Barrier to Health and Poverty Trap

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Abstract: Why have some poor countries been able to take off while others are still stuck in the poverty trap? We observe that (i) with similar or higher levels of educational attainment, trapped countries tend to have poorer health conditions compared to the initially poor countries that later take off, and (ii) improving health conditions in poor countries usually involves large scale investment where such resources can be easily misallocated. We construct a dynamic general equilibrium model with endogenous health and knowledge accumulation, allowing for health-related institutional barriers to affect individual incentives and equilibrium outcomes. We then calibrate the model to fit (i) the U.S. economy (as a benchmark), (ii) a representative trapped economy based on the average economic performance and economic conditions of 41 countries that are still in the poverty trap, (iii) a group of trapped economies with richer institutional data (Bangladesh, Kenya and Nigeria), and (iv) two initially poor countries that later took off (China and India). The results show that, although low among all countries in this study, the U.S. economy still has a health-related institutional barrier of around 15%. The trapped economies all have large barriers ranging from 50% to 73% under which the incentive to invest in health is severely reduced. For China and India, the magnitudes of the barriers are large (about twice as much as the U.S. but only half of trapped economies on average) but not enough to throttle the willingness to invest in health. This paper thereby advances our understanding of the role played by barriers to health in poverty trap.

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"*We are ill because of poverty – poverty is like an illness.*" (respondent from Moldova, *Voices of the Poor*, Vol. I, p. 87)

"*Poor people cannot improve their status because they live day by day.*" (respondent from Vietnam, *Voices of the Poor*, Vol. II, p. 98)

"*For me, a good life is to be healthy.*" (respondent from Ethiopia, *Voices of the Poor*, Vol. II, p. 90)

"*Today we pray to God that nobody gets sick. What could we do?*" (respondent from Macedonia, *Voices of the Poor*, Vol. I, p. 35)

1 Introduction

Large differences in income levels have persisted across countries for decades. Economists have sought to identify the underlying causes of such noticeable disparities and, in particular, to understand why some countries are able to pull out of the poverty trap while other countries remain mired in it. In addition to the accumulation of physical capital per worker advocated by Solow since half a century ago, education and health conditions are generally considered as crucial for the economic development process.[1] Nonetheless, in this still-thin literature, there is no systematic, integrated micro-founded framework to investigate how these two important factors may interact, leading to drastically different development outcomes. Such an omission could harm the prediction power of the model, especially when health and education may affect the development process of different developing economies differently. The chief purpose of the present paper is to rectify these problems by establishing an integrated model with endogenous investment in health and education so as to quantify how institutional barriers to health may interact with education investment to serve to explain the drastically divergent paths of economic development.

Let us begin by displaying some key stylized facts related to the motivation of our study. We focus on three key measures: economic performance (measured by per capita GDP growth rate and per capita GDP relative to the U.S.), health conditions (measured by life expectancy and under 5 mortality rates), and educational attainments (measured by years of schooling). In Figure 1, we plot life expectancy (panel (a)) and years of schooling (panel (b)) against real GDP per capita relative to the U.S. in 1960. While both cross-country relationships are positive as expected, simple eye-balling detects a major difference: the relationship between educational attainments and economic performance is basically linear, but that between health conditions and economic performance is concave.[2] Thus, health conditions appear to be much more important for low income countries to advance to better economic status. To facilitate better understanding, we report in

[1] Hereafter we will use education and knowledge interchangeably.

[2] Because of a heavy clustering of poor nations toward the lower-left corner, we isolate those countries in a separate scatter plot, Figure 1(c).

Table 1 these three key indicators over the period from 1970 to 2007 for selected representative countries under different income groups: high income, middle-income-high, middle-income-low and low income (or, trapped).[3] It is noted that both high income and middle-income-high countries have comparable lengths of life expectancy and years of schooling since 1990,[4] whereas the differences in the life expectancy between middle-income-low and middle-income-high countries are small.[5] Most interestingly, trapped economies are characterized by low income levels, low growth rates, fewer years of schooling and *much shorter life expectancy.* The World Health Organization (WHO) and the United Nations (UN) have exerted strong efforts to improve the health conditions and educational attainment in poor countries over the past 40 years in their attempt at reducing inequalities across nations. Their effort together with individual trapped countries' awareness have led to significantly improved health conditions and educational attainments since 1970, as shown in Table 1.[6]

We are particularly interested in understanding why some initially poor (now middle-income-low) countries could take off (Egypt, China and India), while other poor countries remain trapped in poverty. By examining Table 1 more carefully, we find that there is a notable difference between the initially poor countries that later took off and the trapped countries: *with similar years of schooling, the trapped countries tend to have lower life expectancy.* For example, in 1970, Egypt had 1.3 years of schooling and a life expectancy of 45.9 years. Bangladesh and Malawi had similarly low but slightly longer years of schooling than Egypt, but both countries had a much lower life expectancy compared to Egypt. Now let us compare China with the trapped countries. China has performed very well in health since 1970. With only 3% of the real GDP per capita of the U.S., China has reached a life expectancy of 62.0 years – a miracle with such a low income level. In 1980, with only 4% of the real GDP per capita of the U.S., years of schooling and life expectancy in China were 4.8 and 66.0 years, respectively. However, with similar or much longer years of schooling, up to the year 2008, none of the trapped countries had reached a life expectancy of 66.0 years. A similar

[3] The categorizing criteria are: countries with relative incomes of 0.65 or higher in the year 2000 are grouped as high income countries; countries with relative incomes of 0.2 - 0.65 in 2000 are classified as middle-income-high countries; countries with relative incomes of 0.1 - 0.2 in 2000, or with an average GDP per capita growth rate of 2% or higher during 1970-2007 are classified as middle-income-low countries; and finally, countries with relative incomes of lower than 0.1, or with an average GDP per capita growth rate lower than 2% during 1970-2007 are classified as trapped countries.

[4] Brazil was a bit behind in both measures compared to Argentina, Greece and Korea.

[5] India is an exception: is categorized as a middle-income-low country because of its slow but steady growth of GDP per capita relative to the U.S.

[6] In 1970, the life expectancy in Malawi was less than 40 years, while other trapped countries (Bangladesh, Cambodia, Ghana, Kenya and Zambia) also had a life expectancy of about 40-45 years. As time progressed to the years 2000-2008, life expectancy in the trapped countries (except for Zambia) increased to 53-65 years. The mortality rate for those under 5 was also reduced by about half during 1970 to 2000. At the same time, years of schooling in these trapped countries have also increased substantially since 1970.

case is found when we compare India with Malawi or Zambia: with comparable or shorter years of schooling, India tends to have longer life expectancy than Malawi or Zambia.

Several questions naturally arise after observing the facts described above. Why does health play a different role from education, and through what channel does health affect the performance of an economy? How does health interact with education to lead countries along different development paths? Most importantly, *why are some countries able to perform better in terms of health despite the low income levels? In particular, do there exist country specific factors leading to this outcome? If such factors exist, are they quantitatively critical for leading to such drastically divergent development paths*? These are the central questions our paper designed to address. To address these issues and to generate practically useful policy implications, we force ourselves to put the micro-founded model to reality check: those "Voices of the Poor" quotes above cried out by respondents from various poor nations not only link poor health to poverty (first two quotes) but also point to the poor's high valuation of health (third quote), for which they are unable to pay (fourth quote). Such behavior-driven responses will be taken to heart when we delineate the theoretical framework.

Bearing these important questions and reality considerations in mind, we begin by constructing a basic organizing framework following the aggregate production function approach, capturing how educational attainments and health conditions, in addition to physical capital accumulation and demographic transition, may drive different economic development outcomes. Under this organizing framework, we perform simple cross-country and panel regression analyses using data from 41 countries that are still in the poverty trap as of 2007. The cross-country regression results indicate that, once including regional dummies and total fertility rates, neither years of schooling nor health spending measures are significant statistically at conventional levels. The same conclusion remains in panel regression analyses, but country fixed effects are mostly significant and sizable. This points to the possibility that *country-specific institutions* are crucial for overall economic performance of these trapped countries.

To enable better understanding about how various economic factors inclusive of institutional barriers may drive economic development outcomes, it calls for a deep structure model. Accordingly, we develop an analytically tractable three-period overlapping-generations model with human capital decomposed into health and knowledge capital. Since parental investment in both health and education are crucial for children to have a better position for a better life in their later stages, we assume that all investments in health and knowledge are made by parents. As in Glomm and Ravikumar (1992) and many other studies, parents have limited altruism toward their offspring: they only care about their children's human capital. Health investment takes resources and determines the quality of life and the level of health capital of children, while investment in education takes parental time and determines the level of knowledge capital. Health and knowledge capital together form the children's human capital, which determines the productivity of labor of children. To

capture country-specific factors determining the efficacy of health investment, we assume that there exist health-related institutional factors in the economy. These factors could be harsh to the health environment, such as the prevalence of parasites and infectious diseases, or corruption rooted in the political system. The institutional factors are barriers in essence, diverting resources from the intended purpose of use and depleting the already scarce resources in poor countries. When these barriers "consume" too many resources, or when the institutional barriers are too severe for an economy to deal with them, individuals cease investing in the health of their children. The economy then ends up with poor health conditions and short life expectancies, which further reduce the incentives for capital accumulation and hence destroy the fuel of economic growth. The vicious cycle between poor health, low incentives to invest and bad institutions thus trap the country in poverty.

We provide conditions to guarantee a unique equilibrium, and examine when it is more likely for a poverty trap to emerge. We then calibrate the model to match the U.S. economy and perform comparative statics numerically. We find that under the parameterization of the U.S., parents always invest more in their children's education than in health when they become more altruistic, while pure improvement in the quality of life when old yields the opposite effect. With the U.S. serving as the benchmark, we next proceed to calibrate the model for a number of countries at various development stages of interest, namely, (i) a representative trapped economy based on the average economic performance and economic conditions of the 41 trapped countries, (ii) a group of trapped economies with richer institutional data (Bangladesh, Kenya and Nigeria), and (iii) two initially poor countries that later took off (China and India). Our quantitative results show that the trapped countries under investigation indeed experience much more severe institutional barriers compared to the middle-income-low countries, in the order of 1.5 to 2.5 times. Our results show that all the 41 trapped countries are swamped by their own institutional problems, prohibiting them from pulling out of the poverty trap. For the two representative middle-income-low countries, although the severity of their institutional barriers is much sterner than that of the U.S. (twice as high), such barriers are low enough for them to take off and to proceed along the right track of development.

Related literature

This paper is related to three strands of the literature, namely, (i) health and development, (ii) institutional barriers, bureaucracy and corruption, and (iii) development trap.

The line of research on health and development was pioneered by Grossman (1972) and since then there has been a small, but growing literature devoted to studying the demand for health within an individual optimization framework in which better health promotes longevity (cf. Ehrlich and Chuma 1990; Grossman 1998). The investigation on how the improvement in health (a mortality rate reduction and life expectancy increase) leads to a higher level of education is best shown by

Jayachandran and Lleras-Muney (2009) who show that increases in life expectancy resulting from the decline in maternal mortality rates promote better education for girls in Sri Lanka. Our paper is more related to Chakraborty (2004), and Manuelli and Seshadri (2009). While Chakraborty (2004) considers health capital augmented by public investment, Manuelli and Seshadri (2009) focus on investments in private health and education as well as their consequences for cross-country differences in fertility. Empirical works investigating the contribution of health to economic development include Acemoglu and Johnson (2007), Weil (2007), Lorentzen et al. (2008) and Wang (2012). However, researchers have not yet reached a consensus on the magnitude or the underlying channels of the health improvement effects on economic growth and development. We continue the effort along these lines by proposing a framework for health investments to interact with education investments, playing a key role in identifying whether a developing country can take off successfully.

Theoretical work on bureaucracy, corruption and development began with the contribution by Shleifer and Vishny (1993) and Ehrlich and Lui (1999) and empirical work by Mauro (1995). Shleifer and Vishny argue that weak government induces more corruption and the secrecy need for the corruption rent makes it more distortionary than standard taxation. Ehrlich and Lui (1999) study the relationship between corruption, government and growth by constructing an endogenous growth model with both human and political capital being accumulated over time. The interaction between human capital and political capital generates multiple equilibria, which can serve to explain the prevalence of corruption in countries mired in poverty, the unstable growth experience of some poor countries, and the stable growth experience of rich countries. The central debate in the empirical strand of the literature of corruption and growth is whether corruption leads to lower economic growth: some find that corruption is always bad (e.g., Mauro 1995), while others hold the view that corruption can be a price and incentive mechanism, being beneficial for economic growth at low levels of economic development. More related is the "barriers to rich" literature. In particular, Prescott and Parente (1994) point out that barriers to technology adoption can harm long-run growth, whereas Buera, Kaboski and Shin (forthcoming) argue that barriers to finance can lower and misallocate capital investments thus retarding economic development. In his celebrated book, Easterly (2001) demonstrates many cases showing that bureaucracy and corruption have caused large waste in foreign aids and investments in countries at early stage of development (see also discussion in Collier and Dollar 2001, 2002). We follow this strand of literature, measuring social costs associated with bureaucracy and corruption and relating such barriers to observed development traps.

While the concept of development trap goes all the way back to, the formal dynamic framework has not been constructed until the pivotal work by Azariadis and Drazen (1990). More recently, Galor and Weil (2000) develop a fertility-based Malthusian trap model. However, due to the complexity associated with self-fulfilling driven multiple equilibria, these two frameworks have not been

brought up to empirical tests. Our paper complement theirs by proposing health barriers as a plausible mechanism for development trap and by establishing a framework that is readily calibrated for matching empirical facts and drawing policy prescriptions.

2 On Heath and Development

Straightforward cross-country analysis suggests that while both educational attainments and health conditions are essential for economic development, health conditions appear to be much more important for low income countries to take off. To understand this, let us begin by considering a basic organizing framework following the aggregate production function approach without a deep structure model. Using this framework, we can specify simple reduced form regressions. Since our main focus is to understand why some poor countries could not take off, we apply the regressions to a set of trapped economies whose 2000 real GDP per capita is less than 10% of the U.S. (relative income) or whose long-term average growth rate of real GDP per capita (economic growth) is below 2% during 1970-2007.

For obvious reasons, we restrict our attention to only non-OPEC and non-former USSR countries. In this restricted sample, there are 41 countries classified as trapped, including: (i) 30 sub-Saharan African countries, (ii) 5 Asian countries (Mongolia plus 4 South Asian poor countries), (iii) 4 Latin American (inclusive of Caribbean) countries, and (iv) 1 Middle East (Afghanistan) and 1 Southeastern Europe (Albania) country. From Table 2, we can see that the average of initial relative income of these trapped economies in 1970 is only about 8.75: with Asia the lowest (7.35) and Latin American the highest (14.07). Despite its relatively stronger initial performance, Latin American trapped economies suffer the lowest growth (0.07%, compared to the comparable figure of 1.35% of Asian trapped economies).

We can further plot in Figure 2 the economic growth rate over 1970-2007 against initial relative income in 1970. We find that there does not appear to be a "convergent" pattern in the sense that initially relatively poor countries need not grow fast. What about the relationships between the economic performance and educational attainment, public health spending and institutional barriers? It is commonly believed that countries with higher income levels usually have better educational attainment, higher public health spending (hence the health environment is better) and less barriers. But within the 41 trapped countries under study, are these key indicators crucial for within-the-group variations in economic performance?

To see this, we now plot years of schooling, government health spending share of GDP, and an institutional barrier measure based on the Corruption Perceptions Index (CPI) compiled by Transparency International, against relative income in 2000 or economic growth rate over 1970-2007 for the 41 trapped countries. These are displayed, respectively, in Figures 3(a),(b), Figures

4(a,b), and Figures 5(a,b). From Figures 3(a,b), though the years of schooling in 2000 somehow positively correlated to the income levels in 2000, the qualitative contributions of years of schooling on economic growth rate over 1970-2007 seem to be very weak. One may thus conclude that human capital in the form of formal education is not the fuel to economic growth for trapped countries at their development stage. From Figures 4(a,b), the qualitative contributions of public health spending and economic performance are weak as well. Given how poor the health conditions facing these trapped economies, it is alarming why public health spending could not alleviate such critical problems to induce better overall performance. Also contrary to general beliefs, Figures 5 (a,b) show that the qualitative contributions of the CPI to economic performance within this trapped group of countries are not evident. For this selected group of countries in the poverty trap, it seems that having a better institution (with a higher CPI score) need not guarantee better aggregate economic outcomes.

2.1 An Organizing Framework

Index time by t. The single good in the economy is produced with the beginning-of-period stock of physical capital (K_t) and effective labor (L_t). Denote N as the number of prime age workers, which is constant over time. To a young adult who was born in $t-1$, her human capital (measured at the beginning of the period) is given by H_t. Denote ℓ_t^d as the labor demand for a young adult with human capital H_t and hence the effective labor is measured by $L_t = N_t H_t \ell_t^d$. The aggregate production function takes the standard Cobb-Douglas form:

$$Y_t = A K_t^{\alpha} L_t^{1-\alpha}, \tag{1}$$

where $A > 0$ is the technology scaling factor and $\alpha \in (0,1)$ denotes the capital income share.

The first component of human capital – the key ingredient of our model economy – is health capital (denoted by h_t), which measures the general health condition of a person (therefore embodied), both physically and psychologically. The second component of human capital – as conventionally modeled – is knowledge capital (denoted by m_t). It measures all embodied skills related to the ability to perform the job in producing the single good. In reality, either type of capital may be enhanced by an agent's own effort or by her parent's investment. Given that early childhood development is found essential in both health and skills as stressed by more recent studies pioneered by Heckman (2007) and further elaborated by Cuhan and Heckman (2007) and Manuelli and Seshadri (2009), we highlight the role played by the parent in enhancing a child's health and knowledge capital. To avoid unnecessary modeling complexity, we shall abstract from the consideration of the child's own effort devoted to accumulating health and knowledge capital.

For simplicity, we assume that the health and knowledge shares of human capital are constant.

Thus, the stock of human capital in period t is given by:

$$H_t = Bh_t^{\beta} m_t^{1-\beta}, \tag{2}$$

where $B > 0$ is the technology scaling factor in the human capital sector and $\beta \in (0, 1)$ is the share of health capital. Following the convention, let the knowledge capital be measured in accordance with the Mincer formula depending on the years of schooling E_t:

$$m_t = M \exp(\zeta E_t), \tag{3}$$

where $M > 0$ is the knowledge scaling factor and $\zeta > 0$ measures the education gradient. Substituting (3) into (2) and then (1) and assuming full employment with $N_t \ell_t^d = \bar{N}_t$, we obtain:

$$Y_t = AK_t^{\alpha} \left\{ N_t B h_t^{\beta} \left[M \exp(\zeta E_t) \right]^{1-\beta} \right\}^{1-\alpha}$$

or, taking log,

$$\ln \frac{Y_t}{\bar{N}_t} = \left[\ln A + (1-\alpha) \ln B + (1-\beta)(1-\alpha) \ln M \right] + \alpha \ln \frac{K_t}{\bar{N}_t} + (1-\beta)(1-\alpha) \zeta E_t + \beta (1-\alpha) \ln \frac{h_t}{\bar{N}_t} \tag{4}$$

We next conduct a simple cross-country regression analysis of 41 trapped economies i based on the reduced form (4):

$$\ln\left(Y_i/\bar{N}_i\right) = a_0 + a_1 \cdot \ln\left(K_i/\bar{N}_i\right) + a_2 \cdot E_i + a_3 \cdot \ln\left(h_i/\bar{N}_i\right) + b \cdot X_i + \varepsilon_i$$

where all measures are country-i's average figures over the period from 1970 to 2007 and X_i summarizes all other covariates, including total fertility rate, an institutional barrier measure based on the Corruption Perceptions Index (CPI) compiled by Transparency International, and regional dummies (Africa, Asia, Latin America, relative to the benchmark of Emerging Europe/Middle East). The dependent variable is logged real GDP per capita ($RGDPPC$). In the absence of precise data on physical and health capital, we use the investment to GDP ratio (IR) to proxy the former and the total or public health expenditure to GDP ratio (HR) to proxy the latter. The above cross-country regression therefore becomes:

$$\ln(RGDPPC_i) = a_0 + a_1 \cdot \ln(IR_i) + a_2 \cdot E_i + a_3 \cdot \ln(HR_i) + b \cdot X_i + \varepsilon_i \tag{5}$$

The results are reported in Table 3. In specification (1), we only look at the basic regression with IR_i and E_i without other explanatory variables or regional dummies. Specification (2) adds regional dummies whereas specification (3) adds total fertility rates. In specification (4), health capital proxies are added, where in (a) we use the public health expenditure to GDP ratio and in (b) we use the total health expenditure to GDP ratio. In specification (5), CPI is also included in addition to the specifications in 4(a) and 4(b). The results indicate that, with regional dummies,

the total fertility rate is the only significant explanatory variable, influencing real GDP per capita negatively as expected. The CPI has the correct sign in that countries with better institutions are better performed economically, but it is not significant statistically at conventional levels.

To verify whether the empirical evidence is robust, we further perform panel regression analysis, using a complete panel of the 41 trapped economies over the period of 1970-2007.[7] The regression is specified as:

$$\ln(RGDPPC_{i,t}) = a_0 + \gamma_i + \mu_t + a_1 \cdot \ln(IR_{i,t-1}) + a_2 \cdot E_{i,t-1} + a_3 \cdot \ln(HR_{i,t-1}) + b \cdot X_i + \varepsilon_{it} \quad (6)$$

where robust standard error clustering (of countries) is adopted in the estimation and the three key explanatory variables IR, E and HR, as well as the total fertility rate, are all lagged one period to mitigating the possible endogeneity problem. As it can seen from various specifications, only the investment rate is significant (sometimes marginally) with the expected positive sign and at some occasions the total fertility rate is significantly negative. While most of the country fixed effects are significant, time fixed effects are not. Similar to the cross-country regression analysis, the years of schooling and the health expenditure ratios are not statistically significant. Also, because we do not have long time-series of the CPI over the sample period, we drop it in the panel regression analysis. One may however think that these significant country fixed effects may reflect *country-specific institutions* inclusive of the institutional barriers emphasized in this paper.

So what is the main message learned from the above simple regression exercises? Overall, *within* the 41 trapped economies over the period of 1970-2007, there is no systematic evidence that education, health investment or institutional conditions matter for their macroeconomic performance. To reconfirm this, let us examine the key indicators of selected countries from both the middle-income-low and the trapped country groups: (i) relative income, (ii) years of schooling, (iii) life expectancy at birth, and (iv) mortality rate under five. The time series of these four key indicators are plotted in Figures 6 (a-d). It is evident that the major difference between the two groups is either the middle income low countries were initially more developed (such as Turkey and Egypt) or experienced much faster growth (such as China starting 1980 and speeding up after 1992 and India over the last decade). Over the sample period, it is noted from Figure 6(b) that the performances in education for the two groups of countries are quite similar. Some trapped countries actually do well in education (e.g. Ghana). With regard to the overall health performances, there is a notable difference between the middle-income-low and the trapped country group: *trap countries tend to perform much worse in health*, as shown in Figures 6(c,d). We thus go deeper to examine the causes of the poor health performances in the 41 trapped countries by region. Recall that in our selected

[7] Countries with no information on educational attainment are dropped from the sample (which are Angola, Burkina Faso, Chad, Ethiopia, Madagascar, and Somalia). Nigeria is also dropped from the sample because it only has an estimate of years of schooling in 2005 conducted by the UN, not by Barro and Lee (2010).

trapped country group, 30 are African countries and 5 are Asian countries. From Figure 7(a), even in the very recent year 2002, the major deaths in the trapped countries are still due to communicable diseases and maternal, perinatal and nutritional conditions. In particular, African countries have suffered much more communicable diseases and maternal, perinatal and nutritional conditions (71%) compared to other regions ($37-46\%$). Among deaths due to communicable diseases and maternal, perinatal and nutritional conditions, deaths due to infectious and parasitic diseases alone account for 42.8% of the total deaths in the 41 trapped countries in 2000,[8] we thus narrow down our focus to the deaths due to infectious and parasitic diseases. Figures 7(b)(i,ii) show that African trapped countries still suffer greatly from HIV/AIDS, Malaria and diarrhoeal diseases. While Asian and Middle East trapped countries mainly suffer from diarrhoeal diseases and tuberculosis, Latin African trapped countries' main illness is HIV/AIDS.

