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ABSTRACT

Why have some poor countries been able to take off while others are still stuck in the poverty trap? To address this old question, we observe that (i) with similar or higher levels of educational attainment, trapped countries tend to have much poorer health conditions compared to the initially poor countries that later took 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 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 faced a health-related institutional barrier of 15%. The trapped economies all suffered much large barriers ranging from 50% to 73% under which the incentive to invest in health is severely hindered. For China and India, the magnitudes of such barriers were large (about twice as much as for the U.S. and half that for the trapped economies on average) but not enough to undermine the willingness to invest in health. This paper thereby advances our understanding of the role played by barriers to health in the 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 for the last half a century, education and health conditions are generally regarded as crucial for the process of economic development.[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 very differently. The chief purpose of the present paper is to rectify these problems by establishing an integrated model with endogenous investments in health and education so as to quantify how institutional barriers to health may interact with education decisions to serve to explain the drastically divergent paths of economic development. In his now-classic work, Rostow (1960) has emphasized: "*the creation of the preconditions for take-off required fundamental changes in a well-established traditional society: changes which touched and substantially altered the social structure and political system as well as techiques of production.*" Our study can thus be viewed as to echo Rostow, advocating the institutional barriers to health underlying each country's social structure and political system as keys to economic take-off.

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 the 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(a), we plot relative income (per capita GDP relative to the U.S.) in 1970 and 2000 for countries with less than 20% of U.S. income per capita in the respective years, to illustrate the immobility of poor

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

nations where those with less than 10% of U.S. income per capita in 1970 can hardly move out to the 10-20% group in 2000. We then plot against initial relative income in 1960 (i) the years of schooling (Panel (b)) and (ii) life expectancy at birth (Panel (c)) for the whole sample and for trapped economies with 10% or less relative income in 1970 or with 2% or less average per capita income growth over 1970-2007 (Panel (d)). While Panels (b) and (c) indicate that both cross-country relationships are positive as expected, simple eye-balling leads us to detect 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 their economic status. To facilitate a better understanding, we report in 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] and 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-

[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(d).

[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 less 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. India 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.

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 still-trapped economies: *with comparable years of schooling, the trapped economies tend to have significantly 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. Let us now compare China with the trapped countries. China has performed very well in terms of health since 1970. With only 3% of the real GDP per capita of the U.S., China 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 comparable 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 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 is designed to address. To attempt to answer such questions and to further generate practically useful policy implications, we force ourselves to apply the micro-founded model to a reality check: those "Voices of the Poor" quotes above that are the cries of respondents from various poor nations not only link poverty with poor health (the first quote) but also point to the poor's high level of discounting against the future due to poor health (the second quote) as well as their high valuation of health (the third quote) for which they are unable to pay (the 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 organizational 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 organizational 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 regional dummies and total fertility rates are included, neither years of schooling nor health spending measures are statistically significant at conventional levels. The same conclusion remains in the panel regression analyses, but the country fixed effects are mostly significant and sizable. This points to the possibility that *country-specific institutions* are crucial to the overall economic performance of these trapped countries.

To enable us to better understand about how various economic factors inclusive of institutional barriers may drive economic development outcomes, there is a need 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 are altruistic only in relation to their offspring'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 requires parental time and affects the level of knowledge capital. Health and knowledge capital together form the children's human capital, which subsequently 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 the corruption rooted in the political system. These 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 waste too many resources, individuals cease investing in the health of their descendents. The economy then ends up with poor health conditions and short life expectancies, which further reduce the incentives for knowledge and physical capital accumulation and hence destroy the engine of economic growth. The vicious cycle between poor health, low incentives to invest and bad institutions thus trap the country in poverty for a long period of time.

We provide conditions to guarantee a unique nondegenerate 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 an improvement in the span or quality of life when old encourages parents to shift their investment from the children's education to health, whereas an increase in the parents' genetic transmission to the children's health yields the opposite effect. While both changes lead to relatively higher health to knowledge capital, better genetic transmission is growth-enhancing but a longer life span can be growth-retarding. 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 greater than that of the U.S. (being twice as high), such barriers are low enough (half as much as those of trapped countries) 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) the 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, and that will play 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 (1993) argue that weak government induces more corruption and the secrecy needed 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 on 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, Parente and Prescott (1994) point out that barriers to technology adoption can harm long-run growth, whereas Buera and Shin (2013) argue that barriers to finance can lower and misallocate capital investment thus retarding economic development. In his celebrated book, Easterly (2001) presents many cases that show that bureaucracy and corruption have resulted in a big waste of foreign aid and investment in countries at an early stage of development (see also the discussion in Collier and Dollar 2001, 2002). We follow this strand of the literature, by measuring the social costs associated with bureaucracy and corruption and relating such barriers to observed development traps.

While the concept of the development trap goes all the way back to, the formal dynamic framework was not constructed until the pivotal work by Azariadis and Drazen (1990). More recently, Galor and Weil (2000) have developed a fertility-based Malthusian trap model. However, due to the complexity associated with self-fulfilling driven multiple equilibria, these two frameworks have not been incorporated in empirical tests. Our paper complements the earlier papers by proposing health barriers as a plausible mechanism for the development trap and by establishing a framework that is readily calibrated for matching empirical facts and drawing policy prescriptions.

2 On Health 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 organizational framework following the aggregate production function approach without a deep structure model. Using this framework, we can specify simple reduced form regressions. Although our focus is to understand why some poor countries could not take off, to promote better understanding, we apply regressions to all countries as well as a set of trapped economies whose 2000 real GDP per capita is less than 10% of that 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, respectively.

For obvious reasons, when selecting the sample of trapped economies to conduct regression analysis, 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) 29 sub-Saharan African countries, (ii) 3 East Asian and Pacific countries (Cambodia, Mongolia, and Papua New Guinea), (iii) 3 South Asian poor countries (Afghanistan, Bangladesh, Nepal), (iv) 5 Latin American (inclusive of the Caribbean) countries, and (v) 1 Southeastern European (Albania) country. From Table 2, we can see that the average growth rate of these trapped economies is only about 0.27% and that their average initial relative income in 1970 is only about 8.75% of that of the U.S. While the 3 South Asian economies were the poorest in 1970 (6.32% of the U.S.), Latin American economies were the richest (13.53%) at that time. Despite their relatively stronger initial performance, these Latin American trapped economies suffer the lowest growth (0.11%, compared to the related figures of 0.71% and 1.42% for the South Asian and East Asian and Pacific trapped economies).

We can further plot in Figure 2 the economic growth rate over the 1970-2007 period against initial relative income in 1970 for the 41 trapped economies. 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, then, 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 fewer barriers. However, 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, the share of government health spending in GDP, and an institutional barrier measure based on the Corruption Perceptions Index (CPI) compiled by Transparency International, against relative income in 2000 or the 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), although the years of schooling in 2000 are somehow positively correlated with the income levels in the year 2000, the qualitative contributions of years of schooling on the 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 for 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 are, it is alarming that public health spending could not alleviate such critical problems to induce better overall performance. In addition, 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) does not necessarily guarantee better aggregate economic outcomes.

