* to be nonzero is to ensure the last term in the utility function $ln(q + e)$ to be defined even when education input *q* is set to zero.

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

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

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

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 than 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 accumulation and the growth rate of labor which can also viewed as 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 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), based on the condition $q_0 = 0\ if\ y_0 \leq [(1-\bar{\pi})\bar{\lambda}]/[\bar{\pi} - (1-\bar{\pi})\bar{\lambda}e]$, then *H*=0 as well as γ_H=0. The economy can growth only when the y_0 is large enough to trigger the parental investment in education q_0, then γ_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 rate are raised exogenously to* $\tilde{\bar{\pi}} > \bar{\pi}$.

Proof. From (4.1c), based on the condition $q_0 = 0\ if\ \bar{\pi} \leq \tilde{\bar{\pi}} = (\bar{e} + ey)/(\bar{e} + ey + y).$, then *H*=0 as well as γ_H=0. The economy can growth only when the $\bar{\pi}$ is large enough to trigger the parental investment in education q_0, then γ_H>0.

From propositions 1 and 2 we know that when the government is nonexistent, there

are only two paths to escape from 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 researches often find the first path to be unsuccessful in explaining an economy's escape from 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 the population density but not income levels. In a similar vein, Ashraf and Galor (2011) also empirically demonstrate that the productivity growth in pre-Industrial Revolution only contributes to a larger population.

If we focus on the second path, we do find examples where increasing children survival rate might have led countries out of poverty traps.[3] However, this cannot explain why most countries did not experience large surges in income until after the 1800. 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. It is only until between 1800 and 1970 with the control of infectious diseases one finds mortality rate to decrease.[4] In the literature, most contribute this improvement to a better public health system, especially the establishment of sewage disposal, increased provision of public sanitary facilities, and policies aimed to contain population densities.

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 calibrate 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.

III. Simulation

3.1 Numerical setting

The United Kingdom, the first country to escape from the poverty trap, was also the

[3] In 2002, the WHO argued that over 2 million children have been saved because of vaccination. Some countries implemented their compulsory vaccination programs under the help of the WHO.

[4] In 1861, on average each woman gave birth to 5 children, in which only 3.5 of them will live over10 years old. By 1951, each woman on average gave birth to 2 children, in which 1.9 of them will live past 10 years old.

first to complete the demographic transition. Hence, in this study we calibrate the model according to the U.K. historical records of 1500-1700. Firstly, we assume that the human capital in the current period within the economy comes from both the human capital stock inherited from and the private education expenditure on households' offspring in the previous period.

Secondly, according to Maddison (2003), the income per capita 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 7 while the coefficient of the variable part with income was 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.[6]

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, parents' health expenditure to 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 spending beyond necessity by parents. Though an accurate natural survival rate is not documented, we assume $\bar{\pi}$=1/3 in the simulation.[7]

In addition, the government 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 concave in g to capture the diminishing marginal return of the government expenditure on public health. To get a reasonable range of the survival rate, i.e., [0,1], we assume $\theta(g)$ and $\theta(g)$ in a hyperbolic tangent functional form. Let $\theta(g)$ be $m \times [exp(ag) - 1]/[exp(ag) + 1]$, 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

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

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

$\theta(g)$, 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 $b = 0.0025$.[8]

Finally, following Strulik (2004) the effect of investment in human capital accumulation ($Vq_{t-1}{}^{f}$) is set to has V=10 and f=0.3.

3.2 Simulation result

In this research, human capital(H) accumulated by the education which parents give to their children(q) is the main engine of our setting. In other words, if the initial survival rate is too high or the initial income is too low to motive the parents to invest the education on their child, the economy will stay in stagnation forever. In other words, the public health expenditure plays an important role when an economy has no medical and technological progress. In order to stress that 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 survived children (πn), private spending ratio on health (d) and education (q) under different tax rates of 5%, 10%, 60%, and 70% for 500 periods.[9]

First, we start with a scenario where there exists no any tax and thus no public health expenditure. In this scenario, the real income per capita stays at 700, number of children born is 7.58, and number of survived children is 2.53. Because of high mortality rate, parents are not likely to put in any education and health resources for their children. The income growth rate remains zero and the economy stays in the Malthus trap with the features of low income and high fertility rate.