These preliminary findings will be used to guide our modeling and calibration strategy, to which we now turn.

3 The Model

Since intergenerational altruism and transmission are essential to the issues considered in the present paper, the analysis is conducted within an overlapping-generations framework. In addition to modeling the childhood, we study both the young adulthood and the old adulthood after retirement, where the incorporation of the latter enables one to understand the implications of health investment for the quality of life of the elderly. To abstract from marriage and fertility issues, we assume that there is only a single sex (female) in an economy with a fixed population. Agents have perfect foresight, and are completely identical, both ex ante and ex post. There are two sectors of economic activities: a goods sector and a human capital sector. Human capital consists of two separate components: health capital (related to an individual's physical condition) and knowledge capital (related to an individual's mental capability). Aside from an institutional sunk cost (related to public health environments and investment barriers), goods produced can be used for consumption as well as physical capital and health investments.

3.1 Production

The aggregate production function is given by (1) while the human capital function is specified as in (2). The representative woman born in period $t-1$ decides on the investment in her child's health (x_t) and the time devoted to educating her child (e_t) in period t, which determines the health and knowledge capital and henceforth the human capital for her child in period $t+1$. In addition to

[8] In 2002, respiratory infections, maternal conditions, perinatal conditions and nutritional deficiencies account for 10.4%, 2%, 11.4% and 1.7% of the total deaths in the trapped countries, respectively.

her investment in her child's health, the representative woman's own health may also have a direct effect on her child's health capital due to genetic influences. Thus, the accumulation of the health capital of her child (born in period t) is specified as follows:

$$h_{t+1} = \xi x_t^{\eta} h_t^{1-\eta} + \phi h_t, \tag{7}$$

where $\xi > 0$ measures the productivity of parental investment in the child's health with the share of parental investment given by $\eta \in (0,1)$, and $\phi \in (0,1)$ denotes the strength of the direct parental influence on the child's health capital. Similarly, besides the parental time investment in the child's education, a child's knowledge capital can also be enhanced by her innate ability that is directly related to her parent's knowledge capital:

$$m_{t+1} = \mu \left(e_t + \psi\right) m_t, \tag{8}$$

where $\mu > 0$ is a knowledge scaling factor and $\psi > 0$ measures the strength of intergenerational transmission of the innate ability.

3.2 Household

Each agent lives for three periods: childhood, young adulthood and retirement. A woman in her childhood is entirely passive. In her young adulthood, she gives birth to one child at the beginning of this period and forms health and knowledge capital based on her parent's investment and time effort. As a young adult, she is endowed with one unit of time, which can be devoted to working (ℓ_t) or educating her child (e_t). That is, her time constraint in her young adulthood is given by:

$$\ell_t + e_t = 1. \tag{9}$$

In addition to health investment on her child (x_t), her wage earning ($w_t H_t \ell_t$) can be used for consumption during her young adulthood (c_t^y) or for savings for her old age (s_t):

$$c_t^y + s_t + x_t = w_t H_t \ell_t. \tag{10}$$

As she steps into her old adulthood, she retires and consumes what she has saved by leaving no pecuniary bequest to her child:

$$c_{t+1}^o = R_{t+1} s_t, \tag{11}$$

where $R_{t+1} = 1 + r_{t+1}$ measures the gross interest rate prevailing in period $t+1$. That is, she consumes the interest yields plus her principal before she dies at the end of her old adulthood and exits the market.

A representative woman born in period $t-1$ derives utility from consumption, both in young adulthood and retirement, denoted by c_t^y and c_{t+1}^o, respectively. The utility derived from old

age consumption is discounted not only by the time preference rate $\rho > 0$, but also by a factor $\pi(h_t) \in (0,1)$ which is based on her health capital level (determined in her childhood by her parent and equipped with it when young):

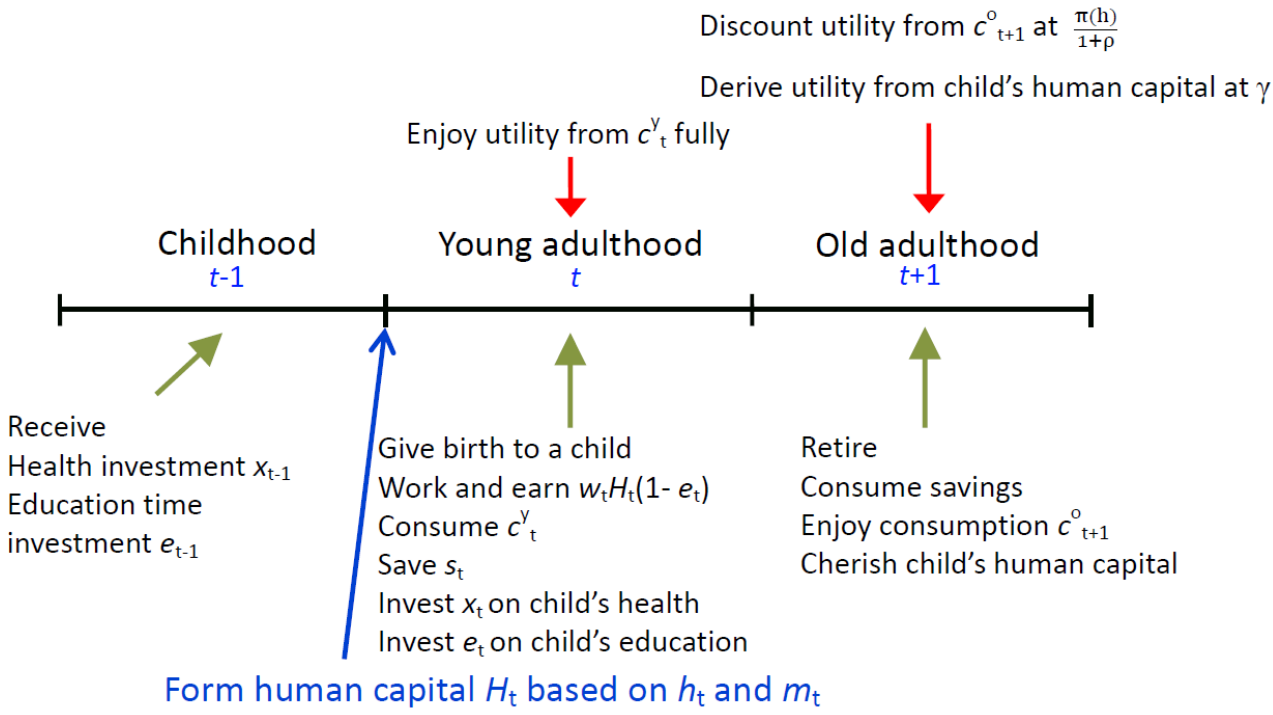
$$\pi(h) = \begin{cases} \pi_H & if \quad h \geq h_c \\ \pi_L & if \quad h < h_c \end{cases}, \ \pi_H > \pi_L.$$

Thus, $\pi(\cdot)$ captures the quality of life when old and $h_c > 0$ is the threshold of the level of health capital – when the level of health capital exceeds h_c, the child will enjoy a better quality of life in her old adulthood. In addition to her own consumption, the representative woman is altruistic, valuing her child's embodied human capital measured by H_{t+1} with an intergenerational discounting factor $\gamma \in (0,1)$ (which will be referred to as the altruistic factor hereafter).

Assuming that the preferences take a log-linear form, we can now specify the representative woman's (born in period $t-1$) optimization problem as follows:

$$\begin{aligned} V_{t-1} = \quad & \max_{c_t^y, c_{t+1}^o, x_t, e_t, H_{t+1}} \ln c_t^y + \tfrac{\pi(h_t)}{1+\rho} \ln c_{t+1}^o + \gamma \ln H_{t+1} \\ & \text{s.t.} \quad (10), (11), (2), (7) \text{ and } (8) \end{aligned} \tag{P}$$

where, needless to say, both the effective wage rate w_t and the (gross) interest rate R_t are taken as given. For better illustration, the timeline facing the representative woman is delineated as follows:



3.3 Institutional Barriers

As discussed above, even if people have the knowledge to take action to fight against diseases, they may fail to do so if the environment is adverse to their efforts. For example, washing hands before preparing food for the family is the key to preventing children under 5 from having diarrhea (which is the most common source of morbidity in developing countries, and may result in death if the patient is not treated well). Yet the unwillingness of the family members to accommodate the "new measure" due to customs or beliefs, or the lack of clean water, frustrates the primary caregivers. To overcome such a problem, large investments in the water and sanitation system are called for, as well as the comprehensive correct health measures to eradicate "incorrect" beliefs and customs. All such "solutions" require large initial investments as well as sequential maintenance costs. However, for poor countries, any amount of effort and health investment, both private and public, would simply not suffice to overcome the unfavorable environment. To make matters worse, resources intended to improve health conditions could be easily misallocated in poor countries due to institutional barriers.

We use an institutional sunk cost to measure the investment barriers attributed to resources required to ensure satisfactory public health environments as described above as well as corruption or unstable political situations. The magnitude of this institutional sunk cost is assumed to be proportional to the average health investment in the economy, $\delta\bar{x}$, where $\delta > 0$ measures the severity of the institutional barriers (i.e., a higher δ denotes a greater waste of resources). As resource waste related to health barriers affects capital accumulation, the physical capital law of motion becomes:

$$K_{t+1} = \max\left\{0, N\left(s_t - \delta\bar{x}\right)\right\}. \tag{12}$$

To simplify the analysis, N is normalized to one henceforth. Equation (12) is also the loanable funds clearing condition in this economy. Institutional sunk costs "eat" the savings of the agents. If there were no institutional sunk costs in the economy, the agents' saving s_t would turn into capital K_{t+1} in the next period, and they can enjoy a full return – the principal as well as the return on capital from K_{t+1}. With an institutional sunk cost, agents' savings are depleted. They now own a smaller capital stock, although from the individual's point of view, their saving is still s_t. This will result in discrepancies between the return on capital an agent receives when old and the marginal product of capital. We will discuss this in the next section. The labor market clearing condition is:

$$\ell_t^d = \ell_t. \tag{13}$$

4 Optimization and Equilibrium

In this section, we will focus only on the benchmark case with positive investment and time devoted to the child's health and education, respectively. In the next section, the benchmark model will be

calibrated to fit the data for the U.S. economy. The discussions on the corner case, where parents engage in zero health investment for their children, as well as the calibrations for other economies inclusive of trapped ones, will be relegated to Section 6.

4.1 Optimization

By solving the generation-t representative woman's optimization problem, we obtain several useful atemporal and intertemporal trade-off relationships (all detailed mathematical derivations and proofs are relegated to the appendix). The first is a prototypical intertemporal consumption-saving trade-off:

$$\frac{1}{c_t^y} = \frac{\pi\left(h_t\right) R_{t+1}}{(1+\rho) c_{t+1}^o}, \tag{14}$$

which equates the marginal utility and the marginal cost of consumption when young: as the quality of life when old improves (higher π), agents adjust consumption by consuming less in their young adulthood.

To ensure an optimizing level of health investment in children, it is required that its marginal benefits and marginal cost be equal,

$$\underbrace{\xi\eta x_t^{\eta-1} h_t^{1-\eta}}_{MP_x} \underbrace{\beta h_{t+1}^{\beta-1} m_{t+1}^{1-\beta}}_{MP_h} \underbrace{\frac{\gamma}{H_{t+1}}}_{MU_H} = \frac{1}{c_t^y}. \tag{15}$$

The term in the first set of brackets in the above equation is the marginal product (MP) of health investment in enhancing the children's health capital, the second is the marginal product of health capital in increasing the children's human capital, and the last is the marginal utility (MU) deriving from children's human capital. Similarly, to optimize parental time devoted to educating children, its marginal benefits must equal its marginal cost,

$$\underbrace{\mu m_t}_{MP_e} \underbrace{(1-\beta) h_{t+1}^{\beta} m_{t+1}^{-\beta}}_{MP_m} \underbrace{\frac{\gamma}{H_{t+1}}}_{MU_H} = \frac{w_t H_t}{c_t^y}, \tag{16}$$

where the marginal cost of devoting time to educating children, measured by the consumption value of foregone earnings. These two optimizing condition can be further simplified to derive the two atemporal trade-offs that guide parents' decision on self-consuming versus investment in their children, by means of improved health or education:

$$\frac{\beta\gamma\eta\xi x_t^{\eta-1} h_t^{1-\eta}}{h_{t+1}} = \frac{1}{c_t^y}, \tag{17}$$

$$\frac{\gamma\left(1-\beta\right)}{e+\psi} = \frac{w_t H_t}{c_t^y} \tag{18}$$

Since agents leave no bequest, old agents own the current capital stocks and will consume them entirely right before they exit the market. The existence of the institutional barriers distorts

the resource allocation in the markets, resulting in breakdowns of the standard factor demand conditions. Since the institutional sunk costs distort the markets and impede capital accumulation, we assume that capital lenders bear the full costs while wage earners still receive a wage rate that is equal to the marginal product of labor, given by,

$$A\left(1-\alpha\right)\left(K_t/L_t\right)^{\alpha}=w_t. \tag{19}$$

To see the above argument more clearly, for an old agent who saves s_{t-1} when young, her current consumption should be $c_t^o=s_{t-1}R_t=\left(w_{t-1}H_{t-1}\ell_{t-1}-c_{t-1}^y-x_{t-1}\right)R_t$. However, part of her saving no longer exists because of the institutional sunk cost while she still believes that she gets hold of s_{t-1}. Although physical capital is still employed and operated efficiently by firms, the interest rate received by the capital lenders, or the old agents, is determined by the goods market clearing condition:

$$c_t^o+c_t^y+\left(1+\delta\right)x_t+K_{t+1}=K_t+Y_t, \tag{20}$$

with $c_t^o=\frac{\pi(h_t)R_tc_{t-1}^y}{1+\rho}$.

4.2 Equilibrium

We are now ready to define and characterize the equilibrium along the balanced growth path. Specifically, A *dynamic general equilibrium* in this economy is a tuple of quantities $\{H_t,h_t,m_t,c_t^o,c_t^y,s_t,x_t,K_t,Y_t\}_{t=0}^{\infty}$ together with a pair of prices $\{w_t,R_t\}_{t=0}^{\infty}$ such that: (i) each woman optimizes, i.e., (2), (7), (8), (9), (10), (11), and (33) - (40), all hold; (ii) production efficiency is met, i.e., (1), and (19) hold; (iii) the physical capital rental rate is determined by (20); and, (iv) goods, loanable funds and labor markets all clear. A *balanced growth equilibrium* (BGP) is a dynamic general equilibrium along which all perpetually growing variables $\{H_t,h_t,m_t,c_t^o,c_t^y,s_t,x_t,K_t,Y_t\}_{t=0}^{\infty}$ grow at constant rates and all other endogenous variables are constant. A balanced growth equilibrium is regarded as *nondegenerate* if these constant growth rates are strictly positive. It is straightforward to show that along a nondegenerate BGP, all perpetually growing variables grow at the *common* rate $g>0$.

Along a nondegenerate BGP, h_t grows at a positive rate g and hence $h_t>h_c$ must hold $\forall t\geq t_c$ where $\pi\left(h_t\right)=\pi_H$. We regard this nondegenerate BGP as the benchmark and transform all perpetually growing quantities into stationary ratios by defining $z\equiv\frac{c_t^y}{H_t}$, $v=\frac{x_t}{H_t}$ and $k=\frac{K_t}{L_t}=\frac{K_t}{H_t\ell_t}$. From (8), $1+g=\mu\left(e+\psi\right)$, which can then be substituted into (7) to derive:

$$1+g=\phi+\xi\left(\frac{H}{h}v\right)^{\eta} \tag{21}$$

That is, both a higher human-health capital ratio and a higher health investment-human capital ratio enhance the long-run economic growth. The above expression, together with (2), yields the

health-to-knowledge capital ratio:

$$\frac{h}{m}=\left\{\left[\frac{\mu\left(e+\psi\right)-\phi}{\xi}\right]^{\frac{1}{\eta}}\frac{1}{Bv}\right\}^{\frac{-1}{1-\beta}}, \tag{22}$$

which depends only on e and v. The effective wage rate is given by $w(k)=(1-\alpha)Ak^{\alpha}$, a function of the effective capital-labor ratio k alone, and the interest rate is determined by (12) and should be a function of parenting time e, the health-human capital ratio v, and the effective capital-labor ratio k.

In the following, we will show that the system can be reduced to 3×3 in (e,v,k) where e can be determined in a recursive manner. This enables the BGP to be characterized simply in the (v,k) space. More specifically, defining for convenience $D_H\equiv 1+\frac{\pi_H}{1+\rho}$ and manipulating the optimizing condition on a mother's time devoted to educating her child yields:

$$\underbrace{\frac{\gamma\left(1-\beta\right)}{e+\psi}}_{MB_e}=\underbrace{\frac{D_H+\frac{\beta\gamma\eta[\mu(e+\psi)-\phi]}{\mu(e+\psi)}}{1-e}}_{MC_e} \tag{23}$$

The left-hand-side of the above equation gives the marginal benefits of spending time on the children's education (MB_e) on the BGP, and the right-hand-side stands for the marginal costs of parental education investment (MC_e) – the sum of the foregone marginal utilities derived from consumption in both adulthoods and investing in the children's health. Essentially, this expression captures the parent's trade-off between two forms of investment in the child. It can be observed that the MB_e locus is downward sloping, starting from $\frac{\gamma(1-\beta)}{\psi}$ and the MC_e locus is upward sloping with a vertical intercept at $D_H+\frac{\beta\gamma\eta(\mu\psi-\phi)}{\mu\psi}$. Therefore, the equilibrium e must be unique provided that $\frac{\gamma(1-\beta)}{\psi}>D_H+\frac{\beta\gamma\eta(\mu\psi-\phi)}{\mu\psi}$.

Next, the transformed effective consumption measure can be derived as:

$$z\left(e,k\right)=\frac{w\left(k\right)\left(1-e\right)}{D_H+\frac{\beta\gamma\eta[\mu(e+\psi)-\phi]}{\mu(e+\psi)}}. \tag{24}$$

Moreover, a mother's effective investment in her child's health ($v=\frac{x}{H}$) is given by,

$$v\left(e,k\right)=\frac{\beta\gamma\eta\left[\mu\left(e+\psi\right)-\phi\right]z\left(e,k\right)}{\mu\left(e+\psi\right)}. \tag{25}$$

We then turn to derive the equations governing the equilibrium (v,k). By substituting (42) into (41) and the physical capital law of motion (12), the two equations governing the equilibrium (v,k) are

$$v = \frac{\beta\eta\left[\mu\left(e+\psi\right)-\phi\right]}{\mu\left(1-\beta\right)}w\left(k\right), \tag{26}$$

$$v = \frac{1}{1+\delta}\left\{w\left(k\right)\left[1-e-\frac{e+\psi}{\gamma\left(1-\beta\right)}\right]-k\mu\left(e+\psi\right)\left(1-e\right)\right\}. \tag{27}$$

For illustrative purposes, we refer to (26) as the *intergenerational trade-off* (IT) locus and (27) as the *capital evolution* (KE) locus. Intuitively, the IT locus, derived from the FOCs with respect to c_t^y, x_t, e_t, h_{t+1}, m_{t+1}, and H_{t+1} captures the intergenerational trade-off between the parent's own consumption and her investments in health and education on children. The KE locus, on the other hand, is derived from the capital evolution equation, or the loanable funds market clearing condition. Given e determined by (23), the IT locus is strictly increasing and strictly concave in k, and the KE locus is strictly concave in k. Together with the property of (23) and proper conditions (see the appendix), we can establish a unique nondegenerate BGP equilibrium.

More importantly, we shall establish, in the following proposition, a sufficient condition for poverty trap to arise. Specifically, let us define:

$$\Delta \equiv \frac{\gamma\left[\beta\eta\phi + (1-\beta)\,\mu\right] - \mu\left\{\psi\left(1+\beta\eta\gamma\right) - \Phi\left[1+\gamma\left(1-\beta(1-\eta)\right)\right]\right\}}{\beta\eta\gamma\left[\mu\left(\psi+\Phi\right)-\phi\right]}$$

where $\Phi \equiv \frac{\gamma(1-\beta)-\psi D_H+\beta\gamma\eta\left(\frac{\phi}{\mu}-\psi\right)}{D_H+\beta\gamma\eta+\gamma(1-\beta)}$ is independent of the severity of institutional barriers to health (δ). We then have:

Proposition 1 (Sufficient condition for poverty trap) *Under $\delta > \Delta$, the economy is stuck in the poverty trap where no health investment occurs.*

Proposition 1 provides a sufficient condition for the poverty trap. Notably, Φ is actually the analytical solution of the equilibrium e derived from (23). Although Proposition 1 only provides a sufficient condition for the poverty trap, its implication is quite useful. It suggests that too much investments in education (high Φ) could do more harm than good for an economy, since the time (valuable resource) directed to educational investment crowds out production and leads to an inability to make other investments. Therefore, for an economy to be on the right track of development, there is a need for a *balanced* investment in both health and education. One can further examine the likelihood of the emergence of a poverty trap using Proposition 1. In particular, it is easily seen that a poverty trap will more easily emerge when the severity of institutional barriers (δ) is larger, the quality of life when old (π_H) is worse, or parental transmission of good health (ϕ) becomes more important.

Figure 8 provides a graphical illustration of the determination of e. Figure 9 depicts the IT and KE loci under Proposition 1 when the BGP equilibrium is unique; it also illustrates the IT and KE loci when the poverty trap emerges. Since the current study focuses on the role of health and health-related institutional barriers, we shall focus on the poverty trap caused by the institutional barriers: if the institutional sunk cost δ is too severe (when $\delta > \delta_c$), the economy will end up staying in the equilibrium E_0. We relegate the discussion of economies mired in poverty traps to Section 5. In what follows, we perform comparative statics upon the nondegenerate equilibrium.

4.3 Comparative Statics

In order to characterize the unique BGP equilibrium, we analytically examine the comparative-static properties concerning changes in the institutional (δ), structural preference (most interestingly, π_H) and technology (most interestingly, ϕ and ξ) parameters on three key endogenous variables (e, v and k). As discussed in the previous subsection, the equilibrium parental time investment in the children's education (e) can be determined recursively, enabling the BGP to be characterized in the (v, k) plane. Therefore, we can elaborate on the responses of parental time investment in the child's education (e) recursively and then illustrate the responses of the health-human capital and effective capital-labor ratios (v and k) diagrammatically.

Due to its recursiveness, let us begin by characterizing the BGP value of parental time devoted to educating a child (e) using Figure 2. Consider the case when the parent becomes more altruistic (higher γ). In response, both the marginal benefits and marginal costs of investing in the child's education (MB_e and MC_e, respectively) must go up, implying upward shifts in both the MB_e and MC_e loci, and the BGP value of e is ambiguous as a result. To ensure realistic outcomes, we shall impose a *normality* assumption in the sense that parental time devoted to educating a child is higher to a more *altruistic* mother, or, formally,:

Condition N (Altruism Normality) $\frac{\gamma(1-\beta)-\psi D_H-\frac{\beta\gamma\eta\phi}{\mu}}{D_H+\beta\gamma\eta+\gamma(1-\beta)} < \frac{1-\beta-\beta\eta\left(\psi-\frac{\phi}{\mu}\right)}{1-\beta-\beta\eta}$.

We then investigate what happens in response to an increase in the parents' quality of life when old (higher π_H), which raises the marginal utility of a parent's own consumption when old and thus reduces her incentive to invest in her child's education. Hence, the MC_e locus shifts upward while the MB_e locus remains unchanged, leading to a lower BGP value of e. We now turn to strengthened intergenerational transmission of health (higher ϕ), which lowers the marginal cost of investing in the child's education and hence shifts the MC_e locus downward, without changing the MB_e locus. Thus, in response, the BGP value of e increases. Because changes in neither the severity of institutional barriers nor the health productivity scaling factor affect the MC_e or the MB_e locus, the BGP value of parental time devoted to child education is irresponsive to such changes. The responses of e to these structural parameter shifts are summarized in Table 5.