2.1 An Organizational 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:

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

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 Cunha 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 per worker 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, when expressed in log form,

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

We first conduct a simple cross-country regression analysis of all economies i based on the following reduced form (4):

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

where all measures are country-i's figures in 2005 and X_i summarizes all other covariates, including the total fertility rate, an institutional barrier measure based on the Corruption Perceptions Index (CPI) compiled by Transparency International, and regional dummies (defined as Advanced Economies, Sub-Saharan Africa, East Asia and the Pacific, South Asia, Europe and Central Asia, the Middle East and North Africa, relative to the benchmark for Latin America and the Caribbean) according to the World Bank and the Barro and Lee 2010)[7]. 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 knowledge capital is computed using the years of schooling of total population aged 15 and up from Barro and Lee (2010) with the Mincerian coefficients from Psacharopoulos (1994). The above cross-country regression therefore becomes:

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

The results of the regressions on all countries are reported in Table 3(a). 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), the CPI is also included in addition to the specifications in 4(a) and 4(b). The results indicate that both the positive effect of knowledge capital and the negative effect of the total fertility rate on real GDP per capita are statistically significant. While the effect of public health expenditure is not significant, the effect of total health expenditure is significant but has the wrong sign. The CPI has the correct sign in that countries with better institutions perform better economically, and it is significant at the 0.1% level.

Similarly, we conduct a simple cross-country regression analysis of the 41 trapped economies (based on the same reduced form) and summarize the results in Table 3(b).[8] Interestingly, the results indicate that, with regional dummies, the total fertility rate is the only significant explanatory variable, with the expected sign. The public health expenditures now affect real GDP per capita positively but are not statistically significant, while the effects of total health expenditures are still negative but are not significant at conventional levels. The CPI has a mixed sign and is not significant.

To verify whether the empirical evidence is robust, we further perform panel regression analysis, using a complete panel of all countries with available data and the 41 trapped economies over the

[7] The World Bank classification of countries by geographic region is for developing countries only and the classification criteria are adjusted every year based on GNI per capita. For consistency, we thus adopt the country classfication used by Barro and Lee (2010).

[8] After dropping countries without complete data, only 34 countries are left.

period 1970-2007 with Guyana as the benchmark.[9,10] The regression is specified as:

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

where robust standard error clustering (of countries) is adopted in the estimation and the three key explanatory variables IR, ζE and HR, as well as the total fertility rate, are all lagged one period to mitigate the possible endogeneity problem.[11,12]

As shown in Table 4, the results for all countries are mixed. Before introducing the time fixed effects or time trend, the effects of the lagged investment rates and the lagged knowledge capital on the real GDP per capita are positively significant. Once time fixed effects or a time trend are introduced, the effect of the lagged investment rate is only marginally significant, and the effect of the lagged knowledge capital becomes insignificant. This is not surprising because both investment and educational attainment are secular growth variables, which are essentially captured by the time dummy and the time trend variables. The effects of the lagged fertility rate and the lagged public health expenditure are even less clear, with mixed signs and basically all insignificant.

We then turn to examine the results for the trapped economies. Since adding time dummy or time trend variables washes out the growth components in the secular growth variables, we hence perform regressions without time fixed effects or a time trend. As shown in Table 4, the effect of the lagged investment rate on the real GDP per capita has the expected signs, while the effect of the lagged knowledge capital is insignificant and has the wrong sign. The effect of the lagged total fertility rate has the expected negative sign but is generally insignificant. Similarly, the lagged public expenditure ratio has a positive effect on the real GDP per capita, as expected, but is also statistically insignificant.[13] To sum up, from the results of the panel regressions, we find that the

[9] From its economic performance, Guyana seems to be "representative" of the trapped economies. Thus, we pick Guyana as our benchmark country in the panel regression for trapped economies. For comparison purposes, we use Guyana as the benchmark country in the panel regression for all countries as well.

[10] 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, and not by Barro and Lee (2010).

[11] The public health expenditures and total health expenditures data are available only after 1995. Hence, we extrapolate the available data based on the HP trend, then multiply the figures by the government expenditure shares as a percentage of GDP to obtain the figures for public health expenditure as a percentage of GDP. For years of schooling, since Barro-Lee (2010) provides estimated average years of schooling at 5-year intervals, we thus intrapolate the available data to obtain annual data.

[12] Since we do not have long time-series of the CPI data over the sample period, we drop it in the panel regression analysis.

[13] For trapped economies, when conducting panel regression analysis, we also consider 5-year intervals with the average of 1970-72 as the initial period. The results are very similar to those of the panel regressions using annual data. The only exception is that the effect of the lagged public health expenditure as a percentage of GDP is negative but not significant at conventional levels.

knowledge capital may affect the real GDP per capita quite differently for countries with different levels of income. However, the results of the cross-country regression and the panel regression are not clear cut, and sometimes even contradictory to the theoretical predictions, and one can not easily draw any conclusive inferences based on these regressions.

While the results based on the above-mentioned explanatory variables are not clear cut, an interesting finding can be obtained from the panel regressions by examining the country fixed effects of the trapped economies. More specifically, using the average performer, Guyana, as the benchmark country (whose average growth rate is 0.29%), from Table 4, the country fixed effects of almost all the trapped countries are significant under conventional levels. One may think that these significant country fixed effects may reflect country-specific institutions inclusive of the institutional barriers emphasized in this paper. Based on these country fixed effect estimates, Bolivia and the Republic of Congo, among these 41 poor countries, have the best institutions for economic development, whereas Afghanistan, Burundi, the Democratic Republic of Congo, Liberia, Malawi and Mali suffer from the worst. We further plot these country fixed effect estimates against the initial performance of these trapped economies in 1970 as well as their performance in 2000. It is evident from Figures 6(a) and 6(b) that the overall performances of these trapped economies are positively related to the betterment of their development institutions measured by the country fixed effects. Such positive correlation is tighter in 2000 than in 1970, indicating a possible causation from development institutions to economic performance. This latter finding thereby motivates our study and serves as a key channel to explain why poor countries with bad institutions remain in poverty over a long duration.

So what is the main message learned from the above simple regression exercises? Overall, *within* the 41 trapped economies over the period 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 7 (a-d). It is evident that the major difference between the two groups is either that the middle-income-low countries were initially more developed (such as Turkey and Egypt) or experienced much faster growth (such as China starting in 1980 and speeding up after 1992 and India over the last decade). Over the sample period, it is noted from Figure 7(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 groups: *trapped economies tend to perform much worse in health*, as shown in Figures 7(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 trapped country group, 29 are sub-Saharan African countries, and 6 are Asian countries (including East Asian and Pacific and South Asian countries). From Figure 8(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.[14] In particular, sub-Saharan African countries have suffered more deaths from communicable diseases and maternal, perinatal and nutritional conditions (73%) compared to Asia and Latin America and the Caribbean ($49 - 52\%$). Figure 8(b)(i) shows that most of the "important" selected communicable diseases, such as parasites, Malaria, HIV/AIDS and childhood-clustered diseases, still occurred mainly in sub-Saharan Africa. South Asia also experienced more deaths due to meningitis, childhood-cluster diseases, diarrhoea and tuberculosis than other regions. Figure 8(b)(ii) further plots the estimated death rates due to the selected communicable diseases by region. It is stunning to find that the deaths due to HIV/AIDS amounted to 17% of total deaths in sub-Saharan Africa! Deaths due to childhood-cluster diseases, diarrhoeal diseases and malaria also accounted for 5% or more of total deaths. In trapped economies in East Asia and the Pacific, tuberculosis, HIV/AIDS and diarrhoeal diseases are the major killing communicable diseases. In Latin America and the Caribbean trapped countries, HIV/AIDS is the main killer and accounted for more than 10% of the total deaths.