Now suppose that the government imposes a tax rates, 5%, and tax revenues are all used as public health expenditure. As we can see from each left panel of figures 4(a)-4(g), when the tax rate is 5% and the public health spending is positive, the survival rate increases by 4% (from 33% to 37%). 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 and health expenditure. Because of zero education spending, the human capital is not accumulated and the economy remains stagnant. That is, this economy is still trapped in a Malthusian sense.

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[8] Based on the 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 to Strulik (2004).

[9] Because the economy approaches the steady state with the constant growth rate (0.13% under our numerical setting) of output per capita within the period of 500, we therefore calibrate the simulation for 500 periods.

However, if the government increases the tax rate to 10%, the results are totally different. According to figure 4(c), the survival rate has a big increase even in the early stage of the economic development. Sharp increase in survival rate turns individuals to raise fewer children and spend more on children's education and health. The high-level education accelerates the accumulation of human capital, and thus promotes economic growth, which in turn helps the government collect more tax revenues and spend more on the 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 the right panel of figure 4(a), we can see that the per capita income is constantly increasing. We also depicted the case of the 60% tax rate in the right panel, where the results are similar to those of the 10% tax rate except that a higher speed of convergence in the case of 60% tax rate.

In addition, we simulated the case with 70% tax rate and illustrated the results in the left-panel figures. Though the survival rate increases from 33% to 70%, individuals have virtually no incentive to allocate resources onto children's education and health due to low disposable income, and thus the economic growth rate remains at a zero level.

We summarize the results of all simulations in tables 1 and 2. Table 1 shows the results of 0, 5%, and 70% tax rates. Compare with the zero tax rate as the benchmark model, we find there is a jump in per capita income for the economies with 5% or 70% tax rate. However, a once-for-all jump in income level due to too low or too high tax rate does not induce a sustainable economic growth due to lack of incentives on children's education and health spending. On the other hand, table 2 presents the results of 10% and 60% tax rates. These results indicate that with a reasonable tax rate the households will continue spending out of disposable income on children's education and health, and thus the per capita income keep growing and so does the human capital accumulation.

IV Some Historical Reviews and Discussion

The above simulations demonstrate that the demographic transition of an economy extremely relies on public health investment financed by tax revenues within a reasonable range of tax rates. However, can this result explain the economic development of the United Kingdom after the Industrial Revolution? Can this result also explain the economic development of United States and China? Let us review some historical factors first.

4.1 United Kingdom

During the Middle Ages (5th-15th Centuries), most of European economies were in the form of feudal system relied mainly on agriculture. Feudal societies were based on the structure of the agricultural system known as manorialism characterized by tenant farmers cultivating and residing on the land owned by a feudal leader. The power of the feudal leader came from the ownership of land.[10] Under the feudal system central government did not directly rule the state and therefore it resulted in the political power fragmentation or decentralization. This is one of the reasons for the low government expenditure to GNP ratio at that time.11 After the mid-15th century, the British agricultural economy started to decline due to the rise of enclosure movement motivated by the flourish of international trade, and therefore the 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 fairly use the tax revenue. 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 the British history, the Glorious Revolution promoted a reasonable tax rate and the Industrial Revolution boosted a production technology. However, the rapid industrialization brought cities dirty living surroundings and severe diseases. It was the subsequent government spending on public health significantly improved the living environment. As a result, the mortality rate declined, demographic transition emerged, technology progress was no longer offset by population growth anymore, and finally the United Kingdom escaped from the Malthus trap.

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[10] Cameron (1989) described the feudal system as follows: "no land without a lord, no lord without land."

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

From the Figure 3 we can observer the same story that a sharp decline in infant mortality rate from 1850 to 1930, however per capita GDP of the U.K. started to increase significantly not until 1940s.

4.2 United States

United States experienced the demographic transition from 1800-1940. During this period, United States undergone the highest level of net in-migration in 1840-1920, biggest civil war in 1861-1865 and the baby boom in the end of WWII. However, the infant mortality rate still markedly decline from 1870s (see Figure2). Before that, lots people die because of periodic epidemics like cholera, yellow fever, dysentery, etc.