We next proceed to perform comparative-static analysis with respect to the two great ratios, v and k, using the IT and the KE loci depicted in Figure 10. The structural parameters may affect the IT and the KE loci directly as well as indirectly through e. We first discuss how the change in e affects the IT and the KE loci.

It is easy to see that e enters the IT locus positively through the *heatlh-knowledge investment balancing effect* (via $e + \psi$ in the numerator). Recall that the IT locus equates the marginal utility of consumption and the two forms of investment in children. Therefore, a higher educational investment should be associated with a higher health investment to restore the balance in marginal

utilities. On the contrary, e generates several opposing effects on the KE locus through different channels. The first channel is through the trade-off between producing and accumulating knowledge (the first $1-e$ in the KE locus). As e increases, labor hours decrease, and resources available for health investment decline. Increases in e also result in a smaller marginal utility from educating children. Agents thus increase their consumption when young and accumulate more capital, and hence generate negative forces toward health investment (through $e+\psi$ in the second and third term in the KE locus). Finally, an increase in e transmits benefits of knowledge accumulation from more effective labor in the future, thereby relaxing the current resource constraint and bringing positive effects to current health investment. The effect of an increase in e on the KE locus is thus ambiguous and we will rely on numerical analysis to determine the relative size of these opposing effects as well as net effects of e on the KE locus.

To sum up, an increase in e always shifts the IT locus up, while the direction of the shift in the KE locus depends on the magnitude of the positive feedback from the accumulated knowledge capital. When the positive feedback dominates other opposing effects and shifts the KE locus upward, the BGP value of v will rise, and whether the BGP value of k will rise or fall depends on the relative magnitudes of the shifts in the two loci. If the upward shift in the KE locus is relatively moderate compared to the shift in the IT locus, the BGP value of k is expected to fall. On the contrary, if the positive feedback from more effective labor is dominated, one would expect that an increase in e will shift the KE locus downward, and the BGP value of k is expected to fall. Yet the BGP value of v depends on the relative shifts in both loci: when the shift in the KE locus is relatively moderate, the BGP values of v will rise, and vice versa.

We are now ready to examine how the structural parameters affect the IT and the KE loci. Figure 10 plots how the IT and the KE loci shift in response to changes in the parameters. Consider first the changes in the severity of the institutional barriers δ. Changes in δ have no influence on the BGP value of e, and only affect the KE locus in a negative way by shifting the KE locus downward. Hence, both the BGP values of v and k decrease.

Next consider the parameters on the preference side. The quality of life when old π_H affects both loci indirectly through e. An increase in π_H decreases the BGP equilibrium e and shifts the IT locus down. If the effects from more effective labor in the future are dominated, the KE locus will shift upward as e decreases. If the magnitude of the shift in the KE locus is larger than the IT locus, both of the BGP values of v and k will rise. Now look at changes in the health capital technology. While ξ has no direct or indirect effect on either the IT or the KE locus, ϕ directly and indirectly influence the IT locus and has an indirect influence on the KE locus through e. An increase in ϕ directly shifts the IT locus downward, and indirectly shifts the IT locus upward through e. As it comes to the KE locus, an increase in ϕ shifts the KE locus downward provided that the effect from knowledge capital accumulation and thus more effective labor in the future is dominated. Hence,

when the direct effect of ϕ on the IT locus dominates the indirect effect, and when the benefits from more effective labor are dominated, one would expect that both loci will shift downward, and the BGP value of v will decrease. The BGP value of k will increase with a relatively moderate shift in the KE locus.

The discussion above can be readily summarized in Table 5 and in the following proposition.

Proposition 2 (Comparative Statics) *Under Condition N, the BGP equilibrium possesses the following properties:*

(i) a more severe institutional barriers to health (higher δ) does not affect parental time devoted to educating a child, but suppresses both the health-human capital and effective capital-labor ratios;

(ii) an increase in the parents' quality of life when old (higher π_H) reduces parental time devoted to educating a child, but raises the health-human capital and effective capital-labor ratios;

(iii) a greater intergenerational transmission of basic health (higher ϕ) increases parental time devoted to educating a child and the effective capital-labor ratio, but decreases the health-human capital ratio;

(iv) a rise in health productivity (higher ξ) does not affect parental time devoted to educating a child or the health-human capital and effective capital-labor ratios.

The comparative statics will be performed numerically in the next section in the calibrated benchmark economy, not only to verify the discussions above, but also to generate unambiguous comparative-static outcomes quantitatively.

5 Numerical Analysis

In this section, we calibrate the benchmark model to match the U.S. economy. Numerical comparative statics as well as sensitivity analysis to check the robustness of the benchmark parameterization are then performed. We illustrate how an increase in the institutional sunk cost could cause an economy to fall into the poverty trap, even if the economy is endowed with the same preferences and technologies as the U.S. In the next section, we calibrate the model to match countries of different income levels, namely, middle-income-low countries and trapped economies. We then show that having too severe health-related institutional barriers is the major reason why trapped countries remain mired in poverty.

5.1 Calibration

We intend to calibrate the model such that the BGP implications of the parameters match the observations for the US economy. The model has 12 parameters: (i) preference parameters – the time preference rate (ρ), the quality of life when old (π_H) and an altruistic factor (γ); (ii) goods production technology parameters – a goods technology scaling factor (A) and an income share of physical capital (α); (iii) human capital technology parameters – the share of health capital (β); (iv) health capital technology parameters – the health capital technology scaling factor (ξ), the share of parental health investment (η) and innate health (ϕ); (v) knowledge capital technology parameters – a knowledge capital scaling factor (μ) and innate knowledge (ψ); and (vi) the institution parameter – the severity of the institutional barriers (δ).

To begin with the calibration, we first set one model period equal to 25 years. Therefore, the representative woman lives for 3 periods – 75 years in total.[9] Since there are two sectors, it is possible to normalize one of the technology scaling parameters, say, the human capital scaling factor to one, i.e., $B = 1$ without loss of generality. We choose $\pi_H = 0.9$, implying a 10% discount over the old age consumption which seems reasonable. The 25-year time preference rate is set at $\rho = 1.0938$, which corresponds to an annual time preference rate of 3%, as is commonly chosen in the macroeconomics literature. Based on the NIPA data over the period $1960 - 2005$, we set the physical capital share of income as $\alpha = 0.32$ and the 25-year economic growth rate (of per capita real GDP) as $g = 69.37\%$ (corresponding to a 2.13% annual economic growth rate of the average economic growth rate of the U.S.).

To calibrate the effective capital-labor ratio ($k = \frac{K}{H\ell}$), we need to know the physical-to-human capital ratio ($\frac{K}{H}$) as well as the fraction of time people devote to work (ℓ). Based on the estimates by Kendrick (1976), the stock of human capital is at about the same level as physical capital for the U.S., and hence we set the physical capital-to-human capital ratio equal to one, i.e., $\frac{K}{H} = 1$. Since parental time investment in the child's education is crucial in this paper, we cannot simply compute ℓ from labor-market work hours data. Instead, we use the 2003-2008 American Time Use Survey: the average hours per day for people engaged in activities related to the children's education and health were 2.1766 hours, and the average sleeping hours were 8.59 hours per day. Therefore, the fraction of time parents devoted to their children's education is $e = 14.0\%$ and the fraction of time devoted to work is $\ell = 86.0\%$. This together with $\frac{K}{H} = 1$ yields an effective capital-labor ratio of $k = 1.1628$.

We now turn to pinning down the technology parameters health and knowledge capital accumulation. Without loss of generality, we set the health-to-knowledge capital ratio to one ($\frac{h}{m} = 1$). In the benchmark case, we assume that health and knowledge contribute equally to the formation

[9] The life expectancy at birth in the US has reached 75 years in 1989, 76 years in 1996 and 77 years in 2000. Source: U.S. Census Bureau, Statistical Abstract of the United States: 2003.

of human capital, and β is set to be 0.5. From (2), we obtain $\frac{H}{h} = 1$ and hence, by the common growth property of the BGP, $v = \frac{x}{H} = \frac{x}{h}$. In spite of lacking a precise measurement, it is reasonable to assume that both the innate ability in knowledge and the direct parental influence on the child's health capital account for 20% of the total formation of the child's knowledge capital and health capital, respectively. That is, $\frac{\psi}{e+\psi} = 0.2$ and $\frac{\phi}{\xi v^{\eta}+\phi} = 0.2$. The first expression, in conjunction with the value of e, immediately yields $\psi = 0.035$, which can then be used with (8) and the value of g to get $\mu = \frac{1+g}{e+\psi} = 9.6782$. Using the second expression and (21), we can calculate: $\phi = 0.2 \cdot (\xi v^{\eta} + \phi) = 0.2 \cdot (1 + g) = 0.3387$. Later on, we will perform sensitivity tests on the preset variables and assumptions.

Next, notice that $\frac{z}{v} = \frac{c^y}{x}$, which is equal to parent's consumption-to-children's health investment ratio. From the NIPA data on consumer expenditure over $1990 - 2008$, the ratio of the average health expenditure to household consumption other than health was around 20%. It is reasonable to assume that more than half of the health expenditure is allocated to children and hence we set $\frac{c^y}{x} = 9$. Hence, by using (41) and rewriting it as $\frac{z}{v} = \frac{c^y}{x} = \frac{1+g}{\beta\gamma\eta(1+g-\phi)}$, together with (23), We are able to obtain the values $\gamma = 0.6271$ and $\eta = 0.4429$. Now we turn to calibrate the technology scaling factor in goods production A and the severity of the institutional barriers δ. In equilibrium, (26) must equal (27). By using this relation, the goods market clearing condition (20), which determines the equilibrium real rate of return on physical capital, and by setting an annual real rate of return on capital of 5.5% (roughly equal to the real interest rate of the U.S. over 1970-2000), we obtain $A = 10.3475$ and $\delta = 0.1698$. Finally, ξ is calibrated using (21) and is equal to $\xi = 1.9151$.

The calibration results for the U.S. economy are summarized in Table 6.

5.2 Comparative Statics

We proceed to numerically compute the responses of (e), (v) and (k) to exogenous shifts in the following parameters: the altruistic factor (γ), the quality of life index when old (π_H), the strength of the direct parental influence on the child's health (ϕ), the knowledge capital scaling factor (μ), the innate knowledge factor (ψ), the share of health capital (β), the share of parental health investment (η), and the goods technology scaling factor (A). In addition to the three endogenous variables in the fundamental BGP equations, We are also interested in the responses of the economic growth rate (g) and four important "great ratios" – the consumption-health spending ratio $(\frac{c^y}{x})$, the health-knowledge capital ratio $(\frac{h}{m})$, the health-human capital ratio $(\frac{h}{H})$, and the knowledge-human capital ratio $(\frac{m}{H})$. The results are summarized in Table 4, where the numbers reported are in elasticities.

Recall that in the benchmark U.S. economy, in response to an increase in parental investment in the child's education (e), the IT locus always shifts up, while the direction of the KE locus depends on the relative magnitudes of several opposing effects. That is, if the positive feedback from more effective labor in the future is dominated by other effects, the KE locus is expected to

shift downward. Thus, the BGP values of v and k increase and decrease, respectively, if the shift in the KE locus is relatively moderate. The numerical results suggest that this is usually the case under the parameterization of the U.S. economy.

Then we proceed to examine the effects of changes in the parameters we are interested in. First, examine the effects of changes in the altruistic factor γ. Our numerical result shows that as γ increases by 1%, parental investment in the child's education e increases by 0.94%, the health-human capital ratio v rises by 0.51%, and the effective capital-labor ratio k falls sharply by 1.24%. In fact, the parameterization of the U.S. economy satisfies altruism normality (Condition N), and hence parents always invest more time in their children as they become more altruistic. Moreover, as parents love their children more, they shift resources away from own consumption toward pecuniary investment in the child's health, thereby leading to a lower consumption-health spending ratio – the $\frac{c^y}{x}$ ratio falls by 1.12%. Furthermore, since parents spend more time educating their children, the rate of accumulation of the knowledge capital is higher, which translates into a higher economic growth rate – g increases significantly by 1.83%. Due to the dominating effects on knowledge capital, the health-knowledge capital and the health-human capital ratios drop by 2.9% and 1.50%, respectively, while the knowledge-human capital ratio increases by 1.63%.

Next, examine the effects of an increase in the quality of life when old π_H. As opposed to a higher altruistic factor, a higher quality of life when old raises a parent's marginal utility of consumption when old, encouraging a shift in her resources from investing in her child to her own enjoyment. As a result, in response to a 1% increase in π_H, parents curtail their time investment on their children's education by 0.28%, leading to a relaxation of their budget constraint: v, k and z increase by 0.18%, 1.49% and 0.23% respectively, resulting in a "portfolio" change in the parents' own consumption and the children's health investment – $\frac{c^y}{x}$ increases slightly by 0.06%. Thus, parents respond to an increase in their quality of life when old by cutting more heavily on education investment than the health investment in children, thereby causing the BGP value of the health-knowledge capital ratio to rise by 1.70%, the health-human capital ratio to increase by 0.83%, and the knowledge-human capital ratio to decrease by 0.80%.

We now turn to examine the effects of the changes in the human capital technology parameters. First, investigate the effects of increases in the strength of the direct parental influence on the child's health capital ϕ. An increase in ϕ cuts down the marginal cost of investing in the child's education. As a result, a 1% increase in ϕ boosts e and g up by 0.02% and 0.04%, respectively. However, the direct effect of the increase in ϕ suppresses the IT locus more, leading to a 0.22% decrease and 0.02% increase in the BGP values of v and k, respectively. Moreover, with better transmission of parents' health capital, parents can consume more, resulting in a higher consumption-health spending ratio – $\frac{c^y}{x}$ increases by 0.25%. The associated direct knowledge capital accumulation effects resulting from better direct parental influence on the child's health capital then cause the BGP value of

the health-knowledge capital ratio to rise by 0.61%, the health-human capital ratio to increase by 0.30%, and the knowledge-human capital ratio to decrease by 0.3%.

Next we look at the effects of changes in the strength of the intergenerational transmission of the innate ability ψ. As ψ increases, it is more valuable to invest in the child's health and of less value to invest in the child's education. As a result, a 1% increase in ψ brings e down by 0.21%. The direct effect of ψ on the IT locus dominates the indirect effect and shifts the IT locus up, together with a moderate downward shift in the KE locus due to several opposing effects, bringing v up by 0.03% and k down by 0.05%. Parents now allocate a slightly larger portion of their resources to the children's health compared to their own consumption – $\frac{c^y}{x}$ decreases by 0.01%. The direct knowledge capital accumulation effect associated with the increase in ψ also raises the economic growth rate g by 0.08%, lowers the BGP values of the health-knowledge capital ratio and the health-human capital ratio by 0.14% and 0.07%, respectively, and increases the knowledge-human capital ratio by 0.07%. In short, both changes in inborn health and innate knowledge only have small effects on the endogenous variables.

Finally we investigate the effects of increases in the knowledge scaling factor μ. The effects of changes in μ on the BGP equilibrium are very similar to ψ, except that the IT locus now shifts moderately upward compared to the downward shift in the KE locus. A 1% increase in μ raises the cost of investing in the child's education, bringing the BGP value of e down by 0.02%. The relatively mild upward shift in the IT locus and the downward shift in the KE locus drive the BGP values of v and k down by 0.25% and 1.4%, respectively. The associated direct human capital accumulation effects boost the economic growth rate g significantly by 2.4%, lower the BGP values of the health-knowledge capital ratio and the health-human capital ratio greatly by 5.1% and 2.74%, respectively, and increase the knowledge-human capital ratio by 3.17%.

To sum up, the numerical results reconfirm the theoretical predictions outlined in Proposition 2 and establish additional findings. The results suggest that changes in the structural parameters affect the BGP equilibrium in the following way: the IT locus and the KE locus always shift upward and downward in response to a higher e. The final changes in the BGP values of v and k depend on the relative magnitudes of the direct and the indirect effects associated with the changes in the parameters, as well as the relative shifts in the IT and KE loci. In the next subsection, we shall conduct sensitivity analysis to verify that the numerical comparative-static findings reported in Table 7 are robust within plausible ranges around the benchmark parametrization.

5.3 Sensitivity Analysis

There are neither estimates of the stock of health capital, knowledge capital, or the share of health capital in human capital formation, nor good measures of the contribution of innate ability to knowledge capital formation or of parental health transmission to the children's health. Although

the benchmark U.S. calibration is based on reasonably chosen assumptions, one may still cast doubt on the calibration criteria and the robustness of the calibration results. Therefore, a sensitivity analysis is performed to examine the qualitative and the quantitative implications under alternative calibration criteria. The alternative calibration criteria include the assumptions of a lack of empirical knowledge as well as the chosen calibration targets. In particular, the following assumptions and calibration alternatives are considered:

- The parental education time investment e: $\{0.07, 0.21\}$.
- The consumption-health spending ratio ($\frac{c^y}{x}$): $\{7, 11\}$.
- The share of health capital in the human capital (β): $\{0.4, 0.6\}$.
- The health-knowledge capital ratio ($\frac{h}{m}$): $\{2, 0.5\}$.
- The inborn health-to-health capital ratio: $\{0.3, 0.1\}$.
- The innate ability-to-knowledge capital ratio: $\{0.3, 0.1\}$.
- The physical capital-to-human capital ratio ($\frac{K}{H}$): $\{2, 0.5\}$.

Generally speaking, the sensitivity analysis suggests that most of the changes in the equilibrium outcomes are nonessential and the model is quite robust. For the parameters under interest (γ, π_H, ϕ, ψ and μ), the changes in the equilibrium outcomes are negligible under different calibration targets and assumptions. The results of the sensitivity tests are reported in the appendix (see also Appendix Table A1).

In the next section, we will calibrate the model to the data for different economies, and discuss how institutional barriers affect countries differently, and thus lead countries onto different development paths.

6 Institutional Barriers and Poverty Trap

In Proposition 1, we show that an economy will be trapped in poverty if the condition specified is satisfied; we also examine the likelihood of an economy falling into a trap as structural parameters shift. An important implication of this proposition is that the health-related parameters such as π_H and ϕ play a crucial role in determining the likelihood of persistent poverty.

Based on the parameters calibrated for the U.S. economy, if the severity of the institutional barriers exceeds 3.8686, an economy endowed with the same technologies and preferences as the U.S. will be absorbed into the state of poverty. This magnitude indicates that for every unit of health investment reaching the intended target successfully, there are more than four units of

resources exhausted in the procedure of delivery due to the problems rooted in the institution: bureaucracy, corruption, or simply the adverse natural environment among others. This magnitude also indicates that roughly 80 percent of the resources allocated to health fail to accomplish the mission. Thus, one may infer that a rich economy like the U.S. is too healthy to fall into a poverty trap.

Since countries at very different development stages differ in terms of their technologies and the preferences of their citizens, the measure of severity of the institutional barriers also varies across nations – as does the condition of falling into the trap. In the following, we proceed with calibrating the model to the data of different income groups: (i) trapped economies: using both a representative trapped economy based on the average performance and conditions of the 41 trapped countries and three selected trapped economies – Bangladesh, Kenya and Nigeria – where rich institutional data are available, thus enabling a deeper analysis of the economic relationship between institutional barriers and poverty trap; and (ii) middle-income-low countries: China and India. We then compare the results with the results of the U.S. economy, and examine how they perform differently in regard to the problems of institutional barriers.

6.1 Trapped economies

In the model, a poverty trap is the corner solution where the representative woman makes no health investment for her child. The first-order conditions with respect to x_t and h_{t+1} do not hold anymore, and hence the IT locus has to be set aside. What calls for attention is that, in the model, the institutional sunk cost comes with the health investment. With zero health investment, the institutional barriers might have been viewed as not affecting the model at all. However, the truth is that it is the huge and unobserved severity of the institutional barriers δ that prevents individuals from engaging in private health investment. To solve this problem, we thus change the notion of health investment from private investment to public investment. We then focus on public health expenditures and collect data and cases that can reflect the leakages in public health expenditure to compute δ because δ is essentially unobservable.[10]

6.1.1 Calibration for trapped economies

To introduce public health investment into the system, we bring a government into the model. The task of the government is to collect a lump-sum tax T_t from its young citizens, and to engage in public health investment for the youngest generation. With the lump-sum tax, the budget constraint

[10] Cases of leakages in other sectors or in public investments are used when cases of leakages in public health expenditures are unavailable.

of the representative woman when young becomes:

$$c_t^y + s_t = w_t H_t \ell_t - T_t. \tag{28}$$

Denote G_t^h as government total health spending. The government runs a balanced budget in every period and hence the total government health expenditure must equal total collected taxes, T_t. To permit balanced growth, we assume that the lump-sum tax grows with aggregate output:

$$G_t^h = T_t = \tau Y_t, \tag{29}$$

where $0 < \tau < 1$. The goods market clearing condition and the loanable funds market clearing condition become

$$c_t^o + c_t^y + G_t^h + K_{t+1} = Y_t + K_t, \tag{30}$$

$$K_{t+1} = s_t. \tag{31}$$

The procedure for solving the corner case is the same as that for solving the interior case, and first-order conditions give equations (14) and (18). In the following, we elaborate on the method of calibration for the corner case and dismiss discussions on the equilibrium behavior of the model since the current focus is to calibrate for the representative trapped economy and the selected trapped countries.

There are 14 parameters to be calibrated – ρ, π_L, γ, A, α, B, β, ξ, η, ϕ, μ, ψ, δ, and τ. The time preference rate ρ is set at 1.0938 to match an annual time preference rate of 0.03. Similar to the benchmark calibration, we make plausible assumptions on the inborn health share and the innate knowledge share from the intergenerational transmission of parental health and knowledge as well as the health capital share β. The importance of parental transmission can differ across countries. Parental health transmission is more important for children when the environment is adverse to health. For example, babies with stronger and healthier mothers survive more easily, and children that inherited good resilience from their parents more easily get over a disease and recover soon. Akin to health, innate knowledge is more important when the average education level is low. When a society remains still, children usually inherit the business and occupation of their parents, and hence the knowledge parents own and how parents pass their knowledge to their children is crucial to the children. The phenomena described above provide a justification for the view that the importance of parental transmission can vary across countries depending on the stage of development. We thus adjust the assumptions for the inborn health share and innate knowledge share according to the overall health conditions (life expectancy at birth) and education levels (average years of schooling). If the health conditions are bad, we upwardly adjust the inborn health share, and the same rule applies to adjusting the innate knowledge share. From Table 2, since our representative trapped economy "performs" poor in both health and education, we set the inborn health share at 0.5 and

the innate knowledge share at 0.6.[11] Then, with the chosen inborn health and innate knowledge shares, together with the data on economic growth rates calculated from PWT 6.3 using data on real GDP per capita, the parameters μ, ψ and ϕ are obtained. In the benchmark U.S. calibration, β is assumed to be 0.5, meaning that health and knowledge are equally important in forming human capital. In a similar manner when adjusting the inborn health and innate knowledge shares, we adjust β according to the health performances and the educational attainment of the representative trapped economy. Thus, we set β at 0.8 to reflect that health plays a more important role in health in human capital for the representative trapped economy where physical strength is arguably much more essential than mental quality in generating the production-use human capital stock.[12]

In the benchmark U.S. calibration, we choose $\pi_H = 0.9$ to reflect a 10% discount over the old age consumption. Note that π_H captures not only how good a person's health condition is, but how long a person can enjoy consumption. Hence, we take data on life expectancy at age 25 from the World Bank and adjust π_L for the trapped country by the formula

$$\pi_L = 0.9 \cdot \left(\frac{\text{Life expectancy at age 25} \ - \ 25}{25} \right).$$

Since there are no estimates of the capital-to-human capital ratio ($\frac{K}{H}$) for the representative trapped economy as well as the selected trapped countries under examination, we assume it to be 0.5 to reflect the belief that although trapped economies have poor funding resources, the inborn and innate human capital are important, and thus the human capital formed shall be larger than the physical capital.