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 childhood, we study both young adulthood and 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.

[14] There is only one country, Albania, in the Europe and Central Asia group. Albania experienced more deaths from noncommunicable diseases. It is thus safe to say that most of the trapped countries (40 out of 41) suffered more from communicable diseases than noncommunicable diseases.

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 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:

$$m_{t+1} = \mu e_t m_t + \tilde{\psi} m_t, \tag{8}$$

where $\mu > 0$ is a knowledge scaling factor and $\psi > 0$ measures the strength of intergenerational transmission of the innate ability. For convenience, define $\tilde{\psi} \equiv \mu\psi$. Equation (8) can be rewritten as $m_{t+1} = \mu\left(e_t + \psi\right) m_t$. In the following, we will look at this expression instead of (8).

3.2 Households

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 in 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 yielded 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):

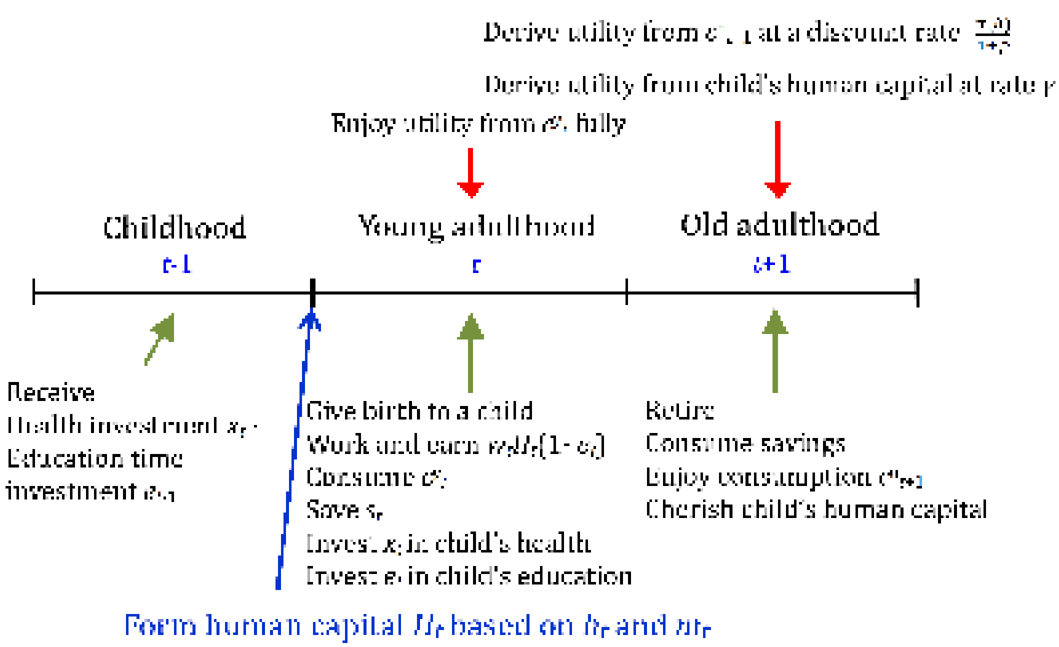
$$\pi(h) = \begin{cases} \pi_H & if \quad h \geq h_c \\ \pi_L & if \quad h < h_c \end{cases}, \ \pi_H > \pi_L.$$

Thus, $\pi(\cdot)$ captures the span/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 diarrhoea (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 systems 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 span or quality of life when old improves (a 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 (MB_x) and marginal cost (MC_x) 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) derived from the children's human capital. This relationship is delineated in Figure 9(a). It is noted that, an increase in the parents' genetic transmission to the children's health (a higher ϕ) raises the children's health capital (h_{t+1}), which, under diminishing returns, lowers the marginal product of health capital and hence the marginal benefit of health (the LHS of the expression). Since the marginal cost of health investment in children (the RHS of the expression) is independent of ϕ, it is expected that in response the optimizing level of health investment in children is lower, other things being equal.

Similarly, to optimize parental time devoted to educating children, its marginal benefits (MB_e) must equal its marginal cost (MC_e),

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

where the marginal cost of devoting time to educating children is measured by the consumption value of foregone earnings (see Figure 9(b)). Consider again an increase in the parents' genetic transmission to the children's health: as it raises the children's health capital, it, by complementarity, also enhances the children's marginal product of knowledge capital, thus leading to a higher marginal benefit of education and more educational investment in children.

The two optimizing conditions discussed above can be further simplified to derive the two atemporal trade-offs that guide parents' decisions on self-consuming versus investment in their children, by means of improved health or education:

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

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

Agents leave no bequest, and hence old agents own the current capital stocks and will consume what they hold 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,

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

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, a portion of her saving is depleted because of the institutional sunk cost while she still believes that she gets full 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:

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

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

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 $\pi(h_t) = \pi_H$. 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), $1 + g = \mu(e + \psi)$, 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:

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

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:

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

The LHS of the above equation gives the "net" marginal benefits of spending time on the children's education (NMB_e) on the BGP, and the RHS stands for the net marginal costs of parental education investment (NMC_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 NMB_e locus is downward sloping, starting from $\frac{\gamma(1-\beta)}{\psi}$ and the NMC_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 $\frac{\gamma(1-\beta)}{\psi} > D_H + \frac{\beta\gamma\eta(\mu\psi-\phi)}{\mu\psi}$. Figure 10 provides a graphical illustration of the determination of e.

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

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

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. Figure 11 depicts the IT and KE loci.

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. In response to a higher physical capital (and hence higher k), saving rises and hence the marginal utility of consumption when old decreases. This in turn reduces the marginal cost of health investment in children. To restore equilibrium, it is thus required that the marginal benefit of health investment be lower and the equilibrium level of health investment be higher. That is, the IT locus is upward sloping.[15] The KE locus, on the other hand, is derived from the capital evolution equation, or the loanable funds market clearing condition. This relationship resembles the sustainable consumption locus in any optimal growth models. It illustrates that, as physical capital grows larger, its user cost eventually outweighs its marginal product as a result of diminishing returns. Thus, the KE locus is hump-shaped where the peak indicates the golden rule level of physical capital accumulation. 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 the poverty trap to arise. Specifically, let us define:

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

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.*

[15] Given that e is determined by (23), the IT locus can be shown to be strictly concave in k.