The mortality decline from 1870s because of the large improvements of public health and the medical innovations. The improvements of public health such as building the sewer systems, providing the water with filtration and chlorination and promoting sewage disposal had efficiently control the disease environments then. The medical innovation such as the development of cholera vaccine in 1879 and the development of plague vaccine in 1897, etc, counted large proportion of prevention from infection of epidemic decease.

Though it is difficult to distinguish the separate effects of these historical factors which can all drive the demographic transition of United States. As our research point, the improvement of public health still has its role.

4.3 China

During the period of 1945 to 1949, China’s environmental hygiene was lack as a result of the end of long war and Civil War army. In the meanwhile, homebirth death, pneumonia and epidemic disease are leading causes of infant death in China, accounting for 200 per thousand babies born in 1950s. China’s per capita income was also quite low in the first fifteen years of the People's Chinese Republic (1949-1964).

Though the whole economy was experiencing a very difficult moment then, government of the People's Republic of China still adopted lots of public health policies to improve birth outcomes and reduce infant mortality. For example, establishing the nationwide health and epidemic prevention system, building the nationwide maternal

and child health-care system, etc.[12] Additionally, in order to improve the medical environments of Chines rural area, Mao established the barefoot doctor scheme for country districts in 1970.[13] After years of hard work on public health, most epidemic deceases like plague, cholera and dysentery were carefully controlled. Rate of maternal and infant mortality rate decreased sharply.

China's economic growth follows an earlier steep decline in infant mortality rate. However, Chin's government officials still worried about the annual growth of the population. Therefore, one child policy had been implemented in 1978. Nevertheless, the first stage of Chinese demographic transition seems done by 1978.

From the case of China, we could know that the government efforts to improve the public health can cause a demographic transition and it may further push the whole economy to the growth regime.

4.4 In Summary

Though UK, US and China experienced in much different economic development paths, we can still find some similarities to explain why these countries can escape from poverty and enter into the growth stage. We find that only through the public health can simultaneously solve the overpopulated problem and the human capital deficiencies. Additionally, the health problem should be treated as top priority for those countries which are struggle in poverty trap as well as health trap.

IV. 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 infant mortality rate, which in turn reduces fertility rate and enhances private investment in both education and health, which further

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[12] During the 1950s, it was widely considered shameful for a woman to give birth in China. Some pregnant women will be hunted out of house to give birth in cattle pen or sheep pen. Moreover, some midwiferies were seriously lacking medical and health knowledge to provide adequate way to help a mother give birth. According to an approximate estimate, two hundred thousand pregnant women and one million new born child died from the inappropriate methods of delivery. The most important reforms of the maternal and child health-care system in the 1950s of China was to promote the correct methods of delivery to the nationwide to decrease the death rate of new born child and mother.

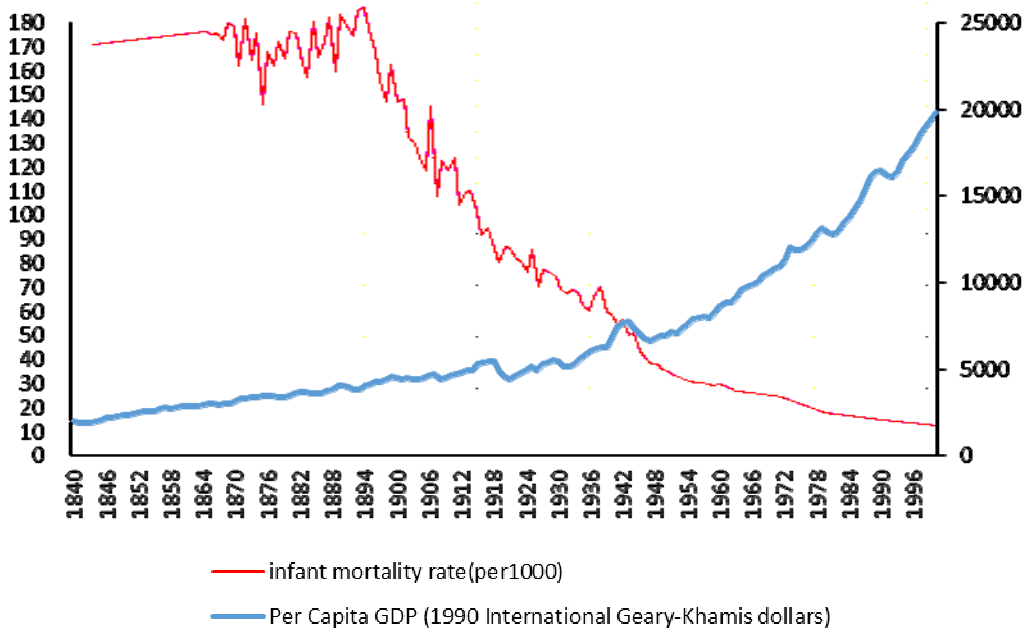
[13] Barefoot doctors are whose received basic medical and paramedical training and provide the basic health care service in rural area. The main task of barefoot doctor is to halt epidemic disease and improve the birth outcomes.