Since there is no time use survey for the trapped countries, we calculate parental time on the educational investment by adjusting the parental time on the educational investment of the U.S. using fertility rates of the U.S. and those of the trapped countries. The total fertility rates in the US have been very stable and remained close to two since 1970. Unlike the U.S. where demographic transition has been completed a century ago, most of the trapped countries experienced a rapid decrease in fertility over the past decades, although some trapped countries still have a total fertility rate around 5. We thus choose to use the average total fertility rates of the 41 trapped countries during 1960-2007 to calibrate for the representative trapped economy.[13] As for the calibration of the selected trapped countries, since we focus more on the performances of the countries around 2000, we choose to use the numbers around year 2000. All fertility rate data are obtained from the World Bank. The data on real interest rates, the consumption-to-total output ratio and the

[11] In the calibration for the selected trapped countries, we compare the performances of health and education *across* the selected trapped countries and the representative trapped economy, and apply the same rule to adjust their inborn health and innate knowledge shares.

[12] In the calibration of the selected trapped countries, if the country has relatively poor health but high educational attainment, we then adjust β up to reflect the significant role played by health in human capital.

[13] The average total fertility rate of the 41 trapped countries during 1960-2007 and 1970-2007 are similar.

earmarking tax-output ratio τ are also needed. Data on real interest rates are obtained from the World Bank and are downwardly adjusted by $20-40$ percent to reflect the more reasonable measure of real rate of returns on (physical) capital.[14] National Account official country data on household final consumption expenditure, government final consumption expenditure, gross capital formation, exports and imports are obtained from the Penn World Table (PWT) 6.3 National Account Data and United Nations Statistics Division (UNSD), and data on the total expenditure on health, general government expenditure on health and private expenditure on health as a percentage of total GDP are obtained from the World Bank. We first calculate total output in the model by deducting private health expenditure, net exports, and government expenditures other than health from total GDP.[15] Private health expenditure also has to be deducted from household final consumption to match the notion of the poverty trap in the model. Then we divide the adjusted household consumption, government expenditures on health, and gross capital formation by the adjusted total output. After all these steps, the total consumption to output ratio and the earmarking output tax rate τ are ready for the calibration procedure, and we now turn to calibrate the capital income share α. It is convenient to define: $D_L \equiv 1 + \frac{\pi_L}{1+\rho}$ and $\Upsilon_L \equiv 1 + \frac{\pi_L R}{(1+\rho)(1+g)}$, both greater than one. Then, manipulating (28), (11), (14) and (29), we can derive $c^y = \frac{wH\ell - T}{D_L} = \frac{(1-\alpha-\tau)Y}{D_L}$. Denote $C = c^y + c^o$ as the aggregate consumption of young and old cohorts. By using (11), aggregate consumption can be written as $C = \Upsilon_L c^y = \frac{\Upsilon_L(1-\alpha-\tau)Y}{D_L}$. We further divide C by aggregate output Y to obtain the total consumption-to-output ratio $\frac{C}{Y} = \frac{\Upsilon_L(1-\alpha-\tau)}{R_L}$. By plugging data on the consumption-to-output ratio, interest rate, and the earmarking tax rate τ, the capital income share can be calculated as $\alpha = 1 - \tau - \frac{C(1+D_L)}{Y\Upsilon_L}$, and the consumption of young cohorts-to-total output ratio is calculated as $\frac{c^y}{Y} = \frac{1-\eta-\tau}{D_L}$. Now, from (18), the altruistic factor γ can be pinned down as $\gamma = \frac{e+\psi}{1-\beta}\frac{wH}{c^y} = \frac{D_L(e+\psi)}{(1-\beta)(1-e)}\frac{1-\eta}{1-\eta-\tau}$. Similarly, the technology scaling factor A can be solved from the loanable funds clearing condition (31) and is given by $A = \frac{D_L R k^{1-\alpha}}{(\Upsilon_L - 1)(1-\alpha-\tau)}$.

The parameters left uncalibrated are the technology scaling factor in the human capital sector B, the technology in producing health ξ, the health investment share η, and the measure for institutional barriers δ. As mentioned before, δ is unobservable in the data and is hidden in the

[14] The real interest rate reported by the World Bank is the lending rate adjusted by the GDP deflator. This is a good measure of the real rate of returns on physical capital in developed economies. It is noted that, with this measure, some trapped countries have extremely high real interest rates, due obviously to severe credit market frictions. Thus, appropriate adjustment in the raw data is avoidable. The average of the real interest rates of the 41 trapped countries is thus very high. We hence adjust the average real interest rates of the 41 countries down by 40 percent, while we adjust the real interest rates in the selected trapped countries by roughly 20 percent so that the "true" annual real interest rate measures are roughly at 5-6 percent.

[15] The model features a closed economy, and in the model there is no government expenditure other than health. Net exports and government expenditure other than health thus have to be deducted from total GDP to match the notion of total output in the model.

amount of government spending. Only through surveys can one know the severity of the institutional barriers and the associated problems stemming from these barriers. We relegate the discussion of unearthing δ to the next subsection. To take an equal stand for health investment and parental health transmission, we assume η to be 0.5 for both the representative trapped economy and the selected trapped countries. Then we turn to calibrate B using (1), (2) and the property that all the ratios of stocks and the stocks-to-output ratio are constant along the BGP. Specifically, we write total output as $Y = Ak^{\alpha}B\left(\frac{h}{m}\right)^{\beta} m\left(1-e\right)$ using (1) and (2), and derive A as $A = k^{\alpha}B\left(\frac{h}{m}\right)^{\beta}\left(\frac{m}{Y}\right)\left(1-e\right)$. Let subscript i denote country i and the representative trapped economy. Then the technology scaling factor in the human capital sector B_i for country i can be calibrated according to the following formula:

$$B_i = \frac{A_{US}}{A_i}\left(\frac{k_{US}^{\alpha_{US}}}{k_i^{\alpha_i}}\right) B_{US} \frac{\left(\frac{h_{US}}{m_{US}}\right)^{\beta_{US}}}{\left(\frac{h_i}{m_i}\right)^{\beta_i}} \left(\frac{m_{US}}{Y_{US}}\frac{Y_i}{m_i}\frac{1-e_{US}}{1-e_i}\right) \tag{32}$$

provided that one knows the health-knowledge capital ratio $(\frac{h}{m})$ of country i. We choose to use the mortality rate for those under five and years of schooling to approximate h and m. Data on the mortality rate under five in 2000 are obtained from the World Bank, and average years of schooling in 2000 are obtained from the Barro-Lee (2010) dataset.[16] We denote q as the mortality rate under five and E as the years of schooling. A higher mortality rate means a smaller stock of health capital, and hence the approximation of health capital should be the inverse of the mortality rate. Notice that the health-knowledge capital ratio of the U.S. is assumed to be one, meaning that the "transformation factor" transforming the mortality rates and years of schooling of the U.S. to a health-human capital ratio of one is $q_{US}E_{US}$. Therefore, $\frac{h_i}{m_i}$ is calculated as $\frac{h_i}{m_i} = \frac{q_{US}E_{US}}{qS}$ and B_i can be readily computed from (32). Finally, by using government health expenditure as input in (7), together with the BGP condition that health and knowledge capital grow at the same rate, ξ_i is computed.[17] Table 8 and Table 9 summarizes the calibration results for the representative trapped economy as well as the calibration results for the selected three trapped countries of interest,

[16] The data of average years of schooling are not available for Angola, Burkina Faso, Chad, Ethiopia, Madagascar, Nigeria and Somalia in the Barro-Lee (2010) dataset. For Nigeria, the estimates of average years of schooling in 2005 and 2010 are available from Human Development Indicators (HDI) complied by United Nations Development Programme (UNDP) and equal to 5. Since estimates of years of schooling usually do not change much within 5 year, we thus set the year 2000 average years of schooling in Nigeria equal to 5. The years of schooling of the representative trapped economy is thus the simple average of the years of schooling in 2000 for countries with data in Barro-Lee (2010) and Nigeria.

[17] The interpretation of ξ_i should be the health technology of the government, and is different from the ξ in the interior case. Since the value of ξ_i does not affect the critical severity of institutional barriers calculated below, I simply plug in the government health expenditure into (7) when calibrating ξ_i. If taking inefficiency lost due to the institutional barriers, ξ_i will be higher.

Bangladesh, Kenya and Nigeria, respectively.

Based on the calibration results of the representative trapped economy and the selected trapped countries, we now proceed to compute the "threshold" severity of the institutional barriers for the representative trapped economy as well as the selected trapped countries, Bangladesh, Kenya and Nigeria. As discussed in the benchmark calibration for the U.S., with different technologies and dissimilar tastes, the severity of the institutional barriers of a country can differ across countries. Denote the critical threshold severity of the institutional barriers as δ_c. If the magnitude of δ is greater than δ_c, the waste and inefficiencies caused by the institutional barriers within an economy are too big for an economy to stand, and private incentives to make investments are completely suppressed. When this happens, an economy ends up mired in poverty. Recall that Proposition 1 provides the sufficient condition for a trap to emerge, but such a strong condition is not needed numerically for computing the threshold δ_c. The necessary and sufficient condition for a trap to emerge is that the slope of the KE locus is smaller than that of the IT locus when k goes to zero. Based on the structural parameters, one can compute the δ such that the slopes of the two loci are equal. Then, one can proceed to examine whether there are interior solutions under the computed δ. A simple way to verify whether the computed δ is the critical threshold δ_c is to plot the IT and the KE loci and see whether they have multiple equilibria under the computed δ. If there is no interior solution, δ_c is found and the analysis ends.

Following the method described above, we compute the threshold δ_c for the representative trapped economy based upon the calibrated structural parameters summarized in Table 8, which turns out to be 0.9501. Similarly, we can compute the threshold values of δ_c for Bangladesh, Kenya and Nigeria based on the calibrated results in Table 9, which are reported in the last row of Table 9. We also compute the threshold δ_c for the U.S. economy, which is equal to 3.8686, and is greater than the δ_c for the three trapped economies. The interpretation for this result is that an economy like the U.S. can "bear" more institutional problems and can still grow without being caught in a poverty trap. Yet, this result does not imply that a rich country can keep on thriving without paying close attention to its institutional problems.

6.1.2 Institutional barriers

We now turn to studying the magnitude of institutional barriers δ in the trapped economies. As we have mentioned, δ is hidden under government expenditures, and one can never learn δ from files and data offered officially by governments. A handful of countries do have information regarding the leakages of government spending, such as public expenditure tracking system, or some estimates and reports on efficiencies of public investment scheme. Such information can serve as a proxy for the institutional barriers. However, most of the trapped countries do not have such information. Nevertheless, one may learn or at least sense the problems associated with δ and the size of δ from

the survey data. In abiding this notion, we first attempt to estimate the magnitudes of δ for the 41 trapped countries based on the available cross-country survey data. Upon obtaining the δ's of the 41 trapped countries, we can then compare the imputed measures of the magnitude of institutional barriers both within these trapped economies and with the U.S. to gain inside on how severe such barriers are relative to the benchmark U.S. economy. For the selected trapped countries, Bangladesh, Kenya and Nigeria, since they have richer information about their institutional problems, we can further impute their δ based on the existing cross-country surveys as well as the available country-specific data. More specifically, we collect country-specific measures for δ based on evaluating the true arrival of resources directed at the intended targets. We then apply a weighted average to the imputed measures under the existing survey data and the true arrival of resources to obtain the severity of the institutional barriers δ of Bangladesh, Kenya and Nigeria. Once all these imputed institutional barriers measures δ are obtained, we are able to compare them with the respective threshold values δ_c to conclude whether these economies are in poverty trap. Notably, it is said that *an economy is trapped if* $\delta > \delta_c$.

We now turn to elaborate the procedure of computing the magnitudes of the institutional barriers δ in the representative trapped economy and the three selected trapped countries.

6.1.2.1 Calibrate by using existing measures

The imputing of the δ using existing measures goes as follows: since the severity of the institutional barriers of the U.S. economy has been calibrated, we can adopt available cross-country measures that evaluate the efficiency of an economy to compute δ's for all the trapped economies using the U.S. calibrated δ as a benchmark. To do this, we choose the Corruption Perceptions Index (CPI) compiled by Transparency International (TI) as our cross-country indicator of institutional problems. The CPI is the mostly widely-used measure for detecting corruption problems. It measures the degree to which public sector corruption is perceived to be within the countries around the world, and is a composite indicator aggregating surveys from different sources to produce a single measure of corruption.[18] The CPI is calculated based upon surveys, using subjective opinions to gather data on levels of corruption in a nation, and has a scale between 0 (the most corrupt) and 10 (the least corrupt).[19]

To incorporate the CPI into the current study, we first take the CPI for the U.S. Recall that δ measures the severity of the institutional barriers, a higher δ means a more severe waste arising from institutional barriers rooted in the economy and hence a higher δ corresponds to a lower CPI. Therefore, the CPI is assumed to be a function of δ given by:

$$CPI_i\left(\delta_i\right) = \frac{10}{1 + a\delta_i},$$

[18] The surveys used by TI differ from year to year, depending on the surveys available in that year. At least three surveys are used for a country to be included in the sample of the CPI in a particular year.

[19] The scale has been changed to 0 - 100 since 2012.

where $a > 0$, which is pinned down using the calibrated U.S. δ. In this way, we connect the CPI to the model, and the magnitudes of the institutional barriers of the 41 trapped counties can thus be computed from this function with the use of the CPI. With the chosen functional form, when there is no waste arising from institutional barriers, the corresponding CPI is equal to 10, and when the institutional barriers are immense, the corresponding CPI is equal to zero. The parameter a is solved by plugging the CPI of the U.S. in 2005 (7.6) together with the calibrated δ of the U.S. (0.1698), and is equal to 1.86. The fitting of the δ measure for the 41 trapped countries based on the CPI is plotted in Figure 11 and is reported to the second to the last column in Table 2. The imputed δ for the representative trapped economy is thus 1.7054. Furthermore, the imputed δ for Bangladesh, Kenya and Nigeria are then 2.6249, 2.0225 and 2.292, respectively.

From Table 2, by comparing the imputed severity of the institutional barriers with the threshold δ_c, we can conclude that all 41 countries are trapped because their institutional barriers all exceed the corresponding threshold. To better understand and interpret the role of δ, we compute the "social waste" measured by $\frac{\delta}{1+\delta}$ (i.e., the ratio of total waste arising from institutional barriers to total health expenditures) for the 41 trapped economies and the counterpart at the threshold $\frac{\delta_c}{1+\delta_c}$ for the representative trapped economy. The imputed social waste and its counterpart at the threshold for the representative trapped economy are reported at the bottom in Table 8, while the computed social waste for the 41 trapped economies are reported in the last column of Table 2. For comparison purposes, we also compute these figures for the U.S.: even as the most advanced economy, its social waste associated with the institutional barriers to health still amounts to 14.5% of the national average investment in health. For the trapped economies, the average social waste is 63.0%, far exceeding the threshold social waste measure of 48.7%. Thus, the trapped economies, on average, have incurred more than four times as much social waste as the U.S., a figure that is of no doubt alarming: they point to *more than three fifths of the health investment in these countries being wasted*. Among these trapped economies, there are not much regional variations in social waste (ranging from 62.4 to 64.5%). For individual countries, social waste ranges from as low as 50% (Ghana) to over 70% (Bangladesh, Chad and Haiti). In Figure 12, we illustrate that, based on the relative scales of δ and δ_c, the likelihood for each of the sample country to pull out. Interestingly, while Ghana and Burkina Faso are most likely (with more than 90% chance) to depart from the poverty trap, the chance for Bangladesh, Chad or Haiti to pull out is below 40%.

A remaining question is whether one may add more qualification to measuring such institutional barriers using the three selected trapped economies in great depth which we now pursue.

6.1.2.2 Calibrate by using both existing and imputed true arrival rate measures for Bangladesh, Kenya and Nigeria

International organizations, such as the World Bank, the UN, the WHO, the IMF and other non-profit private organizations, have provided help in the form of agriculture, health, education

and finance, among other things to developing countries for more than 50 years. Aid from the governments of rich countries is often channeled to developing countries through these organizations. The Organisation for Economic Co-operation and Development (OECD) has kept records of foreign aid, including amounts committed and the amounts disbursed, by donor and by the sector donated to. The data on disbursement and commitment are perfect for our purpose here. Aid from other countries is like a gift from heaven. If a country is bad at allocating and distributing resources, there are reasons to believe that the barriers in the economic system are large.[20]

Thus, data on foreign aid disbursement and commitment are collected from the OECD. In particular, we focus on foreign aid in the health and the water sector. Water resources are crucial for good health, as not having sources of clean water is one of the main reasons why people easily get sick in developing countries. Among all the aid related to health and water, we exclude aid designated for administration and management purposes, water resources protection and river development to focus on aid that is actually designated for helping and promoting good health for people. Table 10 reports the computed disbursement-to-commitment rates (utilization) of foreign aid for Bangladesh, Kenya and Nigeria for the year 2006-2008. Aid is fungible within sectors, and hence the disbursement-to-commitment ratio could be larger than one.

From Table 10, Bangladesh performs better in disbursing aid designated for improving health, while Nigeria performs better when it comes to improving water supply and sanitation. Kenya performs the worst among the three countries. The disbursement-to-commitment ratios for aid designated to be used for primary health, family planning, and water supply and sanitation for Bangladesh, Kenya and Nigeria are 0.6802, 0.5821 and 0.7844, respectively. The interpretation of these numbers is that for a dollar thrown into these economic systems, only about 0.7, 0.6 and 0.8 dollars are actually being delivered to their designated destinations, respectively. However, being delivered does not guarantee actual arrival. What is the percentage of these outgoing resources actually reaching the destination?

Below we provide a brief summary of cases regarding the leakages and corruption problems in Bangladesh, Kenya and Nigeria. We excerpt cases of inflated investments and leakages in drug-related issues. Corruption in the provision of medical service such as absenteeism among doctors and illegal payments for services are also important problems in these countries. However, our purpose is to calculate the "true arrivals" – resources distributed that eventually reach patients or meet the goal, and hence we only focus on cases of excess costs of investments and leakages in the

[20] Aid sometimes comes in the form of a bundle with conditions, and may not match the demand needed so as to result in a low disbursement-to-commitment ratio. Since the problems with foreign aid faced by all recipients are the same, comparing the disbursement/commitment ratios still serves as a good way of gauging the extent of institutional barriers rooted in the countries. Effectiveness of foreign aid is not the focus of this paper, and hence we shall dismiss the discussion on it. Readers interested in the effectiveness of foreign aid are referred to Collier and Dollar (2001, 2002).

system and do not consider other corruption cases here.

(i) *Bangladesh*: Hossain and Osman (2007) provide a very detailed summary of cases of corruption in the health sector in Bangladesh. For example, massive corruption in accepting tender bids for purchasing medical equipment for government hospitals was detected according to a newspaper report. In one case, the lowest bid price was about 50% higher than the estimated cost, while in another, the bid price had been 100% higher than the estimated cost. Although there was no detection of large scale drugs leakage in the records of transactions between the district and upazila (subdistrict) facilities, there is some evidence that union facilities received less (around 93%) of the supplies that were recorded as having been sent (FMRP 2006). A comparison of the average drugs issued to patients as recorded by facilities compared against that reported by patients, however, suggests that it may be through inflated patient numbers that the leakage is adjusted. The Social Sector Performance Survey of primary health found that facilities were recording drug issues equivalent to two to three times the amount the patients reported receiving (FMRP 2006) – representing a 50% to 66% leakage in issuing drugs.

(ii) *Kenya*: Nafula et al. (2004) conducted a public expenditure tracking survey on the education, health and agricultural sectors to identify constraints in service delivery and leakages of public resources at various levels. The main findings in the health sector are summarized as follows. In the health sector, about 85% of the health facilities had inadequate medical supplies, and only 69.7% of the drugs released by the districts reached the health facilities. In a survey conducted by the Kenya Anti-Corruption Commission in 2010 on a sample of facility managers, health care staff and patients, 24.8% of the health providers cited procurement of sub-standard/poor quality drugs, 34.2% cited manipulation of tender documents, and 31.7% mentioned misappropriation of supplies.

(iii) *Nigeria*: Project costs in Nigeria are some 25% higher than the norm for sub-Saharan Africa (or a 20% leakage) and infrastructure projects are generally more than twice the size needed to meet foreseeable demand. Many public sector investment projects are not viable from the start, with actual capacity utilization rates estimated to be about 30% against planned rates of 80%. The overcharging and oversizing of public investment projects has led to excessive costs in the range of 50% of total investment. During 1973-1990, the Nigerian government spent an estimated US$115 billion on public investment projects, while an efficient and effective public investment program could have yielded the same output results for about US $58 billion (Husain and Faruqee 1994, excerpted from Moser, Rogers and Til 1997, p.37). Based on a public expenditure tracking survey conducted during April – June 2002 on a sample of 30 local governments, 252 health facilities and more than 700 health workers in the state of Lagos and

Kogi in Nigeria, Das Gupta et al. (2004) found evidence of a large-scale leakage of public resources away from original allocations in Kogi.

Based on the cases listed above, we determine that Bangladesh has a leakage of roughly $50\% - 66\%$ in both health facility investments and drugs issuing, so that the average leakage is around 58%. For Kenya, we take the number of cases of drug leakage to be $1 - 69.7\% = 30.3\%$. For Nigeria, the cases reveal roughly a $25\% - 50\%$ leakage in investment projects, and we determine that the average leakage for Nigeria is around 37.5%. Together with the disbursement to commitment ratio calculated above, the true arrival rates of resources are 0.2827, 0.4057 and 0.4903 for Bangladesh, Kenya and Nigeria respectively, which are measured by,

$$\text{true arrival rate rate} = \frac{\text{disbursement}}{\text{commitment}} \times \text{(1-leakage rate)}$$

Finally, the implied δ under this method for the three trapped countries are computed using the ratio:

$$\text{imputed } \delta = \frac{\text{1-true arrival rate}}{\text{true arrival rate}}.$$

which are 2.5004, 1.4647 and 1.0398, respectively, summarized in Panel (2) of Table 11.

Now, by taking the simple average of the δ obtained using the two methods, we compute the δ for Bangladesh, Kenya and Nigeria as 2.5626, 1.7436 and 1.6659 (see the second of the last row in Table 11). These severity of barrier measures can then be compared with the country-specific δ_c obtained for the three countries in Section 6.1.2, which are conveniently reported in the last row of Table 11. The results indicate that these three trapped economies all experience severe institutional problems, and the severity of the institutional barriers far outweighs the extent of the problems that these countries can bear. With the presentation of such severe institutional problems, there is no doubt that the effectiveness of aid is low, and incentives to invest in a better future are greatly reduced.

To address this quantitatively, we again resort to the social waste measures for these countries. The results are reported in Table 12. Recall that the social waste associated with institutional barriers to health for the U.S. is about 15% of the national average investment in health. The comparable social waste figures rise all the way to $62 - 72.4\%$ in the three trapped economies under this study, about 4 to 5 times as much as the U.S. in comparison. These latter figures are also striking: *about two thirds of the health investment in these countries have been wasted.*

In conclusion, "how to rectify the institution" must be regarded as priority for the lagged behind countries if they are to manage to step onto the right track toward a better future. One question that naturally arises after seeing the results presented here is: Why can some initially poor countries grow at a miraculous speed and move out of poverty? Do they really perform better in terms of their institutions? This is the question to which we now turn.

6.2 Middle-inome-low countries

After reviewing the cases of three trapped countries, now we switch our attention to middle-income-low countries. In particular, we choose to study China and India since both have large populations and were poor initially, but both of them have exhibited rapid economic growth for over a decade.