Proposition 1 provides a sufficient condition for the poverty trap. Of particular note, 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 investment in education (a high Φ) could do more harm than good for an economy, since the time (the valuable resource) directed to educational investment crowds out production and leads to an inability to engage in 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 span or the quality of life when old (π_H) is worse, or the parental transmission of good health (ϕ) becomes more important.

Figure 11 plots the IT and the KE loci when the BGP equilibrium is nondegenerate; it also illustrates the case of the poverty trap when the condition in Proposition 1 is met. 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 barriers (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.

Before examining the comparative-static properties of changes in δ, π_H, ϕ and ξ, let us begin by characterizing the BGP value of parental time devoted to educating a child (e) using Figure 10. Consider the case when the parent becomes more altruistic (a higher γ). In response, both the marginal benefits and marginal costs of investing in the child's education (NMB_e and NMC_e, respectively) must go up, implying upward shifts in both the NMB_e and NMC_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 a more altruistic mother will devote more parental time to educating a child, 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' span or quality of life when old (a higher π_H). An increase in π_H 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 NMC_e locus shifts upward while the NMB_e locus remains unchanged, leading to a lower BGP value of e. We now turn to a strengthened intergenerational transmission of health (a higher ϕ), which lowers the marginal cost of investing in the child's education and hence shifts the NMC_e locus downward, without changing the NMB_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 NMC_e or the NMB_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 12. 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 *health-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 terms 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 12 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 span or 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 the 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 influences 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 barrier to health (a higher δ) does not affect the 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' span or quality of life when old (a higher π_H) reduces the 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 (a higher ϕ) increases the 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 (a higher ξ) does not affect the 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 with 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 U.S. economy. The model has 12 parameters: (i) preference parameters – the time preference rate (ρ), the span or 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 or 75 years in total.[16] 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

[16] The life expectancy at birth in the US 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.

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 of 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 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 obtain $\mu = \frac{1+g}{e+\psi} = 9.6782$. 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 the 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

In Section 4.3, we have examined analytically the responses of the endogenous variables, (e, v, k), to changes in the three parameters of particular interest: the parents' span or quality of life when old (π_H), the intergenerational transmission of basic health (ϕ), and institutional barriers to health (δ). In this section, we now evaluate numerically the magnitudes of these reponses. For completeness, we also report the responses of other endogeous variables, including the economic growth rate (g), the consumption-human capital ratio (z), 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 $(\frac{m}{H})$. Moreover, we compute the responses to other exogneous shifts, such as the altruistic factor (γ), 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). The results are summarized in Table 7, 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.

With the above qualification, we proceed to examine the effects of changes in the three key parameters. First, a longer lifespan 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 in their children's education by 0.28%, leading to a relaxation of their budget constraint and enabling v and k to rise by 0.18% and 1.49%, respectively. Since the parents' negative response in education investment is greater than that in their health investment in children, the BGP value of the health-knowledge capital ratio turns out to rise by 1.70% and the health-human capital ratio to increase by 0.83%.

Next, an increase in ϕ cuts down the marginal cost of investing in the child's education, so a 1% increase in ϕ boosts e and g 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, better transmission of the parents' health capital causes 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%.

We then examine the effects of a 1% increase in δ that results in more resources wasted. This brings health investment and savings down, leading to a 0.02% and a 0.07% decrease in v and k, respectively. With the parental time devoted to educating child remaining constant, the increase in δ surpresses the health-knowledge capital ratio by 0.04% and health-human capital ratio by 0.02%.

While for the sake of brevity, we shall not discuss the elasticities of other endogenous variables in response to other parameter shifts reported in Table 7. Nonetheless, it is important to check the validity of the key assumption imposed by our theory. We find that the parameterization of the U.S. economy satisfies the altruism normality (Condition N), and hence parents always invest more time in their children as they become more altruistic.

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.

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 the Poverty Trap

In Proposition 1, we show that an economy will be trapped in poverty if the condition specified is satisfied. 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 for 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 the poverty trap; and (ii) middle-income-low countries: China and India. We then compare the results with the results for 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.[17]

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 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 the 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.

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

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" poorly in both health and education, we set the inborn health share at 0.5 and the innate knowledge share at 0.6.[18] 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 forming 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. In a similar manner, when calibrating the selected trapped economies, we adjust β up to reflect the significant role played by health in human capital if the country has relatively poor health but high educational attainment, and vice versa.

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

[18] 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.

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.

There is no time use survey for the trapped countries, and hence 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 U.S. have been very stable and have remained close to 2 since 1970. Unlike the U.S. where demographic transition had been completed a century ago, most of the trapped countries have experienced a rapid decrease in fertility over the past several decades, although some trapped countries still have a total fertility rate of 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.[19] 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 the 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 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.[20] 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. Having all the data on hand, we first calculate total output in the model by deducting private health expenditure, net exports, and government expenditures other than health from total GDP.[21] Private health

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

[20] 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 return 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 unavoidable. 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 down by roughly 20 percent so that the "true" annual real interest rate measures are roughly 5-6 percent.

[21] The model features a closed economy, and in the model there is no government expenditure other than 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 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 $Y = Ak^\alpha B\left(\frac{h}{m}\right)^\beta m(1-e)$ using (1) and (2), and derive A as $A = k^\alpha B\left(\frac{h}{m}\right)^\beta\left(\frac{m}{Y}\right)(1-e)$. 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 $\left(\frac{h}{m}\right)$ 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

Hence, net exports and government expenditure other than health have to be deducted from total GDP to match the notion of total output in the model.

schooling in 2000 are obtained from the Barro-Lee (2010) dataset.[22] 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 $\frac{h_i}{m_i} = \frac{q_{US}E_{US}}{q_i E_i}$ and B_i can be readily computed from (32). Finally, by using government health expenditure as an input in (7), together with the BGP condition that health and knowledge capital grow at the same rate, ξ_i is computed.[23] Table 8 and Table 9 summarize the calibration results for the representative trapped economy as well as the calibration results for the selected three trapped countries of interest, namely, Bangladesh, Kenya and Nigeria.

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 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,

[22] The data of average years of schooling are not available for Angola, Burkina Faso, Chad, Ethiopia, Madagascar, Nigeria and Somalia in Barro-Lee (2010). For Nigeria, the estimates of average years of schooling in 2005 and 2010 are available from Human Development Indicators (HDI) compiled by the United Nations Development Programme (UNDP) and are equal to 5. Since estimates of years of schooling usually do not change much within 5 years, 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.

[23] 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, the government health expenditure is plugged into (7) when calibrating ξ_i.

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 a public expenditure tracking system, or some estimates and reports on efficiencies of public investment schemes. Such information can serve as a proxy for the institutional barriers. However, most of the trapped economies 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 by 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 insight on how severe such barriers are relative to the benchmark U.S. economy. As 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 the poverty trap. Of particular note, it is said that *an economy is trapped if* $\delta > \delta_c$.

We now turn to elaborate on 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 most 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.[24] 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).[25]

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. Thus, 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:

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

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 13 and is reported in 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 of Table 8, while the

[24] 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.