accelerate long-run growth of the economy. Without initial improvement in public health, the economy is likely stuck in stagnation. We calibrate the model using the U.K. historical records in 1500-1700 and simulation results confirm the hypothesis that under reasonable tax rate to finance public health the increase in public health spending is the necessary condition for quantity-quality trade-off of human capital investment and thus stimulate subsequent long run economic growth. However, the scenarios of too low or too high tax rate will not generate the beneficial results leading to sustainable long run growth. Additionally, we compare the economic development experience among UK, US and China, and observe that the government intervention in public health did play an important role through the initial stage of growth.

Our results have a strong policy implication that a developing country can create an environment which is conducive to private human capital investment mainly first by investing in public health financed by a reasonable tax rate. That is, public health improvement can be the prerequisite for generating human capital-growth nexus.

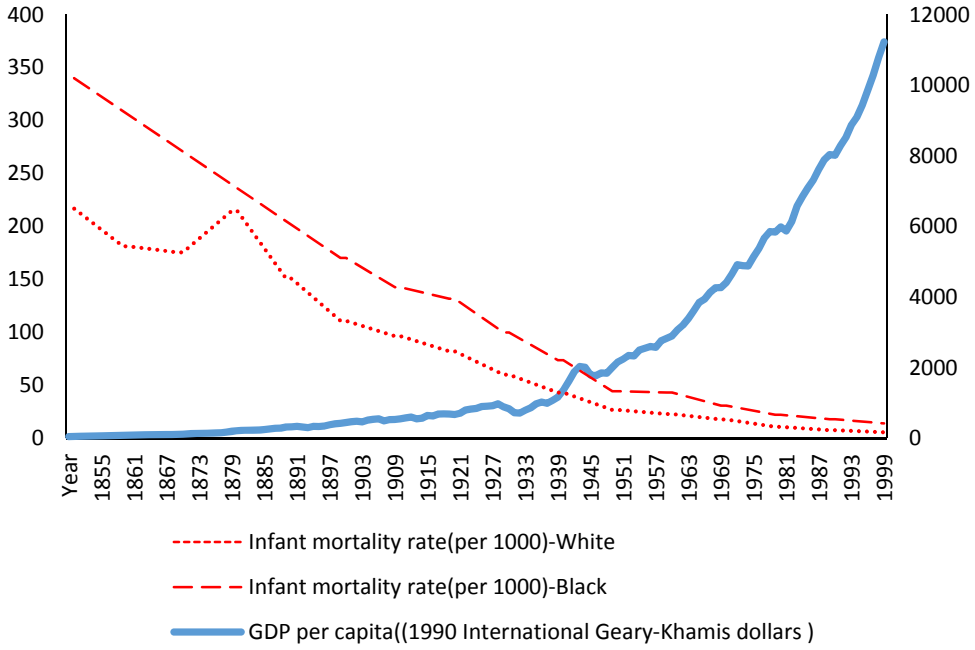
Figures

Figure 1 Infant mortality rate and per capita GDP in the U.K.