We proceed to calibrate for both nations. Since they are not "trapped", the calibration procedure is the same as the benchmark calibration for the U.S. What is worth mentioning is that China and India are still at the stage of transition and have not reached the BGP yet. Hence, when calibrating for China and India, we adjust the economic growth rates down to 3% so as to match the notion of the BGP. While the procedure is the same as in the benchmark calibration, the assumptions regarding the health capital share, the inborn health share and the innate knowledge share still need to be adjusted. Similar to what we have done in the calibration for the trapped economies, based on the assumptions for the U.S. economy, we adjust the health capital share according to the relative health conditions and educational attainment in China and India. Inborn health and innate ability are also adjusted according to health conditions and the educational attainment, respectively. Again, parental education time investment is adjusted according to fertility rates since there are no available time use surveys in China and India. For China, we take a capital income share of 0.4 and a real return of (physical) capital at 7.5%.[21] For India, we set the capital income share to be $\frac{1}{3}$ and the real return of (physical) capital at 6.8% as this is the average interest rate during 1981-2000 obtained from the World Bank. We use the same method to calibrate for the technology scaling factor in the human capital sector with data on mortality rates and years of schooling.

Table 9 reports the results of calibration for China and India, and Table 12 compares the severity of the institutional barriers and the thresholds of the severity for the countries studied in this paper. The message is clear: although they still have low income levels at the current stage, middle-income-low countries experience fewer problems with institutional barriers. The waste shares of middle-income-low countries fall in the range of $30\%-35\%$, a little more than twice the comparable measure for the U.S. and about half of those for the trapped economies. Most importantly, *such barriers are low enough for them to take off and to proceed along the right track of development.*

[21] Bai, Hsieh and Qian (2006) estimate the return on capital in China and find that the return on capital after 1998 has been stable at roughly 20%, and the implied capital share is 0.58. The average real interest rate obtained from the World Bank during 1980-2009 is about 2%. In a discussion note written by Blanchard, using individual firm data from the OECD, the return on capital obtained is lower than that reported by Bai et al. (2006), and ranges between 4.8% - 15%, varying across ownership types. Hence, our choice of a 7.5% return on capital and 0.4 capital income share are acceptable.

7 Conclusion

Why are some poor countries trapped in poverty while others have successfully stepped out of the trap and have moved forward toward prosperity? This paper delivers a simple message: it is because that health-related institutional barriers in trapped economies are very large, thus dampening individuals' incentives to invest severely and resulting in a vicious cycle of poor health, low incentives to invest and bad institutions. How can these countries be rescued from the poverty trap? Making the institution or the environment right is the first priority. Pulling a country out of poverty does not call for an eradication of the institutional barriers either completely or substantially: so long as the country overcomes the threshold institutional barriers, the country is on the right track to development and a better future.

Along these lines, there are at least two major extensions that are worth considering. The first has to do with the provision of policy prescriptions as to how to correct the institutional problems laid out in this study. Although exogenously set in our model for analytic convenience, in reality, institutional barriers are often an endogenous outcome of the natural environment, the perceptions and beliefs of people, and the different political economy forces. Hence, institutions would evolve as time goes by and endogenizing institutions may generate rich feedback to economic performance. Should such channel be built in, one may then perform counterfactual analysis to evaluate various policy tools in the interest of pulling out an economy from the poverty trap over the shortest time span under a given level of resources.

Another important issue is: while health institutions are crucial for the pull-out of trapped economics at their current development stage, are educational factors going to step in to play a more significant role at the later stage to speed up the process of pull-out. That is, might the priority shift from health institutions to educational factors as time goes by? This is highly likely because, as health conditions improve, the incentive to invest in education and the effectiveness of such investments must rise. One may thus expect the role of educational factors to increase along the path toward economic takeoff.

While these avenues of studies are beyond the scope of the present paper, they are important and interesting directions for future research.

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Appendix

In the appendix, the proofs of Propositions 1 and 2, detailed mathematical derivations of the comparative statics, data details and the calibration procedure for trapped countries are provided.

A.1 Mathematical appendix

This appendix provides detailed derivations for individual optimization and equilibrium outcomes and characterization, as well as proofs for Propositions 1 and 2.

Individual Optimization

We solve the generation-t representative woman's problem by deriving the first-order conditions (FOCs). By substituting the time constraint (9) into the budget constraint when young (10), and denoting λ_1, λ_2, λ_3, λ_4, and λ_5 as the Lagrangian multipliers associated with (10), (11), (2), (7) and (8), the FOCs with respect to c_t^y, c_{t+1}^o, s_t, H_{t+1}, e_t, x_t, h_{t+1}, and m_{t+1} are:

$$\begin{aligned}
\frac{1}{c_t^y} &= \lambda_1, && (33)\\
\frac{\pi(h_t)}{(1+\rho)c_{t+1}^o} &= \lambda_2, && (34)\\
\lambda_1 &= \lambda_2 R_{t+1}, && (35)\\
\frac{\gamma}{H_{t+1}} &= \lambda_3, && (36)\\
\lambda_4 \xi \eta x_t^{\eta-1} h_t^{1-\eta} &= \lambda_1, && (37)\\
\lambda_5 \mu m_t &= \lambda_1 w_t H_t, && (38)\\
\lambda_3 \beta h_{t+1}^{\beta-1} m_{t+1}^{1-\beta} &= \lambda_4, && (39)\\
\lambda_3 (1-\beta) h_{t+1}^{\beta} m_{t+1}^{-\beta} &= \lambda_5. && (40)
\end{aligned}$$

We then combine (33)-(35) to derive (14). Substituting (33), (36) and (39) into (37) we derive (15). Similarly, substituting (33), (36) and (40) into (38) yields (16).By using (2) and (8), (15) and (16) can be further simplified as (17) and (18).

Key Equilibrium Relationships

By imposing the BGP conditions and with the use of (21), (17) and (18) can be expressed in stationary ratios as:

$$\begin{aligned}
v &= \frac{\beta\gamma\eta\left[\mu(e+\psi)-\phi\right]}{\mu(e+\psi)} z, && (41)\\
z &= \frac{w(k)(e+\psi)}{\gamma(1-\beta)}. && (42)
\end{aligned}$$

By making use of budget constraints both when young and when old, substituting (14) into (11) to obtain $s = \frac{\pi_H c^y}{1+\rho}$, and then plugging s and (41) into (10), another expression can be derived for z and is given by (24). Equating (42) and (24) yields (23).

Existence and Uniqueness of the BGP Equilibrium

Theorem A (Nondegenerate and unique) *Assume that*

(i) $\frac{\gamma(1-\beta)}{\psi} > D_H + \frac{\beta\gamma\eta(\mu\psi-\phi)}{\mu\psi}$,

(ii) $\frac{\gamma(1-\beta)-\psi D_H+\beta\gamma\eta\left(\frac{\phi}{\mu}-\psi\right)}{D_H+\beta\gamma\eta+\gamma(1-\beta)} < \frac{\gamma\mu(1-\beta)-\psi-(1+\delta)\beta\gamma\eta(\mu\psi-\phi)}{1+\gamma\mu(1-\beta)+(1+\delta)\beta\gamma\eta\mu}$,

(iii) $\frac{\gamma(1-\beta)-\psi D_H+\beta\gamma\eta\left(\frac{\phi}{\mu}-\psi\right)}{D_H+\beta\gamma\eta+\gamma(1-\beta)} > \frac{1}{\mu} - \psi$.

Then there exists a unique nondegenerate BGP equilibrium.

Proof: First, ensure that the solution of e exists. To check whether the solution of e exists, differentiate MC_e with respect to e as follows:

$$\begin{aligned}\frac{dMC(e)}{de} &= \frac{1}{1-e}\left[\frac{\mu(e+\psi)\beta\gamma\eta\mu - \beta\gamma\eta[\mu(e+\psi)-\phi]\mu}{\mu^2(e+\psi)^2}\right] \\ &\quad + \frac{1}{(1-e)^2}\left[D_H + \frac{\beta\gamma\eta[\mu(e+\psi)-\phi]}{\mu(e+\psi)}\right] \\ &= \frac{1}{1-e}\left[\frac{\beta\gamma\eta\phi}{\mu(e+\psi)^2} + \frac{D_H + \frac{\beta\gamma\eta[\mu(e+\psi)-\phi]}{\mu(e+\psi)}}{1-e}\right] > 0.\end{aligned}$$

That is, $MC_e(e)$ is monotonically increasing in e. Since $MB_e(e)$ is monotonically decreasing in e, when $MB_e(0) = \frac{\gamma(1-\beta)}{\psi} > MC_e(0) = D_H + \frac{\beta\gamma\eta(\mu\psi-\phi)}{\mu\psi}$, $MB_e(e)$ and $MC_e(e)$ must have a unique intersection and hence the solution to e exists and is unique. This gives condition (i). Then, from (23), e can be solved as:

$$e^* = \frac{\gamma(1-\beta) - \psi D_H + \beta\gamma\eta\left(\frac{\phi}{\mu}-\psi\right)}{D_H + \beta\gamma\eta + \gamma(1-\beta)}.$$

For the economy not to degenerate, $\mu(e+\psi) > 1$ must be satisfied and hence $e > \frac{1}{\mu} - \psi$. Substituting e^* into the inequality yields

$$\frac{\gamma(1-\beta) - \psi D_H + \beta\gamma\eta\left(\frac{\phi}{\mu}-\psi\right)}{D_H + \beta\gamma\eta + \gamma(1-\beta)} > \frac{1}{\mu} - \psi,$$

which is condition (iii). Now, we turn to find the condition to ensure that the interior solution of (v,k) exists and is unique. It can be observed that the IT locus is monotonically increasing in k, while the KE locus is strictly concave in k. Thus, $\frac{dKE}{dk}|_{k=0} > \frac{dIT}{dk}|_{k=0}$ guarantees that the IT and the KE loci only intersect once. Differentiating the KE and the IT loci with respect to k yields:

$$\begin{aligned}\lim_{k\to 0+}\frac{\frac{dKE}{dk}}{\frac{dIT}{dk}} &= \lim_{k\to 0+}\frac{1}{1+\delta}\left[\frac{\mu(1\text{-}\beta)(1\text{-}e)}{\beta\eta[\mu(e+\psi)\text{-}\phi]} - \frac{e+\psi}{\beta\gamma\eta[\mu(e+\psi)\text{-}\phi]} - \frac{\mu^2(e+\psi)(1\text{-}\beta)(1\text{-}e)}{\alpha(1\text{-}\alpha)Ak^{\alpha\text{-}1}\beta\eta[\mu(e+\psi)\text{-}\phi]}\right] \\ &= \frac{1}{1+\delta}\left[\frac{\mu(1-\beta)(1-e)}{\beta\eta[\mu(e+\psi)-\phi]} - \frac{e+\psi}{\beta\gamma\eta[\mu(e+\psi)-\phi]}\right] > 1.\end{aligned}$$

Rearranging the above inequality leads to:

$$e < \frac{\gamma\mu(1-\beta) - \psi - (1+\delta)\beta\gamma\eta(\mu\psi-\phi)}{1+\gamma\mu(1-\beta)+(1+\delta)\beta\gamma\eta\mu}.$$

Plugging e^* into the above equation yields:

$$\frac{\gamma(1-\beta)-\psi D_H+\beta\gamma\eta\left(\frac{\phi}{\mu}-\psi\right)}{D_H+\beta\gamma\eta+\gamma(1-\beta)}<\frac{\gamma\mu(1-\beta)-\psi-(1+\delta)\beta\gamma\eta(\mu\psi-\phi)}{1+\gamma\mu(1-\beta)+(1+\delta)\beta\gamma\eta\mu},$$

which gives condition (ii). In short, condition (i) ensures that a unique solution for e exists, while condition (ii) ensures that with the equilibrium e given by (23), the solution for (v,k) is unique. Hence, conditions (i) and (ii) guarantee that the BGP equilibrium is unique. Condition (iii) further guarantees that the BGP equilibrium is nondegenerate.

Proof of Proposition 1

The sufficient conditions to for the corner solution is:

$$\begin{aligned}&\text{(a)}\quad \lim_{k\longrightarrow 0}\frac{\frac{\partial KE}{\partial k}}{\frac{\partial IT}{\partial k}}<1,\\ &\text{(b)}\quad \frac{\partial IT}{\partial k}>\frac{\partial KE}{\partial k}\text{ for all }k.\end{aligned}$$

That is, the sufficient conditions are that (i) the slope of the KE locus is smaller than the IT locus as k approaches one, and (ii) the slope of the KE locus is always smaller than the slope of the IT locus. If (b) is not violated, the KE locus either intercepts the IT locus twice, or does not intercept the IT locus at all. From the proof of Theorem A:

$$\begin{aligned}\frac{\frac{dKE}{dk}}{\frac{dIT}{dk}} &= \frac{1}{1+\delta}\left[\frac{\mu(1\text{-}\beta)(1\text{-}e)}{\beta\eta[\mu(e+\psi)\text{-}\phi]}\text{-}\frac{e+\psi}{\beta\gamma\eta[\mu(e+\psi)\text{-}\phi]}\text{-}\frac{\mu^2(e+\psi)(1\text{-}\beta)(1\text{-}e)}{\alpha(1\text{-}\alpha)Ak^{\alpha\text{-}1}\beta\eta[\mu(e+\psi)\text{-}\phi]}\right]\\ &= \frac{\mu(1-\beta)}{(1+\delta)}\left[\frac{1-e-\frac{e+\psi}{\gamma(1-\beta)}}{\beta\eta[\mu(e+\psi)-\phi]}-\frac{\mu(e+\psi)(1-e)}{\alpha\beta\eta[\mu(e+\psi)-\phi](1-\alpha)Ak^{\alpha-1}}\right]\\ &= \frac{\mu(1-\beta)}{(1+\delta)\beta\eta[\mu(e+\psi)-\phi]}\left[1-e-\frac{e+\psi}{\gamma(1-\beta)}-\frac{\mu(e+\psi)(1-e)}{\alpha(1-\alpha)Ak^{\alpha-1}}\right]\\ &< 1\text{ for all }k.\end{aligned}$$

That is,

$$\begin{aligned}1-e-\frac{e+\psi}{\gamma(1-\beta)}-\frac{\mu(e+\psi)(1-e)}{\alpha(1-\alpha)Ak^{\alpha-1}} &< \frac{(1+\delta)\beta\eta[\mu(e+\psi)-\phi]}{\mu(1-\beta)},\\ 1-e-\frac{e+\psi}{\gamma(1-\beta)}-\frac{(1+\delta)\beta\eta[\mu(e+\psi)-\phi]}{\mu(1-\beta)} &< \frac{\mu(e+\psi)(1-e)}{\alpha(1-\alpha)A}k^{1-\alpha},\\ \left\{\frac{\alpha(1\text{-}\alpha)A}{\mu(e\text{+}\psi)(1\text{-}e)}\left\{1\text{-}e\text{-}\frac{e\text{+}\psi}{\gamma(1\text{-}\beta)}\text{-}\frac{(1\text{+}\delta)\beta\eta[\mu(e\text{+}\psi)\text{-}\phi]}{\mu(1\text{-}\beta)}\right\}\right\}^{\frac{1}{1-\alpha}} &< k,\quad\text{for all } k\in R^+.\end{aligned}$$

Hence, (b) is satisfied if

$$\begin{aligned}\left\{\frac{\alpha(1-\alpha)A}{\mu(e+\psi)(1-e)}\left\{1-e-\frac{e+\psi}{\gamma(1-\beta)}-\frac{(1+\delta)\beta\eta[\mu(e+\psi)-\phi]}{\mu(1-\beta)}\right\}\right\}^{\frac{1}{1-\alpha}} &< 0\\ 1-e-\frac{e+\psi}{\gamma(1-\beta)}-\frac{(1+\delta)\beta\eta[\mu(e+\psi)-\phi]}{\mu(1-\beta)} &< 0\\ \gamma\mu(1-\beta)(1-e)-\mu(e+\psi)-\gamma(1+\delta)\beta\eta[\mu(e+\psi)-\phi] &< 0\\ \frac{\gamma\mu(1-\beta)-\mu\psi-(1+\delta)\gamma\beta\eta[\mu\psi-\phi]}{\mu[\gamma(1-\beta)+1+(1+\delta)\gamma\beta\eta]} &< e\end{aligned}$$

Substituting the equilibrium e^* into the above inequality implies:

$$\Phi \equiv \frac{\gamma(1-\beta) - \psi\left(1+\frac{\pi_H}{1+\rho}\right) + \beta\gamma\eta\left(\frac{\phi}{\mu}-\psi\right)}{1+\frac{\pi_H}{1+\rho}+\beta\gamma\eta+\gamma(1-\beta)} > \frac{\gamma\mu(1-\beta)-\mu\psi-(1+\delta)\gamma\beta\eta[\mu\psi-\phi]}{\mu[\gamma(1-\beta)+1+(1+\delta)\gamma\beta\eta]} \equiv \Psi(\delta)$$

where $\Psi(\delta)$ is decreasing in the severity of institutional barriers to health (δ) but Φ is independent of it. By straightforward manipulation, this inequality can be further simplified to,

$$\delta > \Delta \equiv \frac{\gamma[\beta\eta\phi+(1-\beta)\mu]-\mu\{\psi(1+\beta\eta\gamma)-\Phi[1+\gamma(1-\beta(1-\eta))]\}}{\beta\eta\gamma[\mu(\psi+\Phi)-\phi]}$$

which yields the condition in the proposition.

Proof of Proposition 2

Take the total differentiation to (23) with respect to γ:

$$\begin{aligned}
\frac{1-\beta}{e+\psi}d\gamma - \frac{\gamma(1-\alpha)}{(e+\psi)^2}de &= \{+\}de + \frac{1}{1-e}\frac{\beta\eta[\mu(e+\psi)-\phi]}{\mu(e+\psi)}d\gamma, \\
\left\{\frac{1-\beta}{e+\psi} - \frac{1}{1-e}\frac{\beta\eta[\mu(e+\psi)-\phi]}{\mu(e+\psi)}\right\}d\gamma &= \left\{\{+\} + \frac{\gamma(1-\alpha)}{(e+\psi)^2}\right\}de.
\end{aligned}$$

The term before $d\gamma$ can be rearranged as:

$$\frac{1-\beta}{e+\psi} - \frac{1}{1-e}\frac{\beta\eta[\mu(e+\psi)-\phi]}{\mu(e+\psi)} = \frac{1}{e+\psi}\left\{1-\beta-\frac{1}{1-e}\frac{\beta\eta[\mu(e+\psi)-\phi]}{\mu}\right\}.$$

This term > 0 iff

$$e < \frac{1-\beta-\beta\eta\left(\psi-\frac{\phi}{\mu}\right)}{1-\beta-\beta\eta}.$$

Substituting e^* into the above inequality, we have:

$$\frac{\gamma(1-\beta)-\psi D_H+\beta\gamma\eta\left(\frac{\phi}{\mu}-\psi\right)}{D_H+\beta\gamma\eta+\gamma(1-\beta)} < \frac{1-\beta-\beta\eta\left(\psi-\frac{\phi}{\mu}\right)}{1-\beta-\beta\eta},$$

which gives the condition in the Proposition. Once imposing this condition, all the comparative statics follow in a straightforward manner.

A.2 Data

In the following, we list the sources of data we have used in this paper. All data are obtained from PWT 6.3, the United Nations Data Retrieval System (UNdata, data.un.org/Default.aspx), the World Bank, and the Barro-Lee educational attainment dataset (2010).

Penn World Table 6.3: Real GDP per capita (rgdpl)

UNdata – National Account official country data

Table 4.1:

I. Production account – Uses: Consumption of Fixed Capital (D) (SNA93 item code K.1)

II.1.1. Generation of income accounts: Resources Gross Domestic Product, Uses Compensation of Employees (CE) (SNA93 item code B.1*g and D.1)

III.1 Capital account – Changes in Assets: Gross Fixed Capital Formation (I) (SNA93 item code P.51)

World Bank

World Bank indicators – Real Interest Rate (data.worldbank.org/indicator)

World Development Indicators (WDI) and Global Development Finance (GDF) database: Life expectancy at birth, Mortality rate under 5, Fertility rate, Health Expenditure per Capita (% of GDP, private, public, and total)

Barro-Lee educational attainment dataset (2010)

Average Years of Total Schooling, age 15 and over

Transparency International

Corruption Perceptions Index (CPI)

A.3 Sensitivity test

The results of the sensitivity test are reported in Table A.1. The results show that the model predictions are robust.

Table 1. Performances: comparison across countries

	High Income				Middle Income High				Middle Income Low					Trap						
	USA	UK	Japan	Germany	Greece	Korea	Argentina	Brazil	Colombia	Egypt	Turkey	China	India	Bangladesh	Cambodia	Ghana	Kenya	Nigeria	Malawi	Zambia
Growth rate per capita, 1970-2007	2.13	2.27	2.14	1.92	2.26	5.74	0.92	1.93	1.87	3.19	2.24	7.62	3.11	1.12	1.10	0.76	0.42	0.01	1.92	-0.89
Per capita GDP/GDPUS																				
1970	1.00	0.70	0.70	0.76	0.57	0.14	0.57	0.24	0.19	0.11	0.17	0.03	0.06	0.09	0.09	0.10	0.10	0.08	0.04	0.14
1980	1.00	0.69	0.76	0.80	0.65	0.22	0.51	0.35	0.22	0.12	0.17	0.04	0.06	0.06	0.04	0.07	0.08	0.07	0.05	0.12
1990	1.00	0.69	0.86	0.79	0.52	0.40	0.29	0.26	0.19	0.12	0.17	0.06	0.07	0.05	0.04	0.05	0.06	0.04	0.03	0.10
2000	1.00	0.69	0.73	0.74	0.51	0.49	0.32	0.22	0.17	0.12	0.16	0.11	0.07	0.05	0.05	0.04	0.05	0.03	0.03	0.08
2005	1.00	0.72	0.71	0.71	0.61	0.53	0.32	0.21	0.17	0.12	0.17	0.15	0.08	0.05	0.06	0.04	0.05	0.04	0.03	0.04
2007	1.00	0.75	0.70	0.73	0.65	0.55	0.36	0.22	0.18	0.13	0.18	0.20	0.09	0.05	0.07	0.04	0.05	0.06	0.03	0.05
Years of schooling																				
1970	10.77	7.29	8.20	5.02	6.52	6.34	6.30	2.81	3.92	1.31	2.43	3.43	1.57	1.38	5.06	3.58	2.17	NA	1.57	2.98
1980	12.03	7.71	9.25	5.61	7.10	8.29	7.30	2.77	4.90	2.65	3.55	4.75	2.34	2.25	5.31	5.05	3.79	NA	2.33	4.13
1990	12.15	8.13	9.97	8.04	8.58	9.35	8.34	4.46	5.99	4.38	5.01	5.62	3.45	3.16	5.54	6.17	5.60	NA	2.89	4.89
2000	12.71	8.81	10.92	9.95	8.89	11.06	8.73	6.41	6.91	5.91	6.08	7.11	4.20	4.48	5.79	7.12	6.62	NA	3.48	6.13
2005	12.09	9.21	11.26	11.85	9.89	11.47	9.13	7.17	7.05	6.59	6.47	7.62	4.68	5.20	5.90	7.50	7.10	5.00	4.38	6.33
Life expectancy at birth																				
1960	69.77	71.13	67.67	69.54	68.85	54.15	65.22	54.50	56.72	45.93	50.26	46.60	42.43	40.26	42.40	45.86	46.33	38.00	37.77	45.08
1970	70.81	71.97	71.95	70.46	71.84	61.25	66.59	58.56	60.88	50.43	55.69	61.97	48.83	44.10	43.63	48.93	52.19	42.00	40.52	48.97
1980	73.66	73.68	76.09	72.63	74.36	65.80	69.51	62.49	65.48	56.56	60.33	65.97	55.12	47.74	39.97	53.09	57.69	45.00	44.77	51.90
1990	71.80	75.88	79.10	75.40	77.00	71.80	72.50	66.70	68.30	62.89	64.70	68.40	57.60	54.40	54.85	58.40	59.80	46.00	46.70	52.00
2000	76.90	77.86	81.30	78.30	78.20	76.00	74.60	70.30	70.99	68.23	69.90	71.20	60.90	61.20	56.88	58.30	51.30	46.00	47.30	43.10
2005	77.74	79.07	81.93	79.31	79.17	78.43	74.77	71.65	72.27	69.54	71.39	72.58	62.78	64.59	59.26	56.53	52.41	49.00	51.03	42.82
2008	78.30	79.90	82.80	80.20	80.10	79.80	75.50	73.30	72.98	70.14	74.30	73.80	64.30	64.70	60.97	61.90	54.30	50.00	52.90	48.20
Mortality under 5 (per 1000)																				
1960	30.00	26.10	40.90	40.00	46.00	137.50	71.70	177.70	143.60	303.60	217.50	NA	240.10	243.20	NA	212.30	201.40	NA	360.40	212.70
1970	23.20	20.80	17.40	26.00	31.80	52.00	69.40	135.00	104.00	236.30	200.40	116.60	186.40	236.40	NA	183.00	151.80	251.00	323.30	177.90
1980	14.90	14.20	9.90	15.30	19.80	19.60	43.40	90.40	51.90	176.30	136.50	59.10	148.90	203.50	153.40	149.20	110.20	216.00	253.50	159.80
1990	11.20	9.50	6.20	8.60	10.50	8.70	27.90	55.70	35.00	89.50	84.20	45.50	118.20	147.50	116.70	120.10	99.10	213.00	218.10	178.60
2000	8.40	6.60	4.40	5.30	6.50	6.40	20.70	34.00	26.10	46.60	41.60	36.00	92.70	89.60	106.40	105.80	104.70	186.00	164.40	165.70

Note: 1. The growth rate refers to the geometric average growth rate of GDP per capita for the years from 1970 to 2007.