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

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 is not much regional variation in social waste (ranging from 61.8 to 66.1%). For individual countries, social waste ranges from as low as 50% (Ghana) to over 70% (Bangladesh, Chad and Haiti). In Figure 14, we illustrate, based on the relative scales of δ and δ_c, the likelihood for each of the sample countries to pull out. Interestingly, while Ghana and Burkina Faso are most likely (with more than a 90% chance) to escape 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 in greater depth such institutional barriers using the three selected trapped economies 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.[26]

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 sectors. 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

[26] 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-to-commitment ratios still serves as a good way of gauging the extent of institutional barriers rooted in the countries. The 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).

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 period 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 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 services 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 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 states 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, as 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). The severity of these barrier measures can then be compared with the country-specific δ_c obtained for the three countries in Section 6.1.1, 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 for the U.S. in comparison. These latter figures are also striking: *about two thirds of the health investment in these countries has been wasted.*

In conclusion, "how to rectify the institution" must be regarded as a priority for the countries that lag behind 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-income-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%.[27] 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 wastage 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 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.*

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 the health-related institutional barriers in trapped economies are too large that individuals have fewer opportunities to invest in their offspring and this results in a vicious cycle of poor health, low investments and bad institutions. How, then, can these countries be rescued from the poverty trap? Straightening the institutions to ensure correct incentives is therefore the first priority. Pulling a country out of poverty does not call for an eradication of the institutional barriers either completely or substantially: as 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 channels be built in, one may then perform counterfactual analysis to evaluate various

[27] 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 (2006), 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.

policy tools in the interest of pulling an economy out of the poverty trap in the shortest possible time span under a given level of resources. Another important issue is: while health institutions are crucial for the pulling out of trapped economies at their current development stage, are educational factors going to step in to play a more significant role at a later stage to speed up the process of the pulling 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. These avenues of studies, while beyond the scope of the present paper, 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, and data details are provided.

A 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 NMC_e with respect to e as follows:

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

That is, $NMC_e(e)$ is monotonically increasing in e. Since $NMB_e(e)$ is monotonically decreasing in e, when $NMB_e(0) = \frac{\gamma(1-\beta)}{\psi} > NMC_e(0) = D_H + \frac{\beta\gamma\eta(\mu\psi-\phi)}{\mu\psi}$, $NMB_e(e)$ and $NMC_e(e)$ 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, $\frac{\partial KE}{\partial k}|_{k=0} > \frac{\partial IT}{\partial k}|_{k=0}$ guarantees that the IT and the KE loci only intersect once. Differentiating the KE and the IT loci with respect to k yields:

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

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 for the corner solution are:

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

That is, the sufficient conditions are that (i) the slope of the KE locus is smaller than the IT locus as k approaches zero, and (ii) the slope of the KE locus is always smaller than the slope of the IT locus. If (b) is violated, the KE locus may intercept the IT locus twice. From the proof of Theorem A:

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

That is,

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

Hence, (b) is satisfied if

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

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

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

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,

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

which yields the condition in the proposition.

Proof of Proposition 2

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

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

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

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

This term > 0 iff

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

By 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 this condition is imposed, all the comparative statics follow in a straightforward manner.

B Data

B.1 Data

All data series were retrieved from the Penn World Table (PWT) 6.3, the United Nations Data Retrieval System (UNdata, data.un.org/Default.aspx), the World Bank, the Barro-Lee educational attainment dataset (2010), and the OECD online database.

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), year 2005

OECD

International Development Statistics (IDS) online databases, http://www.oecd.org/dac/stats/idsonline.htm

B.2 List of countries and details of panel regression analysis

Below we list the countries with complete data and hence being examined under the regression analysis in Section 2. The results of the country fixed effects in the panel regression analysis are provided as well.

All countries (134 countries)

Afghanistan, Albania, Algeria, Argentina, Armenia, Australia, Austria, Bahrain, Bangladesh, Barbados, Belgium, Belize, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burundi, Cambodia, Cameroon, Canada, Chile, China, Colombia, Democratic Republic of Congo, Republic of Congo, Costa Rica, Cote d'Ivoire, Croatia, Cuba, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Fiji, Finland, France, Gabon, Gambia, Germany, Ghana, Greece, Guatemala, Guyana, Haiti, Honduras, Hungary, Iceland, India, Indonesia, Iran, Iraq, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Korea, Kuwait, Kyrgyzstan, Laos, Latvia, Lesotho, Liberia, Libya, Lithuania, Luxembourg, Malawi, Malaysia, Mali, Malta, Mauritius, Mexico, Moldova, Mongolia, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Nicaragua, Niger, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, Slovak Republic, Slovenia, South Africa, Spain, Sri Lanka, Sudan, Swaziland, Sweden, Switzerland, Syria, Tajikistan, Tanzania, Thailand, Trinidad & Tobago, Tunisia, Turkey, Uganda, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Yemen, Zambia, Zimbabwe.

Trapped economies (34 countries)

Afghanistan, Albania, Bangladesh, Benin, Bolivia, Burundi, Cambodia, Cameroon, Democratic Republic of Congo, Republic of Congo, Cote d'Ivoire, Gambia, Ghana, Guyana, Haiti, Honduras, Kenya, Liberia, Malawi, Mali, Mongolia, Mozambique, Nepal, Nicaragua, Niger, Papua New Guinea, Rwanda, Senegal, Sierra Leone, Sudan, Tanzania, Uganda, Zambia, Zimbabwe.

Panel regression analysis

Most countries have country fixed effects statistically significant at 5% or below. For brevity, we only list countries with country fixed effects that are NOT statistically significant at the 5% level.

Panel regression - all countries

- Regression (1): Benin, Burundi, Cambodia, China, Democratic Republic of Congo, Gambia, Ghana, Laos, Malawi, Mali, Mongolia, Nepal, Niger, Rwanda, Sudan, Tajikistan, Uganda, Vietnam, Yemen, Zambia.
- Regression (2): Benin, Burundi, Cambodia, China, Ghana, Kenya, Laos, Lesotho, Malawi, Mali, Mongolia, Niger, Rwanda, Sudan, Tajikistan, Uganda, Vietnam, Yemen, Zambia.
- Regression (3): Cameroon, Cote d'Ivoire, Haiti, India, Kenya, Nicaragua, Pakistan, Papua New Guinea, Senegal, Sierra Leone, Syria, Tajikistan, Zimbabwe.
- Regression (4): Cameroon, China, Cote d'Ivoire, Haiti, India, Iraq, Nicaragua, Pakistan, Papua New Guinea, Sierra Leone, Syria, Tajikistan, Zimbabwe.
- Regression (5): Cameroon, Cote d'Ivoire, India, Kenya, Nicaragua, Pakistan, Papua New Guinea, Senegal, Sierra Leone, Syria, Tajikistan, Zimbabwe.
- Regression (6): Cameroon, China, Cote d'Ivoire, Haiti, India, Iraq, Kenya, Nicaragua, Pakistan, Papua New Guinea, Senegal, Sierra Leone, Syria, Tajikistan, Zimbabwe.