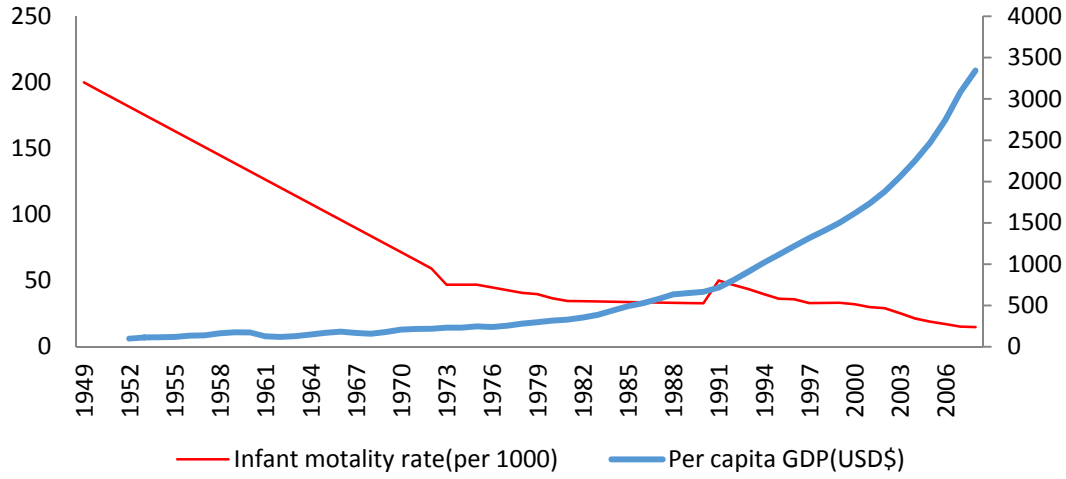
Source: University of Portsmouth, The World Economy: Historical Statistics (Angus Maddison)

Figure 2 Infant mortality rate and per capita GDP in the USA



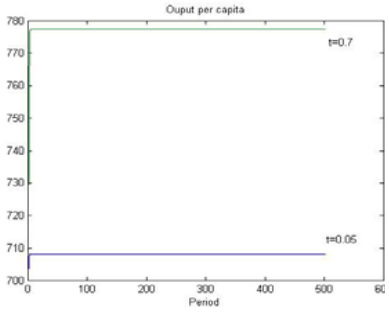
Source: Michael Haines, Colgate University (infant mortality rate), The World Economy: Historical Statistics (Angus Maddison)

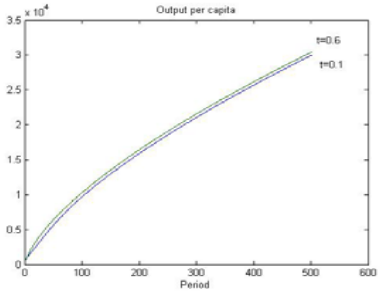
Figure 3 Infant mortality rate and per capita GDP in China



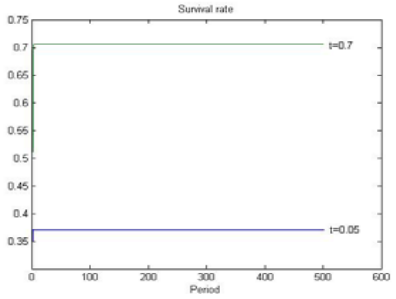
Source: China compendium of statistics, China population statistics yearbook

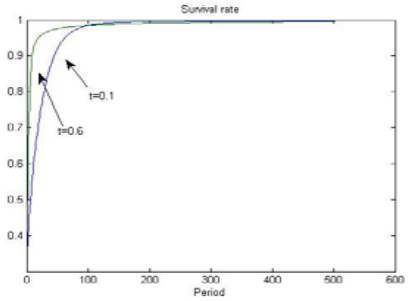
Figure 4 Simulation results



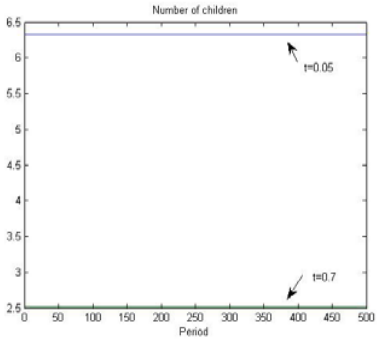


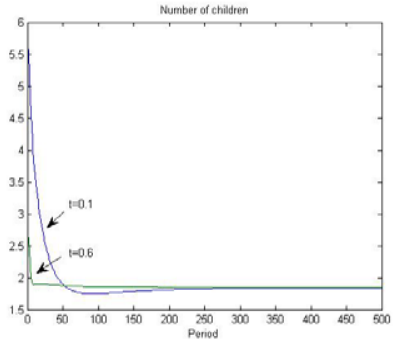
4(a) Dynamic path of output per capita(y) under different tax rate