2. Source: Data for GDP per capita, Penn World Table 6.3; years of schooling, Barro-Lee (2010), and the UN for Nigeria; life expectancy, fertility and others, World Bank.

Table 2. Performances: comparison across the 41 trapped countries

Country	Per capita GDP growth rate (%)	Per capita real GDP relative to US, 1970 (%)	Per capita real GDP relative to US, 2000 (%)	Investment share, % of real GDP per capita	Public health exp., % of GDP	Health exp., % of GDP	Life expectancy at birth, 1960-2011	Life expectancy at 25, 2000-2005	Mortality rate, under-5 (per 1,000)	Fertility rate, 1960-2011	Years of schooling, 15+, 2000	2005 CPI Score	Implied δ from CPI	Implied social waste (%)
Afghanistan	-0.37	4.31	0.85	13.96	1.43	6.29	40.3	36.5	226.4	7.63	2.82	2.5	1.6129	61.7
Albania	1.69	12.09	7.98	38.70	2.35	5.97	70.7	52.7	31.5	3.58	9.91	2.4	1.7025	63.0
Angola	1.45	17.47	7.74	18.54	2.18	2.68	41.3	38.6	222.2	6.96	No data	2	2.1505	68.3
Bangladesh	1.12	8.80	4.72	9.72	1.17	3.16	56.2	45.1	155.8	5.04	4.48	1.7	2.6249	72.4
Benin	0.96	5.49	3.60	10.84	2.15	4.52	46.5	45.5	198.3	6.44	3.11	2.9	1.3163	56.8
Bolivia	0.73	14.97	8.16	10.91	3.38	5.31	55.0	46.2	150.5	5.20	8.29	2.5	1.6129	61.7
Burkina Faso	1.49	4.32	2.95	10.76	2.67	5.53	46.4	40.3	232.0	6.56	No data	3.4	1.0436	51.1
Burundi	-0.62	4.36	1.83	4.35	3.15	8.82	45.7	38.3	193.6	6.23	2.53	2.3	1.7999	64.3
Cambodia	1.10	9.03	4.51	5.05	1.72	6.26	49.8	42.1	105.1	5.10	5.79	2.3	1.7999	64.3
Cameroon	0.89	8.61	6.44	7.78	1.07	4.72	49.3	38.6	168.8	5.72	5.43	2.2	1.9062	65.6
Chad	0.79	8.04	2.92	8.47	1.87	5.38	47.1	40.5	211.6	6.53	No data	1.7	2.6249	72.4
Congo, Dem. Rep.	-4.03	7.40	1.02	5.30	1.37	5.14	45.4	39.6	194.2	6.53	3.36	2.1	2.0225	66.9
Congo, Rep.	1.33	7.26	6.55	7.87	1.49	2.68	54.6	39.2	128.8	5.57	5.86	2.3	1.7999	64.3
Cote d`Ivoire	-0.27	12.30	5.65	7.42	1.16	5.04	49.1	40.5	181.1	6.54	3.86	1.9	2.2920	69.6
Ethiopia	0.43	5.01	2.39	4.74	2.41	4.39	47.1	40.7	183.1	6.43	No data	2.2	1.9062	65.6
Gambia	0.07	6.63	3.24	9.03	2.49	5.77	48.1	40.3	204.5	5.87	2.64	2.7	1.4536	59.2
Ghana	0.76	10.38	3.66	7.40	2.87	6.36	54.6	42.6	140.3	5.82	6.57	3.5	0.9985	50.0
Guyana	0.29	11.35	5.91	52.16	4.48	5.51	60.7	45.2	64.0	3.68	8.09	2.5	1.6129	61.7
Haiti	-0.11	8.03	4.41	12.34	1.59	5.70	52.9	42.9	165.3	5.24	4.46	1.8	2.4492	71.0
Honduras	1.18	12.81	8.17	24.32	3.47	5.94	61.9	50.5	89.4	5.56	6.20	2.6	1.5302	60.5
Kenya	0.42	9.64	5.10	10.16	1.79	4.33	54.6	36.2	120.9	6.56	6.62	2.1	2.0225	66.9
Liberia	-4.18	11.52	1.27	12.40	2.13	8.10	44.3	43.9	221.8	6.35	3.43	2.2	1.9062	65.6
Madagascar	-0.70	7.23	2.43	4.27	2.35	3.66	51.5	43.9	143.2	6.29	No data	2.8	1.3825	58.0
Malawi	1.92	4.28	2.63	13.47	3.52	6.26	44.8	35.6	240.7	6.79	3.48	2.8	1.3825	58.0
Mali	1.86	3.50	2.93	7.63	2.60	6.11	41.4	37.8	290.9	6.86	1.21	2.9	1.3163	56.8
Mongolia	1.87	6.54	4.60	36.29	3.55	4.88	59.3	44.2	90.0	4.96	7.82	3	1.2545	55.6
Mozambique	1.51	7.51	3.27	4.00	3.61	5.13	43.1	37.4	218.9	6.13	1.05	2.8	1.3825	58.0
Nepal	1.38	5.87	4.56	15.83	1.56	5.44	52.3	45.4	164.8	5.07	2.93	2.5	1.6129	61.7
Nicaragua	-1.52	20.47	5.48	27.83	4.36	8.01	61.5	49.6	95.7	5.14	5.42	2.6	1.5302	60.5
Niger	-1.25	6.28	2.09	9.62	2.21	4.35	43.0	39.6	269.9	7.49	1.37	2.4	1.7025	63.0
Nigeria	1.46	7.33	3.45	9.90	1.69	5.50	45.1	38.4	215.3	6.28	5.00	1.9	2.2920	69.6
Papua New Guinea	1.31	6.50	5.70	19.84	3.02	3.74	53.0	41.0	109.3	5.24	3.47	2.3	1.7999	64.3
Rwanda	-0.11	7.47	2.54	3.59	3.21	6.67	44.4	36.1	187.5	7.16	3.18	3.1	1.1967	54.5
Senegal	-0.24	10.92	4.65	4.87	2.23	4.98	49.4	40.4	187.8	6.52	4.22	3.2	1.1425	53.3
Sierra Leone	-0.97	13.57	3.03	5.89	1.41	13.41	39.4	33.2	278.9	5.67	2.98	2.4	1.7025	63.0
Somalia	-1.85	4.59	1.22	21.11	No data	No data	44.0	40.6	180.0	6.78	No data	2.1	2.0225	66.9
Sudan	1.68	5.74	3.61	18.79	1.28	4.54	51.3	42.9	127.7	5.94	2.82	2.1	2.0225	66.9
Tanzania	1.12	3.00	1.89	10.29	2.33	4.49	49.8	37.7	163.2	6.28	4.73	2.9	1.3163	56.8
Uganda	0.16	5.74	2.78	3.46	1.80	7.19	48.6	34.4	169.1	6.94	4.32	2.5	1.6129	61.7
Zambia	-0.89	18.68	2.38	17.63	3.64	6.18	47.4	29.4	166.3	6.76	6.20	2.6	1.5302	60.5
Zimbabwe	-0.88	13.67	8.18	15.59	0.00	0.01	53.7	23.6	103.3	5.72	7.00	2.6	1.5302	60.5
Average	**0.27**	**8.75**	**4.06**	**13.22**	**2.26**	**5.32**	**49.9**	**40.4**	**170.5**	**6.03**	**4.59**	**2.5**	1.7054	63.0
Africa	*0.09*	*8.31*	*3.58*	*10.91*	*2.17*	*5.25*	*47.7*	*38.7*	*186.9*	*6.31*	*4.22*	*2.5*	1.6797	62.7
Asia	*1.35*	*7.35*	*4.82*	*17.35*	*2.20*	*4.69*	*54.1*	*43.5*	*125.0*	*5.08*	*4.90*	*2.4*	1.8184	64.5
Latin America	*0.07*	*14.07*	*6.55*	*18.85*	*3.20*	*6.24*	*57.8*	*47.3*	*125.2*	*5.28*	*6.09*	*2.4*	1.7806	64.0
E Euro/Middle East	*0.66*	*8.20*	*4.42*	*26.33*	*1.89*	*6.13*	*55.5*	*44.6*	*129.0*	*5.61*	*6.36*	*2.5*	1.6577	62.4

Note: 1. The per capita growth rate refers to the geometric average growth rate of GDP per capita for the years from 1970 to 2007; investment share (% of real GDP per capita) is the average of year 1970-2007; health expenditure (public and total, % of GDP) is the average of the available data from 1995-2010.

2. Source: Data for GDP per capita and investment share, Penn World Table 6.3; years of schooling, Barro-Lee (2010), and the UN for Nigeria; life expectancy, fertility and mortality, the World Bank and the UN; 2005 CPI score, Transparency International.

Table 3. Cross-country regressions (41 trapped countries)

Variable	(1)	(2)	(3)	(4)		(5)	
				(a)	(b)	(a)	(b)
log of investment share,% of GDP	0.0342	0.0329	-0.0788	-0.0763	-0.1073	-0.0809	-0.1091
	(0.1516)	(0.1542)	(.1499)	(0.1495)	(0.1485)	(0.1533)	(0.1525)
Years of schooling, 15+	0.1631***	0.1628***	0.0870	0.0773	0.0695	0.0751	0.0688
	(0.0485)	(0.0471)	(.0536)	(0.0542)	(0.0540)	(0.0559)	(0.0555)
Africa		0.6167	0.5660	0.5446	0.4752	0.5344	0.4717
		(0.3847)	(0.3565)	(0.3561)	(0.3557)	(0.3647)	(0.3645)
Asia		0.8809**	0.5222	0.5127	0.4425	0.5089	0.4410
		(0.4156)	(0.4119)	(0.4109)	(0.4082)	(0.4184)	(0.4162)
Latin America		0.9267**	0.7425*	0.7753*	0.7242*	0.7771*	0.7241*
		(0.4243)	(0.3997)	(0.3998)	(0.3927)	(0.4070)	(0.4001)
Fertility rate			-0.2995**	-0.3058**	-0.3148**	-0.3112**	-0.3166**
			(0.1234)	(0.1232)	(0.1216)	(0.1272)	(0.1255)
log of public health expenditure, % of GDP				-0.0759		-0.0802	
				(0.0709)		(0.0741)	
Log of total health expenditure, % of GDP					-0.1025		-0.1030
					(0.0717)		(0.0732)
2005 CPI						0.0522	0.0184
						(0.2073)	(0.1993)
Constant	6.5917***	5.9357***	7.8649***	8.0092***	8.2027***	7.9203***	8.1698***
	(0.4938)	(.5623)	(0.9496)	(0.9566)	(0.9619)	(1.0358)	1.0426

Note:

Total observations: 35 countries. Standard errors are in parentheses. * Significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

Table 4. Panel regressions (41 trapped countries)

	Annual Data		*5-year Interval*	
Variable	(1)	(2)	(1)	(2)
log of lagged investment share,% of GDP	0.1133*	0.1096***	0.0784	0.0774*
	(0.0605)	(0.0370)	(0.0549)	(0.0445)
Lagged years of schooling, 15+	-0.0705	-0.0245	-0.0206	-0.0019
	(0.0424)	(0.0360)	(0.0242)	(0.0300)
Lagged fertility rate	-0.08673*	-0.0551	-0.0682	-0.0329
	(0.0500)	(0.0455)	(0.0487)	(0.0403)
log of lagged public health expenditure, % of GDP		-0.0203		-0.0080
		(0.424)		(0.0156)
Constant		5.0240***		4.9203***
		(0.4336)		(0.4561)
Country fixed effects	Yes***	Yes***	Yes***	Yes***
Time fixed effects	No	No	Yes	Yes

Note:

1. Total observations: 34 countries. Standard errors are in parentheses. * Significant at 10 percent; ** significant at 5 percent; *** significant at 1 percent.

2. Due to collinearity, CPI 2005 actually takes over the effects of the dummy of Ghana.

3. Country fixed effects are significant at 1 percent level for most of the countries.

Table 5. Effects of changes in parameters on the equilibrium parental time devoted to educating child

Increases in parameter	δ	π_H	ϕ	ξ
Effects on parental time devoted to educating child e	0	-	+	0
Effects on health-human capital v	-	+	-	0
Effects on effective capital-labor ratio k	-	+	+	0

Table 6. Parameters and targets for the U.S. calibration

Parameters		Value	Source/Target
Data			
Annual economic growth rate		0.0213	PWT 6.3
Annual interest rate		0.055	1980-2005 average, the World Bank
Parental time devoted to educating child	e	0.14	American Time Use Survey, 2003-2008
Physical capital-to-human capital ratio	K/H	1	Kendrick (1976)
Physical capital share	α	0.32	Capital income share for the U.S.
Consumption-to-health expenditure ratio	c^y/x	9	Consumer health expenditure share $\fallingdotseq$ 0.2 and 1/2 goes for children
Preset Variables			
Time preference rate	ρ	1.0938	Annual time preference rate 0.03
Quality of life when old	π_H	0.9	10% discount over the old age consumption
Human capital technology scaling factor	B	1	Normalization
Health capital share	β	0.5	Assumed
Health capital-to-knowledge capital ratio	h/m	1	Assumed
Inborn health share		0.2	Assumed
Innate knowledge share		0.2	Assumed
Calibrated Parameters			
Capital per effective labor	k	1.1628	Calculated from k=$K/(H(1-e))$
Altruistic factor	γ	0.6271	Calibrated
Good production scaling factor	A	10.3475	Calibrated
Health investment share	η	0.429	Calibrated
Health technology scaling factor	ξ	1.9151	Calibrated
Knowledge technology scaling factor	μ	9.6782	Match annual economic growth rate
Parental health transmission	ϕ	0.3387	Match inborn health share
Parental knowledge transmission	ψ	0.035	Match innate knowledge share
Severity of institutional barriers	δ	0.1698	Calibrated
Real rate of return on physical capital	R	3.813	Match annual interest rate 5.5%

Table 7. Comparative Statics – benchmark calibration

	v	k	e	g	c^y/x	z	h/m	h/H	m/H
BV	0.4579	1.1628	0.1400	1.6937	9.0000	4.1211	1.0000	1.0000	1.0000
γ	0.5106	-1.2490	0.9382	1.8326	-1.1231	-0.6412	-2.8988	-1.5061	1.6288
π_H	0.1757	1.4878	-0.2823	-0.5513	0.0573	0.2335	1.7028	0.8337	-0.8033
ϕ	-0.2249	0.0212	0.0184	0.0360	0.2492	0.0215	0.6086	0.3020	-0.2953
ψ	0.0255	-0.0502	-0.2084	0.0813	-0.0083	0.0172	-0.1362	-0.0682	0.0684
μ	-0.2448	-1.4032	-0.0176	2.4055	-0.2320	-0.4739	-5.1010	-2.7379	3.1722
δ	-0.0216	-0.0673	0.0000	0.0000	0.0000	-0.0216	-0.0430	-0.0215	0.0215

Note: BV = benchmark values of the variables.

Table 8. Calibration of the representative trapped economy

Data and Parameters			Source/Target
Data of the representative trapped economy			
Relative real GDP per capita to the US	y	4.0607	US=100, year 2000, PWT 6.3
	yEKS	3.8546	US=100, year 2000, PWT 6.3
Ave. Model *C*/Model *Y*		76.36%	PennWorld NIA data
Ave. *I*/Model *Y*		21.25%	PennWorld NIA data
Ave τ (computed public health spending share)		2.4%	PennWorld NIA data
2005 CPI Score (0 to 10)		2.4707	Transparency International
Total fertility rate		6.0285	WHO/World Bank
Life expectancy at birth		49.8701	WHO/World Bank
Life expectancy at 25, 2000-2005		40.4170	WHO/World Bank
Mortality rate, under-5 (per 1,000)		170.5291	WHO/World Bank
Real interest rate		8.77%	IFS/World Bank
1970 - 2007 average real GDP per capita growth rate	g	0.27%	PennWorld NIA data, relative to US
Years of schooling, 15+, year 2000		4.5894	Barro-Lee (2010)
Effective discounting:			
Time preference rate	ρ	1.0938	
Quality of life when old	π_L	0.555	Adjusted
Parental time devoted to educating child			
Parental time investment	e	0.0478	Adjusted according to fertility rate
Shares and great ratios:			
Physical capital share	α	0.46586	Calibrated
Aggregate consumption to output ratio	C/Y	0.7636	Data
Investment-to-output ratio	I/Y	0.2125	
Earmarking health tax	τ	0.0239	
Real rate of return on physical capital		0.0526	Adjust down by 0.6 (similar to Kenya/Nigeria)
Physical capital-to-human capital ratio	K/H	0.5	Assumed
Capital per effective labor	k	0.52512	Calibrated
Human Capital Production Technology:			
Health capital-to-knowledge capital ratio	h/m	0.20628	Calibrated
Relative output ratio	Y_{US}/Y_i	24.626	Data
Health capital share in human capital	β	0.8	Same as Kenya/Nigeria
Human capital technology factor	B	0.4964	Calibrated
Intergenerational health and knowledge transmission:			
Health investment share	η	0.5	Assumed
Inborn health share	h_b	0.5	Assumed
Innate knowledge share	m_b	0.6	Assumed
Other Calibrated Parameters:			
Altruistic factor	γ	0.8318	Calibrated
Goods production scaling factor	A	7.0890	Calibrated
Knowledge technology scaling factor	μ	8.9388	Match annual economic growth rate
Parental knowledge transmission	ψ	0.0718	Match innate knowledge share
Health technology	ξ	1.5317	Calibrated
Parental health transmission	ϕ	0.5345	Match inborn health share

Institutional barriers and the corresponding social waste			
US's δ	0.1698	US's social waste	14.51%
a of the fitting function	1.8599		
δ_c of the representative trapped economy	0.9501	Average social waste	48.72%

Table 9. Calibration results for Bangladesh, Kenya, Nigeria, China, India and the US

		Trapped Economies			Middle-income-low		Developed	
Parameters description		Bangladesh	Kenya	Nigeria	China	India	US	Source/Target
Effective discounting								
Time preference rate	ρ	1.0938	1.0938	1.0938	1.0938	1.0938	1.0938	Annual time preference rate 0.03
Quality of life when old	π	0.72	0.4018	0.4838	0.8253	0.72	0.9	See text.
Life expectancy at 25		45.07	36.16	38.44	50	45	54.38	1995-2005 average, UN
Parental time devoted to educating child								
Parental time investment	e	0.096	0.058	0.048	0.1629	0.096	0.14	US: American Time Use Survey, 2003-2008; others: imputed based on US number and fertility circa 2000
Fertility rate		3	5	6	1.77	3	2.06	World Bank, circa 2000
Shares and great ratios:								
Physical capital share	α	0.5227	0.3880	0.2460	0.4	0.3333	0.32	Trapped economies: calibrated; others: imputed (based on other research)
Consumption to health investment ratio	c^y/x	-	-	-	15	17	9	Data, adjusted
Aggregate consumption to output ratio	C/Y	0.733	0.79	0.85	-	-	-	Data, adjusted
Investment-to-output ratio	I/Y	0.255	0.192	0.129	-	-	-	Data, adjusted
Earmarking health tax	τ	0.012	0.018	0.021	-	-	-	Data (G^h/Y)
Real rate of return on physical capital		0.06	0.05	0.05	0.075	0.068	0.055	World Bank, available period, adjusted
Annual economic growth rate	g	0.0112	0.0042	0.0146	0.03	0.03	0.0213	PWT 6.3 (adjusted for China and India)
Physical capital-to-human capital ratio	K/H	0.5	0.5	0.5	0.5	0.5	1	US: Kendrick (1976); others: imputed
Capital per effective labor	k	0.5532	0.5297	0.5253	0.5973	0.5532	1.1628	$k=K/(H(1-e))$
Human Capital Production Technology:								
Years of schooling, 15+, year 2000	E	4.477	6.624	5	7.106	4.201	12.706	Barro and Lee (2010)
Mortality rate under 5, per 1000	q	86	111	186	33	86	9	2000 data, World Bank
Health capital-to-knowledge capital ratio	h/m	0.297	0.22	0.1736	0.4877	0.2603	1	Calibrated (US=1)
Relative output ratio	Y_{US}/Y_i	21.186	19.61	28.97	9.4607	14.0845	1	PWT 6.3, year 2000 data
Health capital share	β	0.65	0.8	0.8	0.5	0.6	0.5	Imputed
Human capital technology factor	B	0.4964	0.6973	0.7347	0.3616	0.6385	1	Calibrated (US=1)
Intergenerational health and knowledge transmission:								
Health investment	η	0.5	0.5	0.5	0.2345	0.1752	0.429	Imputed. Middle

share								income: calibrated
Inborn health share	h_b	0.4	0.6	0.6	0.3	0.4	0.2	Imputed
Innate knowledge share	m_b	0.55	0.5	0.6	0.3	0.6	0.2	Imputed
Other Calibrated Parameters								
Altruistic factor	γ	0.9309	0.7285	0.8509	0.8125	0.9324	0.6271	Calibrated
Good production scaling factor	A	8.3648	7.8704	4.4009	10.2617	9.4965	10.3475	Calibrated
Knowledge technology scaling factor	μ	6.1839	9.9149	10.3369	8.9951	8.712	9.6782	Match annual economic growth
Parental knowledge transmission	ψ	0.1175	0.056	0.0721	0.0698	0.1442	0.035	Calibrated
Health technology	ξ	3.5257	1.3660	1.7154	2.5199	1.6439	1.9151	Calibrated
Parental health transmission	ϕ	0.5284	0.6663	0.7453	0.6281	0.8375	0.3387	Calibrated
Health Barriers Threshold Implied from the Model								
Threshold of the severity of institutional barriers	δ_c	1.0853	0.9561	1.5569	5.9125	5.8459	3.8686	Calibrated

Table 10. Aid to the Health and Water Sector: 2006-2008 Average

	Bangladesh			Kenya			Nigeria		
	Commitment	Disbursement	Utilization	Commitment	Disbursement	Utilization	Commitment	Disbursement	Utilization
Primal Health Care	146.3437	171.7559	1.1736	521.8655	342.1186	0.6556	580.4078	448.3996	0.7726
Basic health infrastructure	1.9160	11.1595	5.8244	5.9379	3.0473	0.5132	1.4067	1.3723	0.9756
Medical services, training & research	5.8102	3.2111	0.5527	12.5509	8.9924	0.7165	0.4265	7.9111	18.5482
Reproductive health care	47.1568	27.4084	0.5812	21.0394	12.7005	0.6036	25.2682	19.2662	0.7625
Infectious disease control	35.3479	23.8532	0.6748	44.5070	63.5729	1.4284	138.5042	102.9075	0.7430
Basic health care	39.6482	92.4866	2.3327	25.3352	21.5505	0.8506	55.5346	62.8895	1.1324
STD control including HIV/AIDS	16.4646	13.6371	0.8283	412.4951	232.2551	0.5630	359.2677	254.0531	0.7071
Family Planning	7.9873	12.5222	1.5678	8.1762	2.3501	0.2874	11.3681	4.1248	0.3628
Water Supply and Sanitation	168.8475	35.5385	0.2105	135.9223	43.1901	0.3178	56.3095	55.8264	0.9914
Water supply & sanit. - large syst.	141.8091	7.4140	0.0523	87.0683	23.1588	0.2660	27.3482	37.7021	1.3786
Basic drinking water supply and basic sanitation	26.1358	24.4393	0.9351	40.6423	19.6737	0.4841	2.1954	14.3696	6.5452
Waste management/disposal	0.8921	2.0295	2.2751	7.9644	0.0345	0.0043	26.6521	3.6408	0.1366
Educ./training: water supply & sanitation	0.0105	1.6557	157.5410	0.2473	0.3232	1.3065	0.1138	0.1138	1.0000
All – Primal Health Care, Family Planning, Water Supply and Sanitation	323.1785	219.8167	0.6802	665.9640	387.6588	0.5821	648.0854	508.3508	0.7844

Note: Numbers shown for commitments and disbursements are 2006-2008 average, USD million, constant 2007 prices.