Panel regression - trapped economies

- The information for the country fixed effects of trapped economies is provided in Note 2 in Table 4.

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	0.07	0.04	0.19
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	0.08
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	0.05
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	0.02
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

Notes: 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, the 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**
Sub-Saharan Africa	*0.08*	*8.20*	*3.50*	*9.49*	*2.09*	*5.24*	*47.3*	*38.5*	*191.2*	*6.40*	*4.09*	*2.5*	*1.6820*	*62.7*
East Asia and the Pacific	*1.42*	*7.36*	*4.94*	*20.39*	*2.76*	*4.96*	*54.0*	*42.4*	*101.5*	*5.10*	*5.69*	*2.5*	*1.6181*	*61.8*
South Asia	*0.71*	*6.32*	*3.38*	*13.17*	*1.39*	*4.96*	*49.6*	*42.31*	*182.36*	*5.91*	*3.41*	*2.23*	*1.9503*	*66.1*
Latin America & the Caribbean	*0.11*	*13.53*	*6.43*	*25.51*	*3.46*	*6.09*	*58.4*	*46.9*	*112.99*	*4.96*	*6.49*	*2.4*	*1.75*	*63.6*
Europe & Central Asia	*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*

Notes: 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 for the period 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(a). Cross-country regressions: All countries.

	(1)	(2)	(3)	(4)		(5)	
				(a)	(b)	(a)	(b)
Log of investment share,% of GDP	0.478****	0.269**	0.146	0.136	0.148	0.0609	0.0558
	[0.123]	[0.115]	[0.103]	[0.104]	[0.101]	[0.0946]	[0.0885]
Knowledge capital, 15+	3.197****	2.798****	1.551****	1.610****	1.589****	1.078***	0.926***
	[0.287]	[0.315]	[0.345]	[0.350]	[0.336]	[0.330]	[0.309]
Log of Fertility rate			-0.395****	-0.403****	-0.400****	-0.368****	-0.356****
			[0.0647]	[0.0648]	[0.0629]	[0.0586]	[0.0551]
Log of public health expenditure, % of GDP				-0.0219		-0.146	
				[0.116]		[0.107]	
Log of health expenditure, % of GDP					-0.389**		-0.573****
					[0.151]		[0.135]
CPI2005						0.198****	0.219****
						[0.0363]	[0.0341]
Advanced economies		0.827****	0.743****	0.746****	0.881****	0.148	0.213
		[0.186]	[0.164]	[0.176]	[0.169]	[0.193]	[0.180]
Sub-Saharan Africa		-0.257	0.198	0.252	0.228	0.0592	-0.00809
		[0.196]	[0.187]	[0.190]	[0.185]	[0.174]	[0.165]
East Asia &the Pacific		-0.0387	-0.175	-0.184	-0.321*	-0.321*	-0.461***
		[0.208]	[0.185]	[0.197]	[0.188]	[0.179]	[0.165]
South Asia		-0.366	-0.292	-0.293	-0.428*	-0.392	-0.489**
		[0.286]	[0.252]	[0.271]	[0.252]	[0.245]	[0.219]
Europe &Central Asia		-0.26	-0.417**	-0.431**	-0.434**	-0.289*	-0.275*
		[0.192]	[0.171]	[0.171]	[0.167]	[0.156]	[0.147]
Middle East&North Africa		0.655***	0.656****	0.655****	0.526***	0.423***	0.236
		[0.187]	[0.165]	[0.166]	[0.168]	[0.155]	[0.153]
Constant	4.669****	5.511****	8.048****	8.067****	8.734****	8.128****	9.060****
	[0.325]	[0.417]	[0.554]	[0.555]	[0.599]	[0.499]	[0.522]

Notes:
1. Sample size after dropping countries without observations: (1)-(3)=134, (4)(a,b)-(5)(a,b)=133.
2. Knowledge capital is computed using years of schooling of total population (age 15 and up) and Mincerian coefficients (Psacharopoulos (1994)).
3. Zimbabwe does not have health expenditure data in 2005 and hence is not included in the sample in (4) and (5).
4. Standard errors are in brackets. * p<0.1, ** p<0.05, *** p<0.01, **** p<0.001.

Table 3(b). Cross-country regressions: Trapped countries.

Variable	(1)	(2)	(3)	(4)		(5)	
				(a)	(b)	(a)	(b)
Log of investment share,% of GDP	0.0324	-0.0835	-0.0798	-0.0906	-0.08	-0.0909	-0.0852
	[0.137]	[0.168]	[0.156]	[0.161]	[0.158]	[0.165]	[0.160]
Knowledge capital, 15+	1.400***	1.078**	0.447	0.499	0.386	0.52	0.309
	[0.411]	[0.496]	[0.532]	[0.561]	[0.557]	[0.593]	[0.578]
Fertility rate			-0.243**	-0.245**	-0.232**	-0.241**	-0.237**
			[0.103]	[0.110]	[0.108]	[0.115]	[0.110]
Log of public health expenditure, % of GDP				0.0971		0.12	
				[0.174]		[0.242]	
Log of total health expenditure, % of GDP					-0.282		-0.331
					[0.253]		[0.268]
CPI, 2005						-0.0435	0.149
						[0.318]	[0.238]
Sub-Saharan Africa		-0.343	0.00897	0.0511	-0.0344	0.0617	-0.0782
		[0.324]	[0.335]	[0.362]	[0.362]	[0.378]	[0.373]
East Asia &the Pacific		0.118	0.00417	0.0363	-0.0436	0.0518	-0.0842
		[0.387]	[0.362]	[0.377]	[0.370]	[0.401]	[0.380]
South Asia		-0.219	-0.162	-0.0447	-0.247	-0.0262	-0.251
		[0.409]	[0.379]	[0.433]	[0.400]	[0.462]	[0.405]
Europe &Central Asia		0.323	0.126	0.126	0.167	0.128	0.184
		[0.587]	[0.549]	[0.571]	[0.562]	[0.583]	[0.570]
Constant	6.446****	7.155****	8.460****	8.348****	8.985****	8.399****	8.812****
	[0.358]	[0.679]	[0.837]	[0.887]	[0.969]	[0.980]	[1.020]

Note:
Sample size after dropping countries with incomplete data: (1)-(3)=34, (4)(a,b)-(5)(a,b)=33. Standard errors are in brackets. * $p<0.1$, ** $p<0.05$, *** $p<0.01$, **** $p<0.001$.