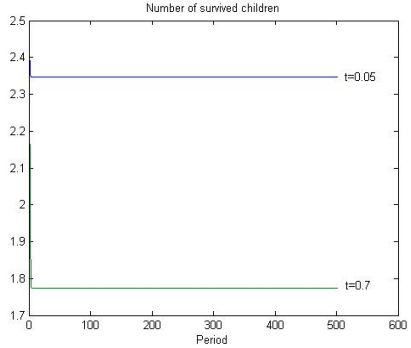


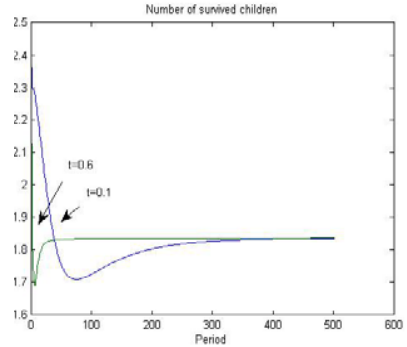
4(b) Dynamic path of survival rate(π) under different tax rate





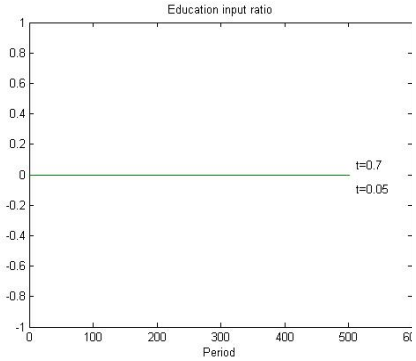
4(c) Dynamic path of number of children(n) under different tax rate

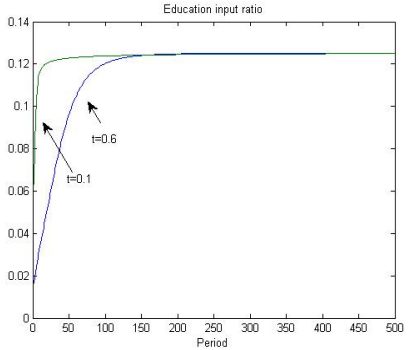


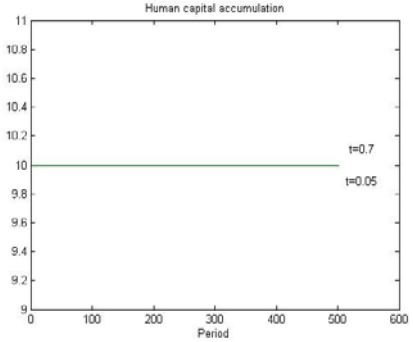


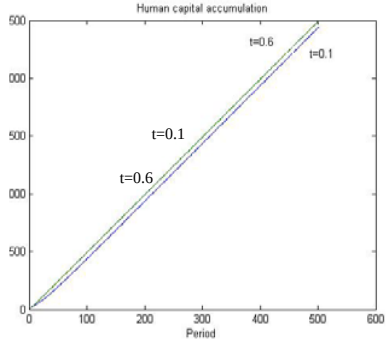
4(d) Dynamic path of number of survived children($L = \pi n$) under different tax rate

Figure 4 Simulation results(Cont.)