Sources: CRS statistics/OECD, www.oecd.org/dac/stats/idsonline

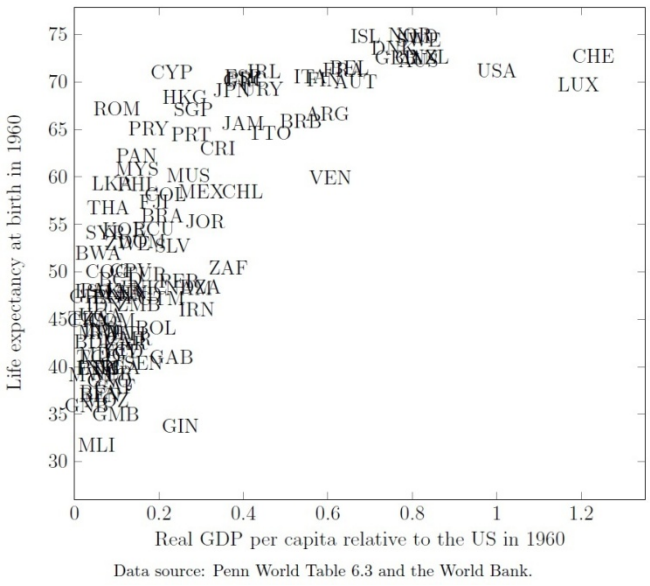
Table 11. Computation of institutional barriers for trapped countries

	Bangladesh	Kenya	Nigeria
(1) The CPI measure			
CPI in 2005	1.7	2.1	1.9
Imputed δ from CPI	2.6249	2.0225	2.2920
(2) True arrival			
Disbursement to commitment ratio	0.6802	0.5821	0.7844
Leakage	0.5800	0.3030	0.3750
True arrival rate	0.2857	0.4057	0.4903
Imputed δ from true arrival	2.5004	1.4647	1.0398
Weighted average δ from (1) and (2)	2.5626	1.7436	1.6659
Calibrated threshold δ_c	1.0853	0.9561	1.5569

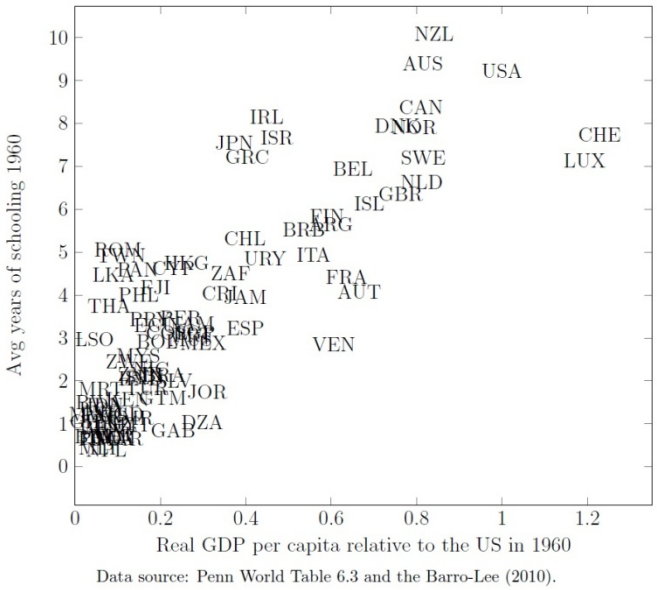
Table 12. Summary of institutional barriers across countries

	Bangladesh	Kenya	Nigeria	China	India	US
δ	2.5626	1.7436	1.6659	0.4426	0.5315	0.1698
δ_c	1.0853	0.9561	1.5569	5.9125	5.8459	3.8686
Waste share – $\delta/(1+\delta)$	0.7193	0.6355	0.6249	0.3068	0.3471	0.1451
Threshold waste share – $\delta_c/(1+\delta_c)$	0.5205	0.4888	0.6089	0.8553	0.8539	0.7946

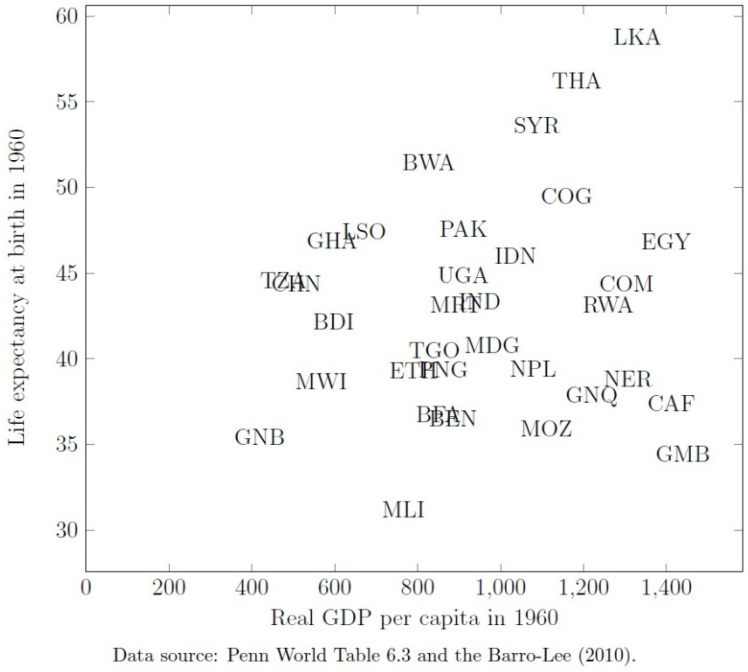
Figure 1. Life expectancy, years of schooling and relative real GDP per capita



(a) Life expectancy vs. relative real GDP per capita, 1960.



(b) Years of schooling vs. relative real GDP per capita, 1960.



(c) The poor nations: Life expectancy vs. relative real GDP per capita, 1960.

Figure 2. Non-convergence of the 41 trapped countries

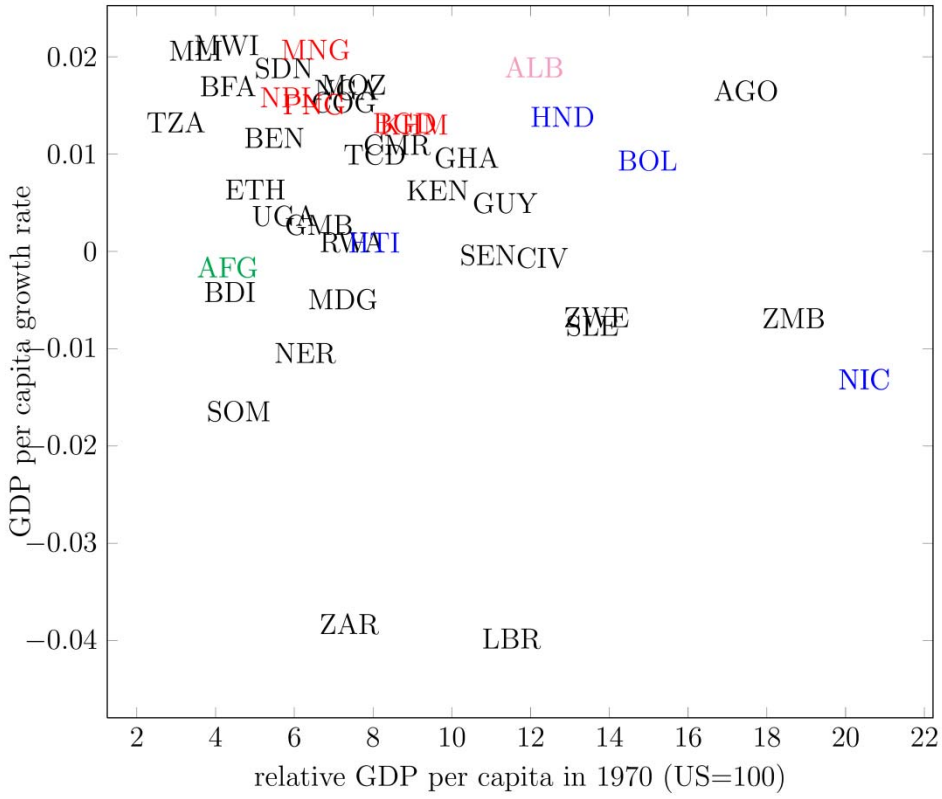
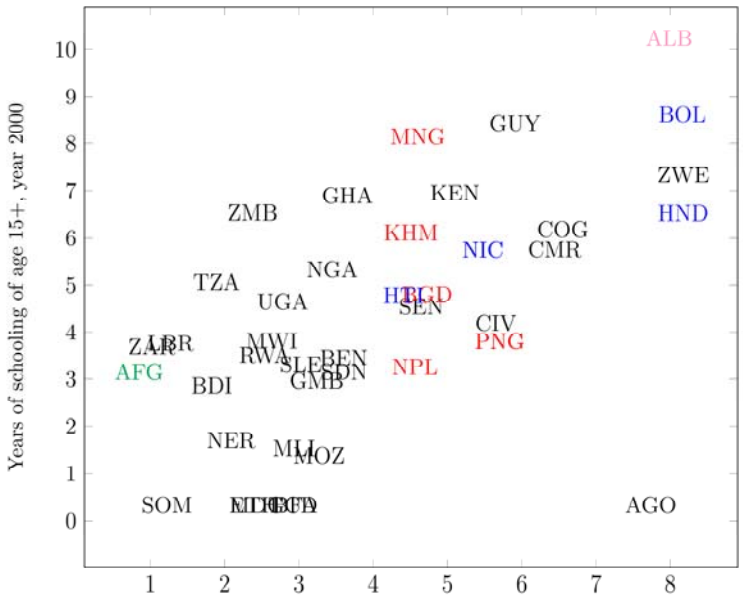
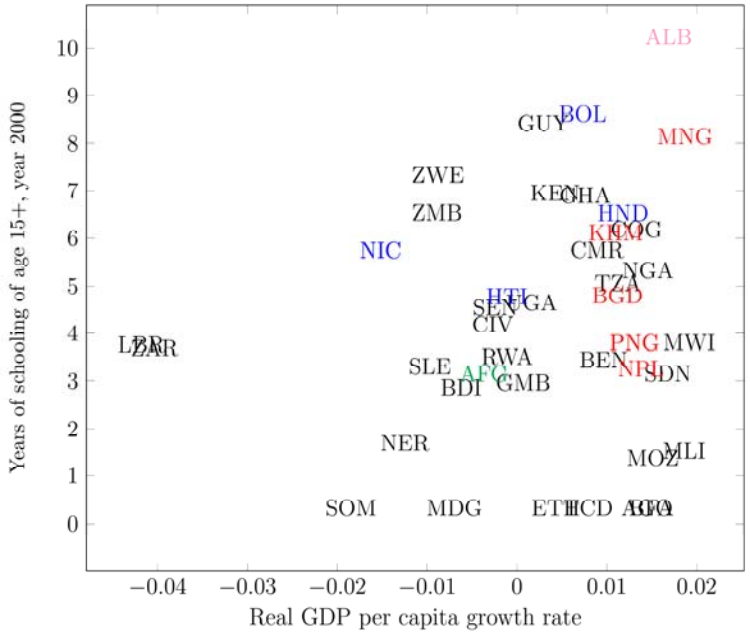


Figure 3. Educational attainment and economic performance of the trapped countries

(a) Years of schooling v.s. relative real GDP per capita



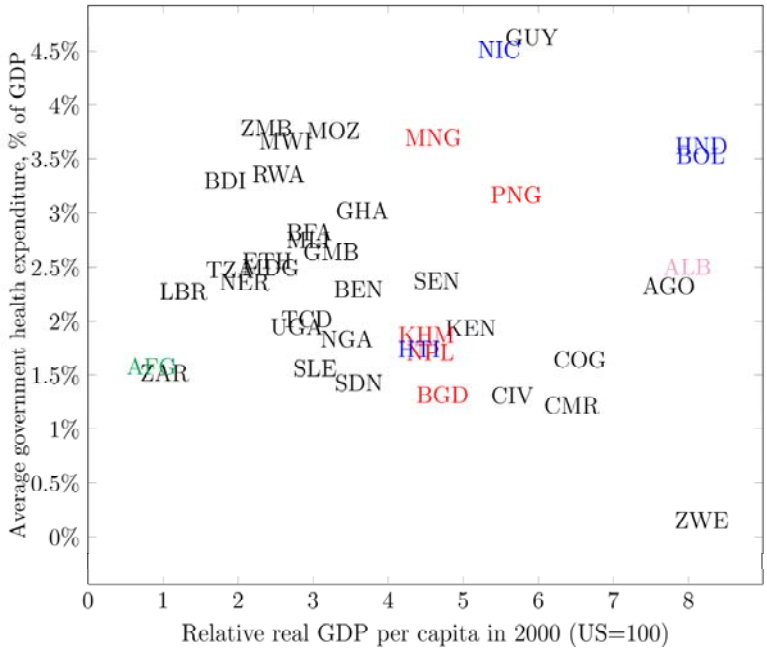
(b) Years of schooling v.s. growth of real GDP per capita, 1970-2007



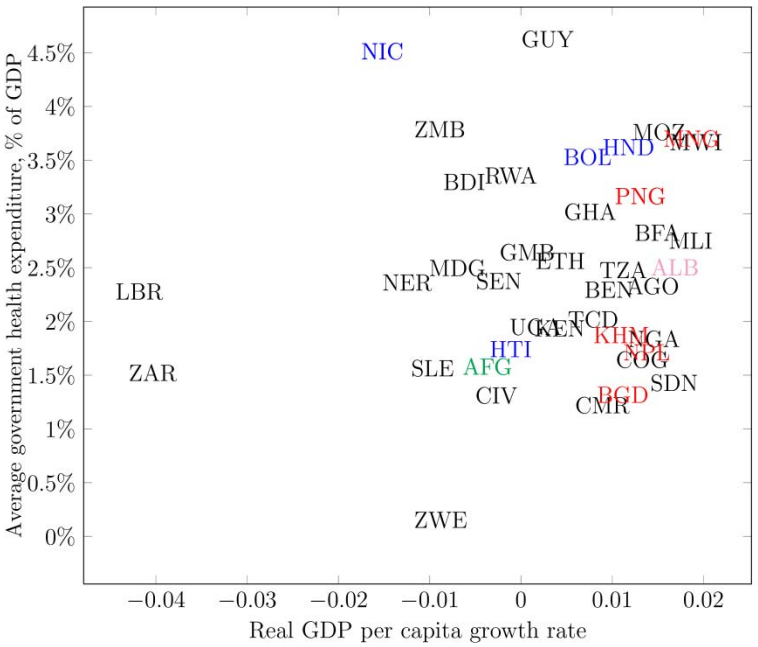
Source: Barro and Lee (2010) and the PWT 6.3. The real GDP per capita growth rate is the average growth rate during 1970 to 2007.

Figure 4. Public health expenditure share and economic performance of the 41 trapped countries

(a) Public health expenditure v.s. relative real GDP per capita in 2000



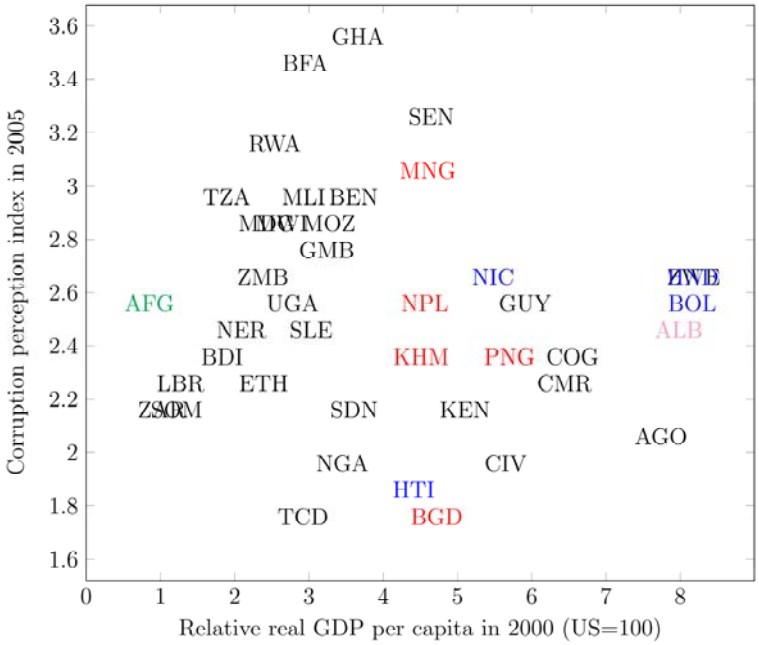
(b) Public health expenditure v.s. growth of real GDP per capita, 1970-2007



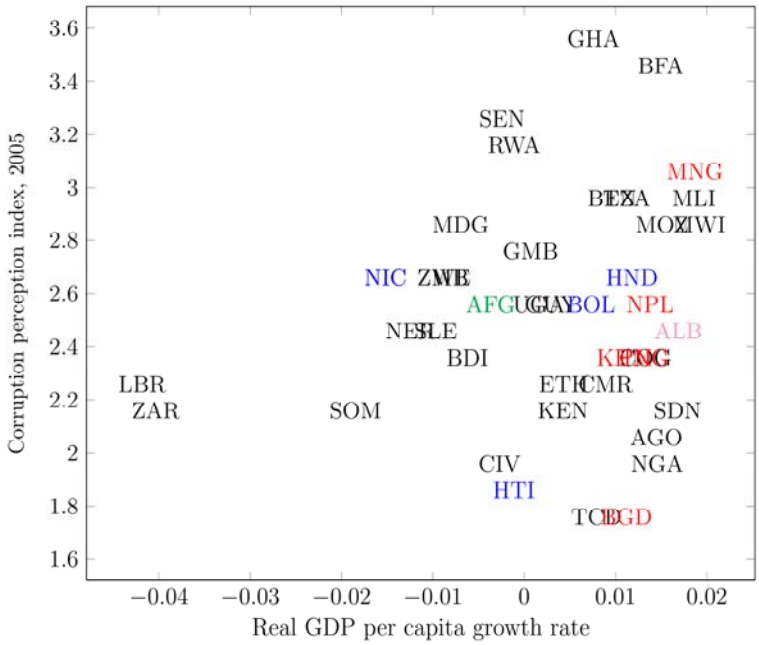
Source: The PWT 6.3 and the World Bank. The real GDP per capita growth rate is the average growth rate during 1970 to 2007; the average government health expenditure refers to the average of the available data during 1995-2010.

Figure 5. The Corruption Perception Index and economic performance

(a) The Corruption Perception Index v.s. relative real GDP per capita in 2000



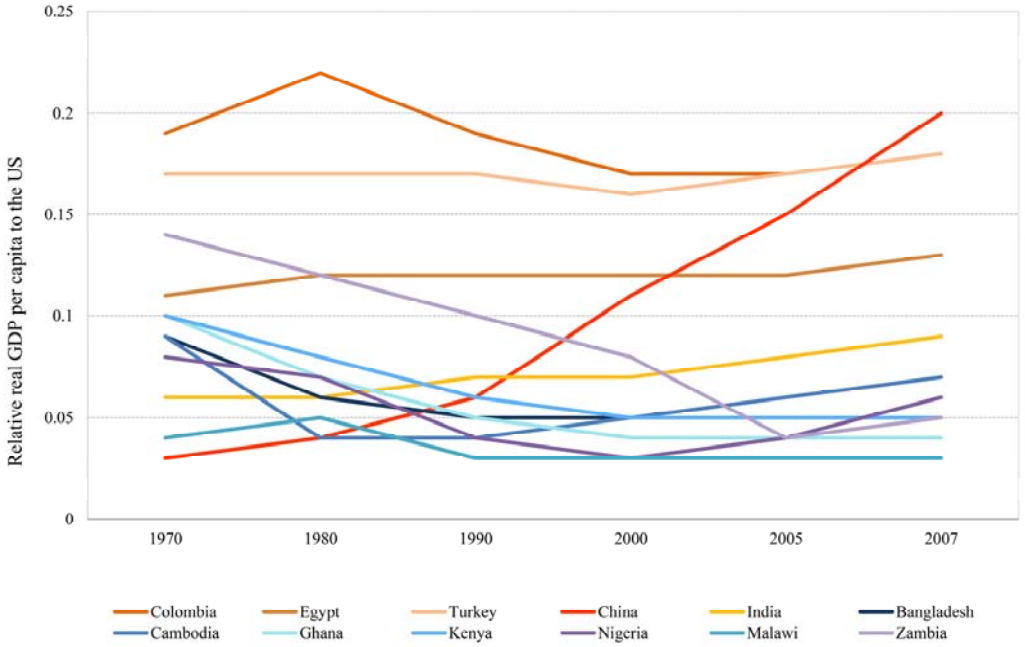
(b) The Corruption Perception Index v.s. growth of real GDP per capita, 1970-2007



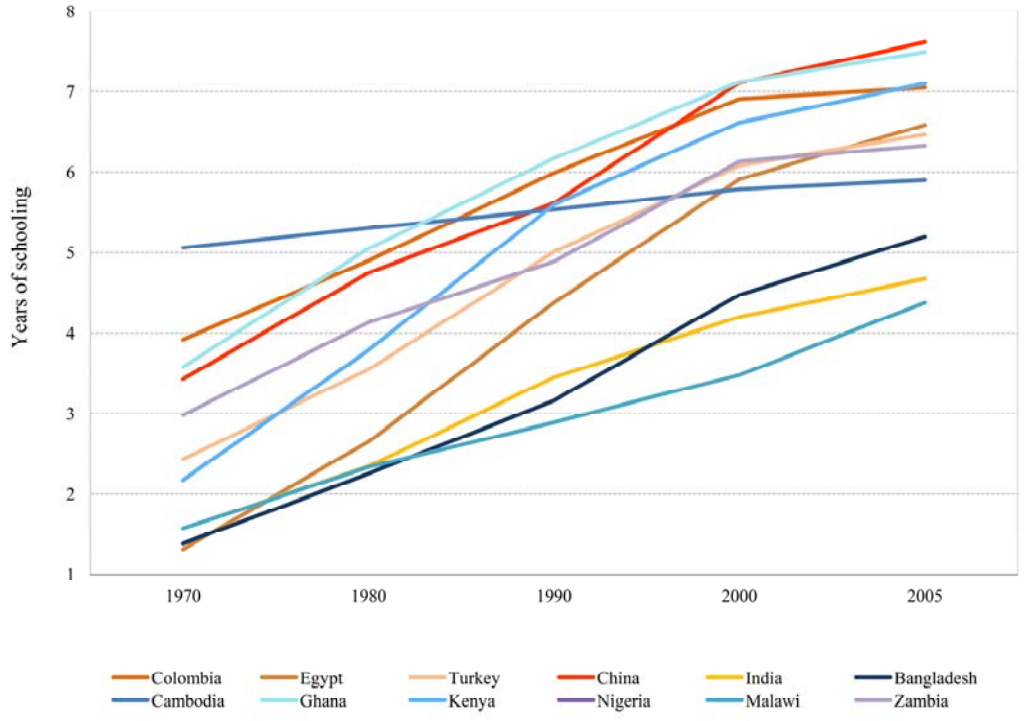
Source: Transparency International and the PWT 6.3. The real GDP per capita growth rate is the average growth rate during 1970 to 2007.