Table 4. Panel regressions

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)
	All countries						*Trapped economies*	
Log of lagged investment share,% of GDP	0.105**	0.108**	0.078	0.079*	0.098	0.097**	0.126*	0.114**
	[0.049]	[0.044]	[0.049]	[0.041]	[0.048]**	[0.040]	[0.068]	[0.046]
Lagged knowledge capital, 15+	0.853***	1.179****	-0.330	-0.224	-0.387	-0.291	-0.789	-0.017
	[0.316]	[0.294]	[0.394]	[0.348]	[0.382]	[0.336]	[0.513]	[0.349]
Lagged fertility rate	-0.009	0.030	0.022	0.067*	0.023	0.067*	-0.106*	-0.032
	[0.040]	[0.040]	[0.040]	[0.036]	[0.040]	[0.035]	[0.060]	[0.052]
Log of lagged public health expenditure, % of GDP		0.023		-0.019		-0.024		0.015
		[0.029]		[0.029]		[0.029]		[0.027]
Constant	6.583****	6.184****	7.558****	6.939****	7.223****	6.913****	8.201****	7.363****
	[0.384]	[0.331]	[0.420]	[0.323]	[0.393]	[0.319]	[0.581]	[0.394]
Country fixed effects[2]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects[3]	No	No	Yes	Yes	No	No	No	No
Time trend[4]	No	No	No	No	Yes	Yes	No	No

Notes:

1. Total observations: 134 countries for all countries and 34 countries for trapped economies. Guyana is the benchmark. Standard errors are in parentheses. *p<0.1, **p<0.05, ***p<0.01, **** p<0.001.
2. Country fixed effects significant at 5% level: All countries: Regression (1): 114 out of 134 countries. Regression (2): 115 out of 134 countries. Regression (3): 121 out of 134 countries. Regression (4): 121 out of 134 countries. Regression (5): 122 out of 134 countries. Regression (6): 119 out of 134 countries. A detailed list of countries with significant country fixed effects is provided in the Appendix. Trapped economies: Regression (1): 23 countries out of 34 countries have country fixed effects significant at 5% level or below. The countries are Afghanistan, Albania, Benin, Bolivia, Burundi, Cameroon, Chad, Democratic Republic of Congo, Republic of Congo, Cote d'Ivoire, Gambia, Honduras, Liberia, Malawi, Mali, Nepal, Nicaragua, Niger, Rwanda, Sudan, Tanzania, Uganda, and Zimbabwe. Regression (2): 22 countries out of 34 countries have country fixed effects significant at 5% level or below. The countries are Afghanistan, Albania, Benin, Bolivia, Burundi, Cameroon, Democratic Republic of Congo, Republic of Congo, Cote d'Ivoire, Honduras, Liberia, Malawi, Mali, Nepal, Nicaragua, Niger, Rwanda, Sierra Leone, Sudan, Tanzania, Uganda, Zimbabwe
3. All countries: Regression (3): Time fixed effects statistically significant at 5% or below for year 1971-1990 and 1996-2007. Regression (4): Time fixed effects significant at 5% or below for all years. Trapped economies:
4. Time trend: t= year-1970. Coefficients for t are 0.017 and 0.022 for Regression (5) and Regression (6), respectively. Both are statistically significant at conventional levels.

Table 5. Effects of changes in parameters on the equilibrium parental time devoted to educating a 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 ≒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	0.4659	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	0.5251	Calibrated
Human Capital Production Technology:			
Health capital-to-knowledge capital ratio	h/m	0.1461	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	0.9782	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	1.2891	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	0.1555	0.1230	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 Sectors: 2006-2008 Average

	Bangladesh			Kenya			Nigeria		
	Commitment	Disbursement	Utilization	Commitment	Disbursement	Utilization	Commitment	Disbursement	Utilization
Primary 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–Primary 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 averages, in USD million, at constant 2007 prices.

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

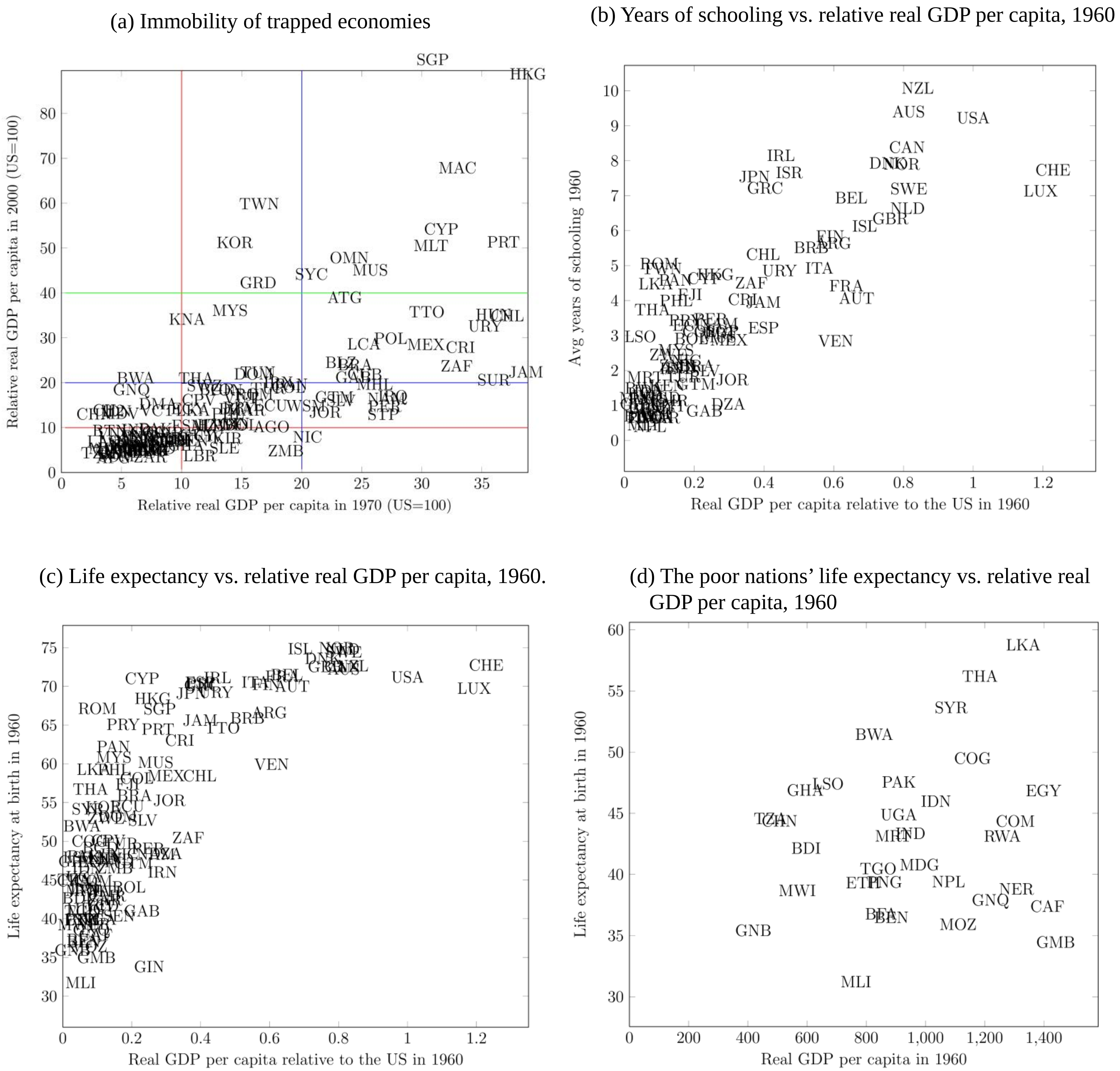
Table 11. Computation of institutional barriers for trapped countries