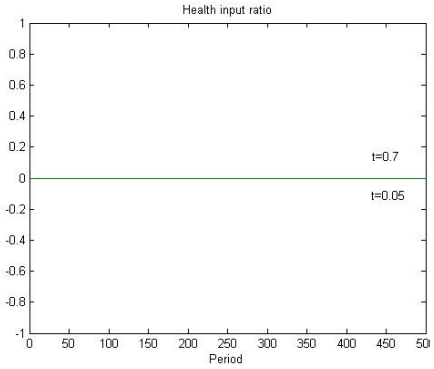


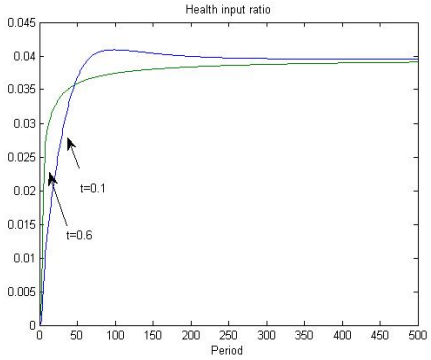




4(f) Dynamic path of education input ratio(n) under different tax rate

4(e) Dynamic path of education input ratio(α) under different tax rate





4(g) Dynamic path of health input ratio(d) under different tax rate

Table 1 Calibration results under tax rates equals to 0, 0.05 and 0.7

	t=0	t=0.05	t=0.7
Output per capita(y)	700.00	708.10	777.37
Survival rate(π)	0.33	0.37	0.70
Number of children(n)	7.58	6.32	2.51
Number of survived children($L=$)	2.53	2.34	1.77
Education input ratio(q)	0.00	0.00	0.00
Human capital accumulation(h)	10.00	10.00	10.00
Health input ratio(d)	0.00	0.00	0.00

Note: The economy transition towards a steady-state in a period without any economic growth under these scenarios.

Table 2 Calibration results under tax rate equals to 0.1 and 0.6 in the steady state

	t=0.1	t=0.6
Output per capita (y)	29971.18	30415.74
Survival rate (π)	0.99	0.99
Number of children (n)	1.84	1.84
Number of survived children (L)	1.83	1.83
Education input ratio (q)	0.13	0.13
Human capital accumulation (h)	2440.90	2495.66
Health input ratio (d)	0.04	0.04

Notice: The economy converge towards a steady state with constant growth rate around 500^{th} period. Therefore, the calibration results show the outcome of all variables in the 500^{th} period.

Appendix

Proof that (q=0, d =0) is the only feasible corner solution when an economy has the mechanisms of endogenous growth factor in our calibration setting. From the equation (4.1a)-(4.1e), we can rewrite the equation as below:

$$\frac{b_3}{n} = \frac{b_1}{c_1}[(e+d+q)y+\bar{e}] \qquad \text{(A1)}$$

$$[\frac{b_3(1-\bar{\pi})\lambda}{\bar{\pi}+(1-\bar{\pi})\lambda d} - \frac{b_1}{c_1}ny]d = 0 \qquad \text{(A2)}$$

$$[\frac{b_4}{e+q} - \frac{b_1}{c_1}ny]q = 0 \qquad \text{(A3)}$$

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 $q = 0$.

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國科會補助專題研究計畫項下出席國際學術會議心得報告

日期：2013 年 4 月 27 日

計畫編號	NSC 101-2410-H-004 -018 -		
計畫名稱	公共衛生支出、人力資本與內生成長		
出國人員姓名	莊奕琦	服務機構及職稱	政治大學經濟學系
會議時間	102 年 4 月 3 日 至 102 年 4 月 6 日	會議地點	Vienna, Austria
會議名稱	（中文）第 75 屆大西洋國際經濟會議 （英文） 75th International Atlantic Economic Conference, International Atlantic Economic Society		
發表論文題目	（中文）公共衛生支出、人力資本與內生成長 （英文）Public Health, Human Capital and Economic Growth		

一、參加會議經過

This 75th International Atlantic Economic Conference was held in the beautiful city Vienna, the world's capital of music and a pivot between the East and the West. This conference was organized by International Atlantic Economic Society found in 1973 with the goa; of increasing the opportunity for exchange of new ideas among economists in the world. This three days of conference was well organized with many sessions across different areas of economic studies, including European Economic policy, financial crisis and inflation, agricultural and natural resources, economic growth and aggregate productivity, globalization and economic integration, monetary and fiscal policy, and country studies, etc. Besides ordinary sessions, there are some keynote speeches offered by presidential address and invited or distinguished addresses, which I believe is a particular benefit to attend the conference as it usually provides special topics based the local development with international perspective. Professor Reinhard Neck, President of IAES, spoke on "Austrian Economics and Economics of Carl Menger," who together with many economists formed the so-called Austrian School. The presidential address gave us the comprehensive view on the evolution of ideas of those Austrian economists and their contribution on the discipline. Invited speaker Mr. Andreas Schieder, State Secretary of Austrian Federal Ministry of Finance, gave a speech on "Inequality in Distribution and Growth," a topic which is relevant to all economies in the world. He described the distribution situation in Austria and government policy toward the issue in particular the fiscal policy. Dr. Ewald Nowotny, governor of Austrian National Bank, invited all