Figure 6. The economic performance, educational attainment and health performances for selected middle-income-low and trapped countries

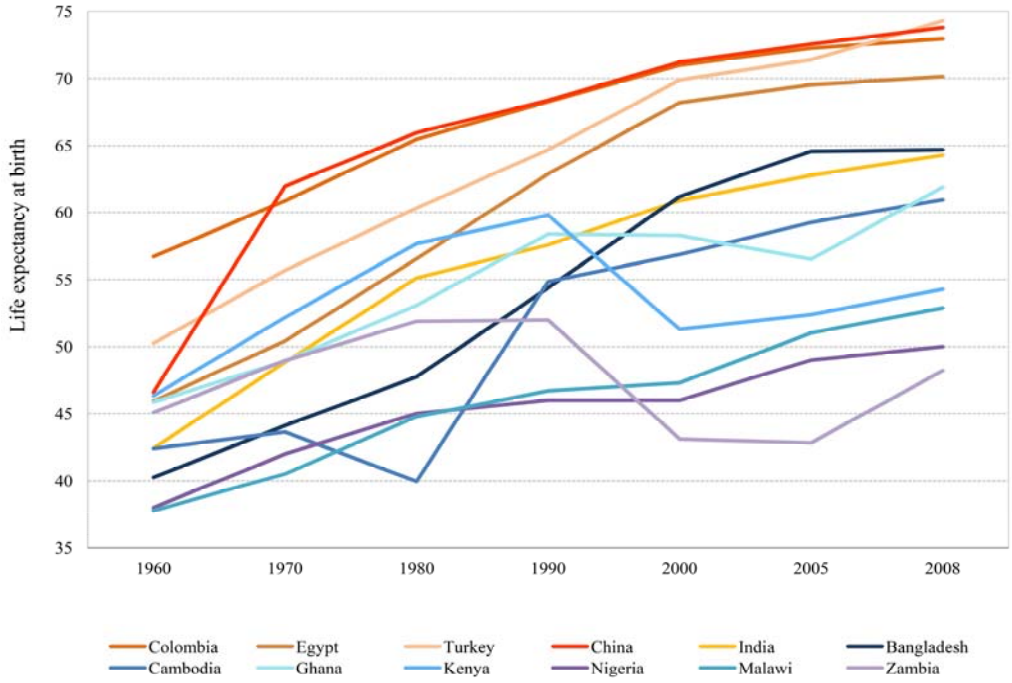
(a) Relative output per capita



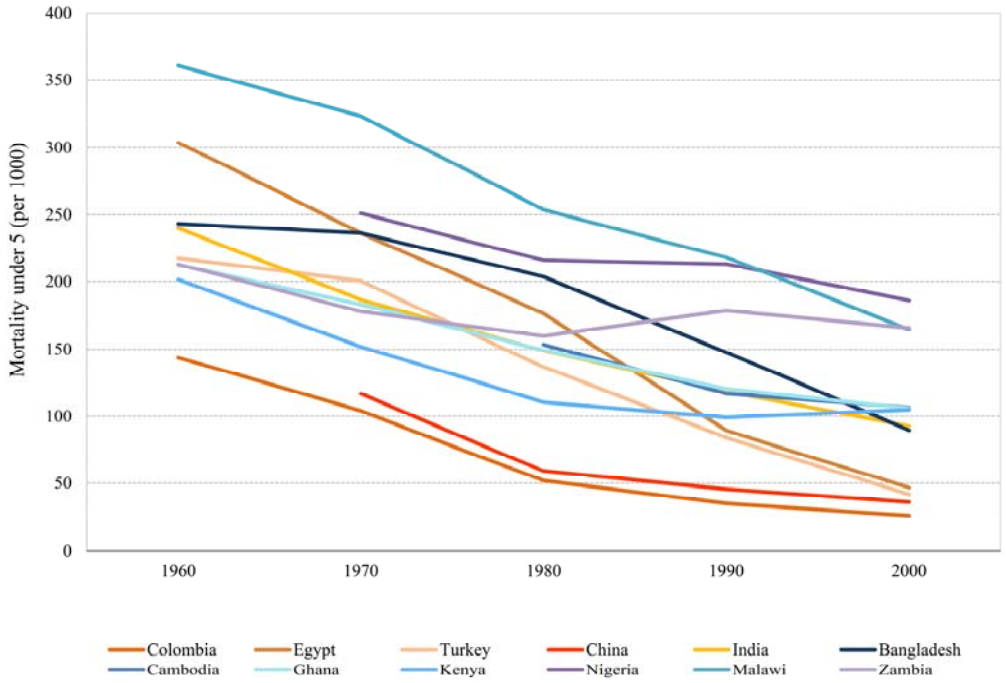
(b) Years of schooling



(c) Life expectancy at birth



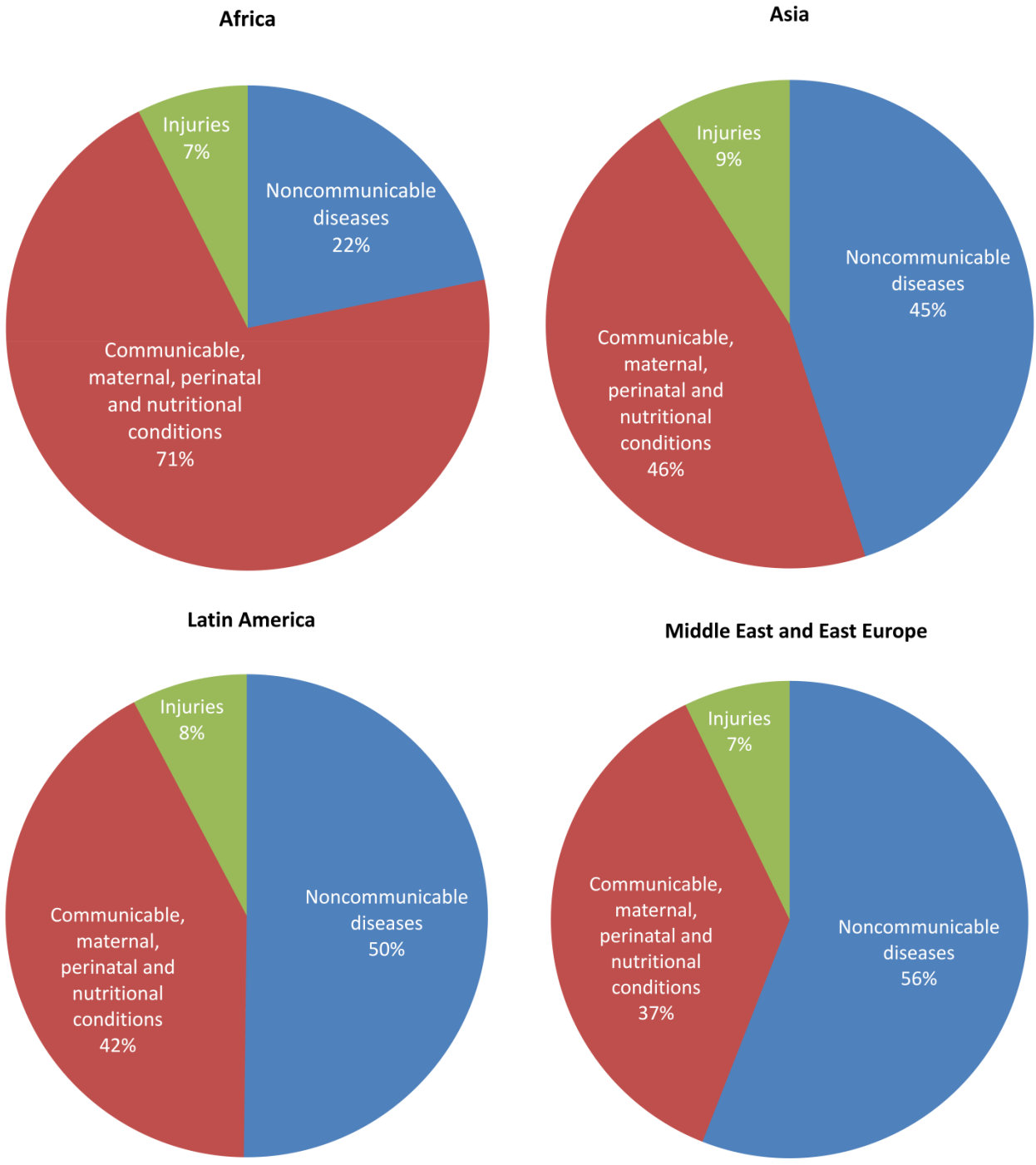
(d) Mortality rate under 5



Source: The PWT 6.3 and the World Bank/UN dataset.

Figure 7: Causes of death in the trapped countries by region

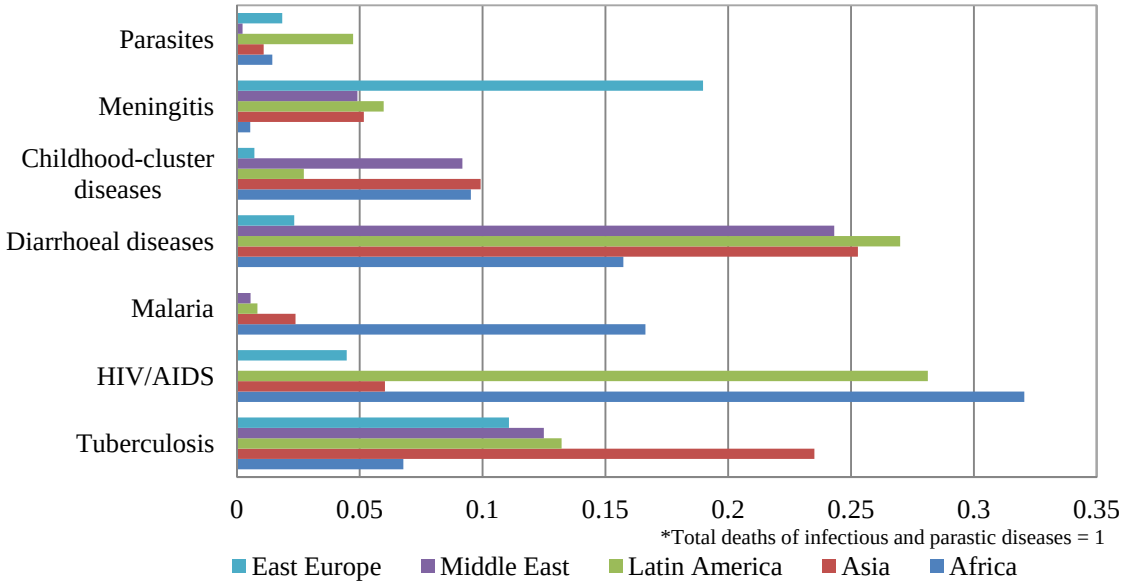
(a) Causes of death, by category



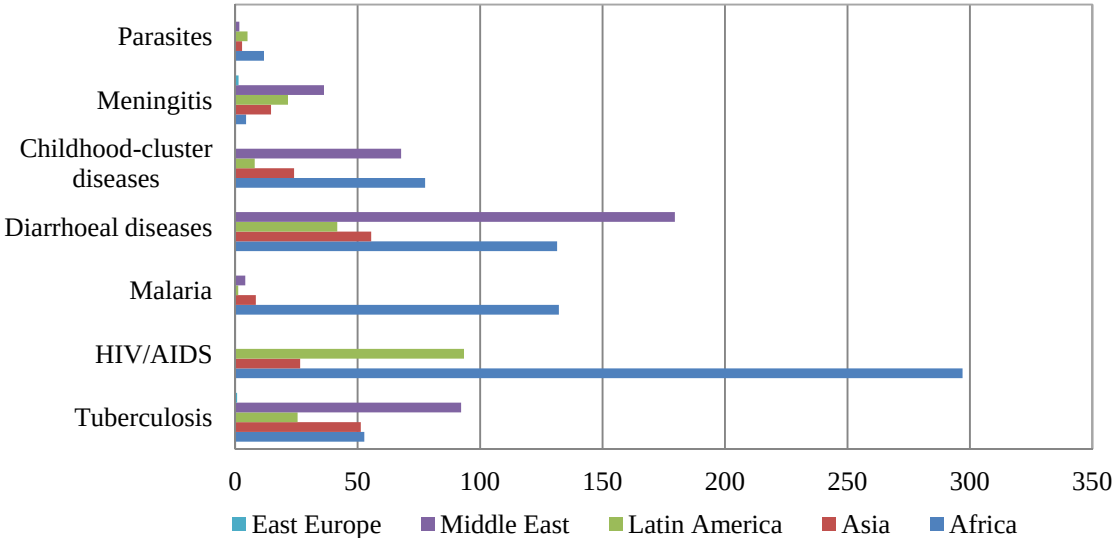
Source: Computed using table 1: Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), the World Health Organization.

(b) Infectious and parasitic diseases in trapped countries in 2002, by region.

(i) Infectious and parasitic diseases – by cause



(ii) Deaths per 100,000 population



Source: Upper panel: Table 1: Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), the World Health Organization. Lower panel: Table 3: Estimated deaths per 100,000 population by cause, and Member State, 2002 (a), the World Health Organization. Parasites include tropical-cluster diseases (Trypanosomiasis, Chagas disease, Schistosomiasis, Leishmaniasis, lymphatic filariasis, and Onchocerciasis) and intestinal nematode infections (Ascariasis, Trichuriasis, and Hookworm disease). Childhood-cluster diseases include Pertussis, Poliomyelitis, Diphtheria, Measles, and Tetanus.

Figure 8. Equilibrium determination of parental time devoted to educating child.

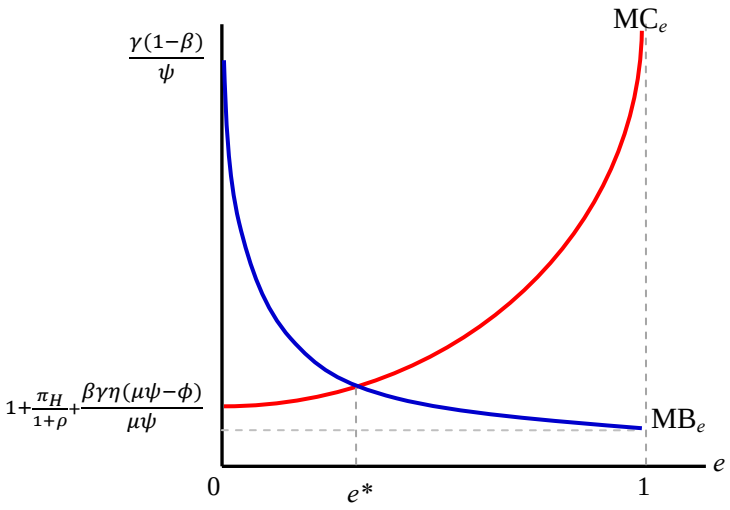


Figure 9. Equilibrium child health investment and capital accumulation, institutional changes, and traps.

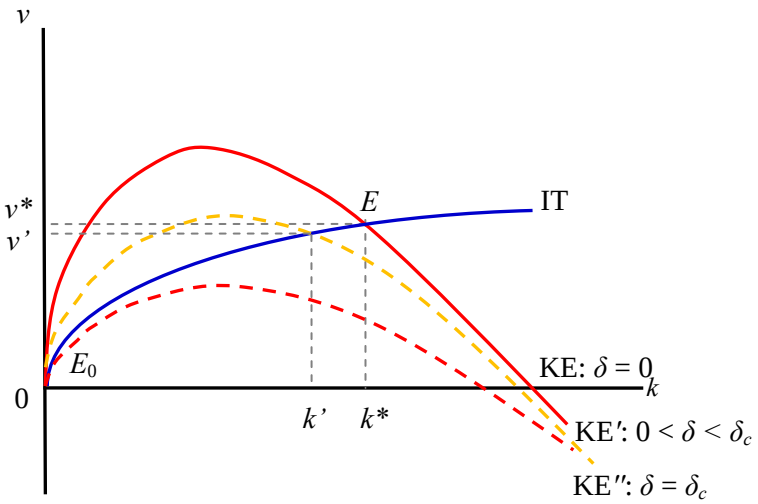
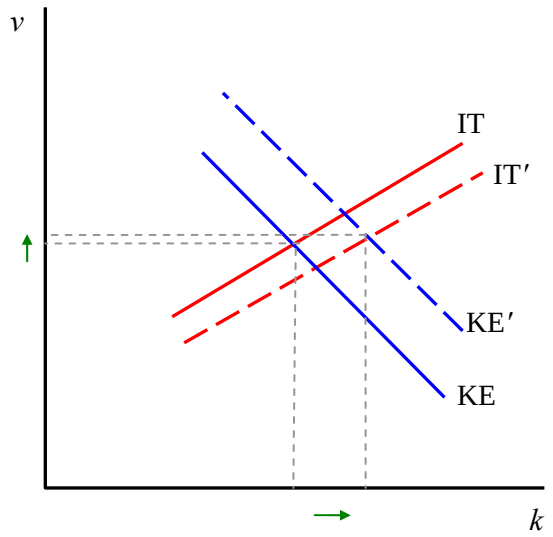
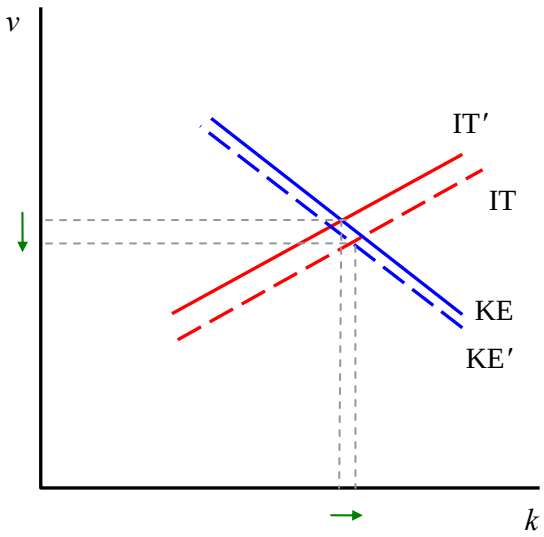


Figure 10. Comparative statics with respect to preferences and health technology changes

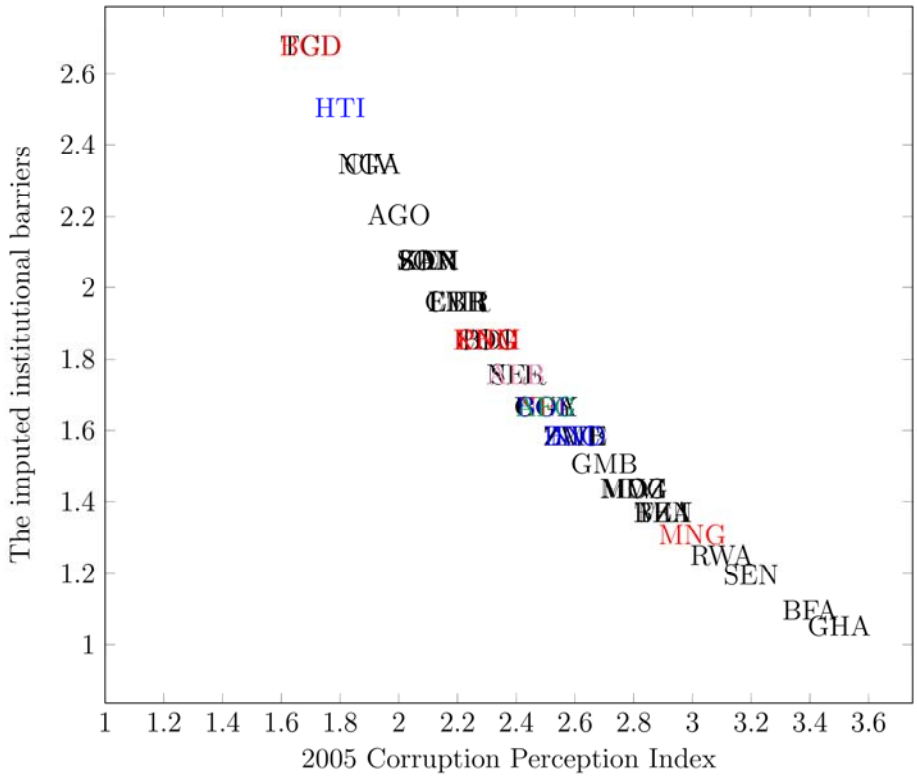


(a) π_H increases



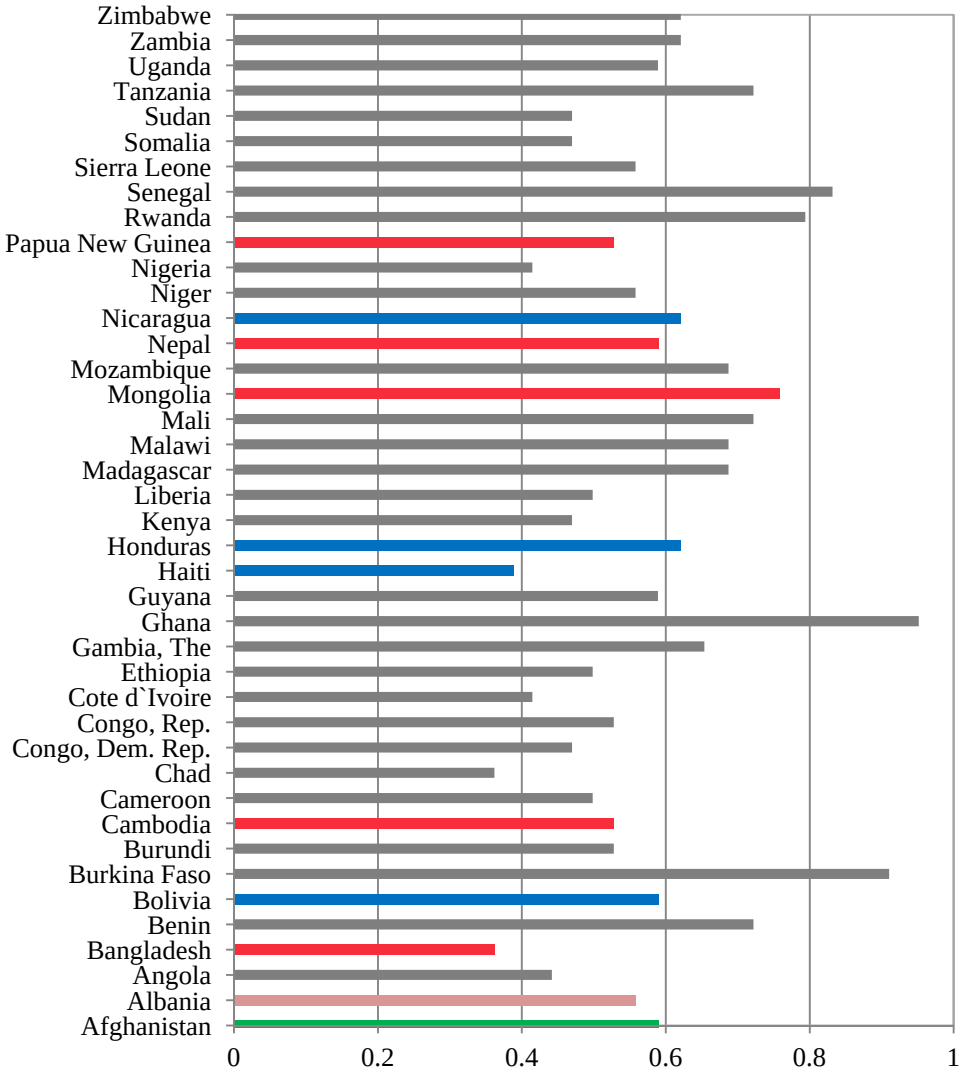
(b) ϕ increases

Figure 11. The Corruption Perception Index and the institutional barriers of the trapped economies



Source: 2005 Corruption Perception Index is obtained from Transparency International and the institutional barriers are computed by the authors. Note that the range of CPI is between 0 and 10.

Figure 12. Chance of pull-out



Note: Grey: African countries; red: Asian countries; blue: Latin American countries; pink: east European country; green: middle east country.