conference participants to visit the Australian National Bank, a historical building of Ausria. Before the dinner, Governor Nowotny gave a speech on “The Future of the European Integration: Economic Challenges and perspectives,” starting from the outbreak of global financial crisis in 2008 and its subsequent quantitative easing monetary policy adopted by many economies to cope with the economic downturn. On the last day, an invited address was given by famous public economist Professor Dennis Mueller of University of Vienna on “Religion and the State,” a very interesting topic that triggers many warm responses from the audience. Prof. Mueller emphasized that religion is like a kind of club and therefore government should not subsidize or give favorable tax treatment to any religion. If activities offered by religion are good for the society, then we should subsidize the activities but not religion per se. I found the argument very enlightening. These varies invited addresses gave participants the time to get together and generate discussion on some common economic issues confronting every economies. Overall, I think this is a very well-organized and successful international conference and our scholars should be encouraged to attend.

二、與會心得

As a Taiwan scholar, this is a tremendous opportunity for me to attend this international conference, to exchange academic ideas, and to share the expertise and experience with distinguished scholars from different disciplines and countries. I presented a paper on “Public health, human capital, and economic growth” at the session of economic growth and aggregate productivity. My paper advocates that public health spending can be a prerequisite condition for economic growth, a though generated by the stylized facts economies such as the U.K. and China all experienced a sharp drop in mortality rate before the economic take-off into a long period of enduring growth. My discussant Dr. Felipe Saffie from University of Pennsylvania made many constructive suggestions and comments, which also caused many warm discussions from audience. I benefited a lot from attending this conference. During coffee break or lunch, I was also able to discuss with many conference participants including issues such as green revolution in South Africa, pension system in Germany and the U.K., real estate market and retirement scheme in Austria, and India economic development. By attending the conference I can hear many ideas and opinions from scholars and policy makers and share my experience with them as well. This is actually a valuable personal experience for me, I had benefited from many scholars research results and experience that sharpen my understanding in many aspects regarding academic research agenda setting and articulation. The more I attend an

international conference, the more I feel confident to present my idea, discuss with other scholars, and make the right response to questions. Thus, I highly recommend our researchers to participant international conference like this to gain the most updated information and knowledge from scholars all over the world.

三、考察參觀活動(無是項活動者略)

I took this opportunity to visit University of Vienna and Vienna University of Business and Economics and be able to discuss with them regarding exchange of students and possible academic collaboration.

四、建議

I strongly recommend domestic scholars to joint international conference or interdisciplinary conference such as IEAS to learn more multicultural experience and at the mean time to enhance Taiwan's visibility on the international academic arena. To organize a panel and form a research team to present at the international conference should be considered as an effective way for internationalization of our higher education.

五、攜回資料名稱及內容

Conference agenda and papers.

六、其他

國科會補助計畫衍生研發成果推廣資料表

日期:2013/11/27

國科會補助計畫	計畫名稱: 公共衛生支出、人力資本與內生成長
	計畫主持人: 莊奕琦
	計畫編號: 101-2410-H-004-018- 學門領域: 經濟發展、技術變動與成長

無研發成果推廣資料

101 年度專題研究計畫研究成果彙整表

計畫主持人：莊奕琦	計畫編號：101-2410-H-004-018-
計畫名稱：公共衛生支出、人力資本與內生成長	

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	2	2	100%	人次	
		博士生	0	0	100%		
		博士後研究員	1	1	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	1	1	100%		
		研討會論文	1	1	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
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		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 □未發表之文稿 ■撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：(以 100 字為限)

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）(以 500 字為限)

本研究提供一理論模型，說明人力資本投資的內生成長之所以能成功的一先決條件是利用公共衛生支出的增加，大幅的降低嬰兒猝死率及生育率，從而帶來數量與質量抵換的人力資本投資誘因，進而促進經濟發展。本理論透過模擬數值分析獲得檢證，並由英國，美國及中國的歷史資料中獲得支持。本研究可供落後國家發展經濟的重要政策參考，即投入公共衛生支出將是一先決條件。