	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 – δ_c /(1+δ_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) Immobility of trapped economies

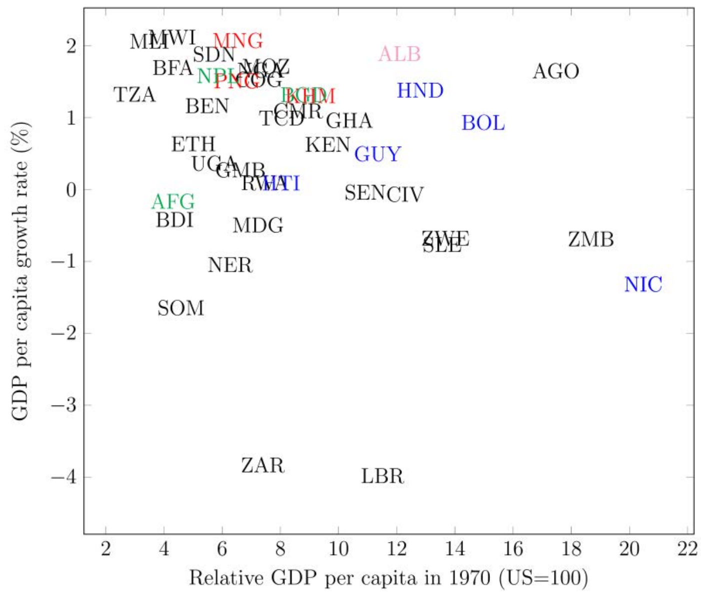
(b) Years of schooling vs. relative real GDP per capita, 1960

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

(d) The poor nations' life expectancy vs. relative real GDP per capita, 1960

Source: Barro-Lee (2010),the PWT 6.3 and the World Bank.

Figure 2. Non-convergence of the 41 trapped countries

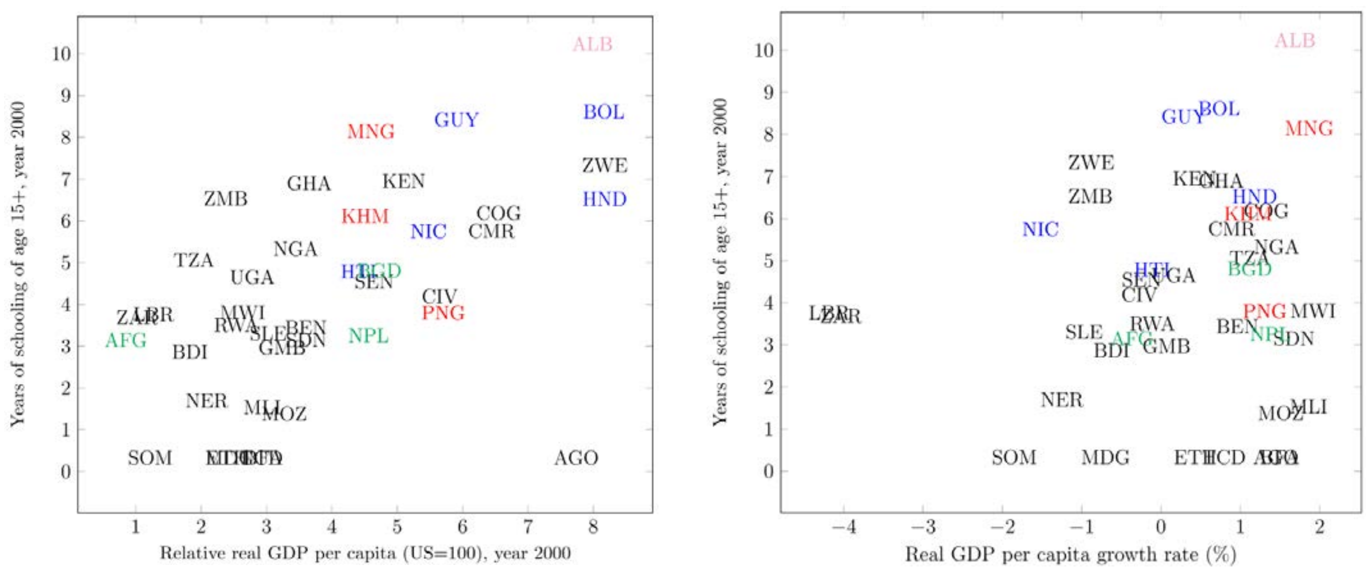


Source: The PWT 6.3. The data range is from 1970 to 2007.

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

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

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

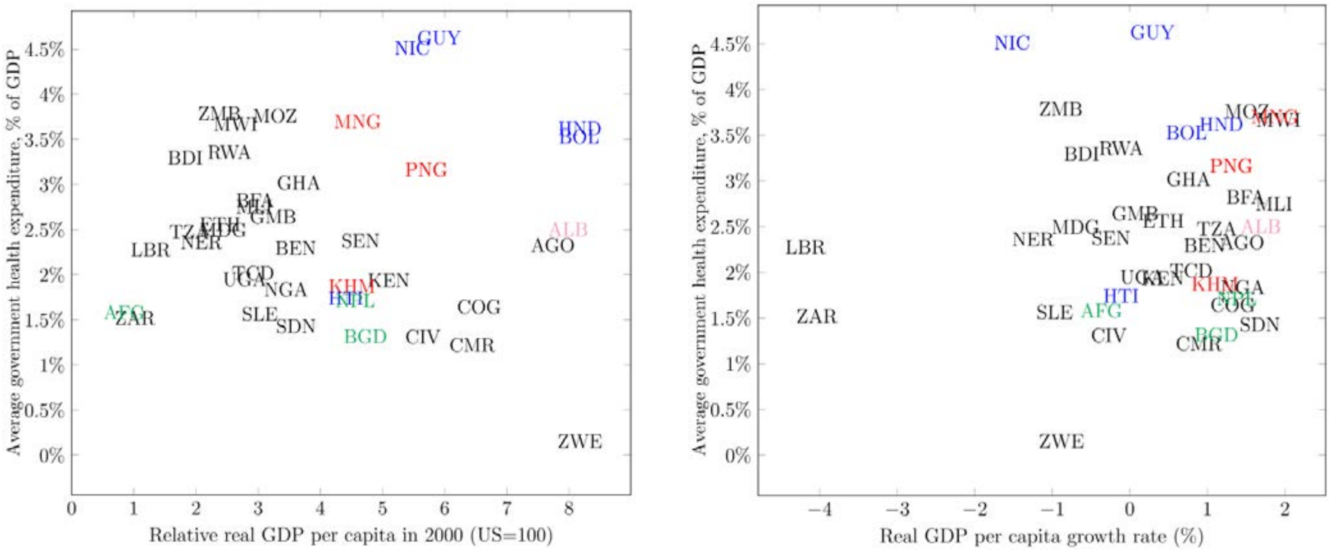


Source: Barro-Lee (2010) and the PWT 6.3. The real GDP per capita growth rate is the average growth rate during 1970 to 2007.

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

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

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

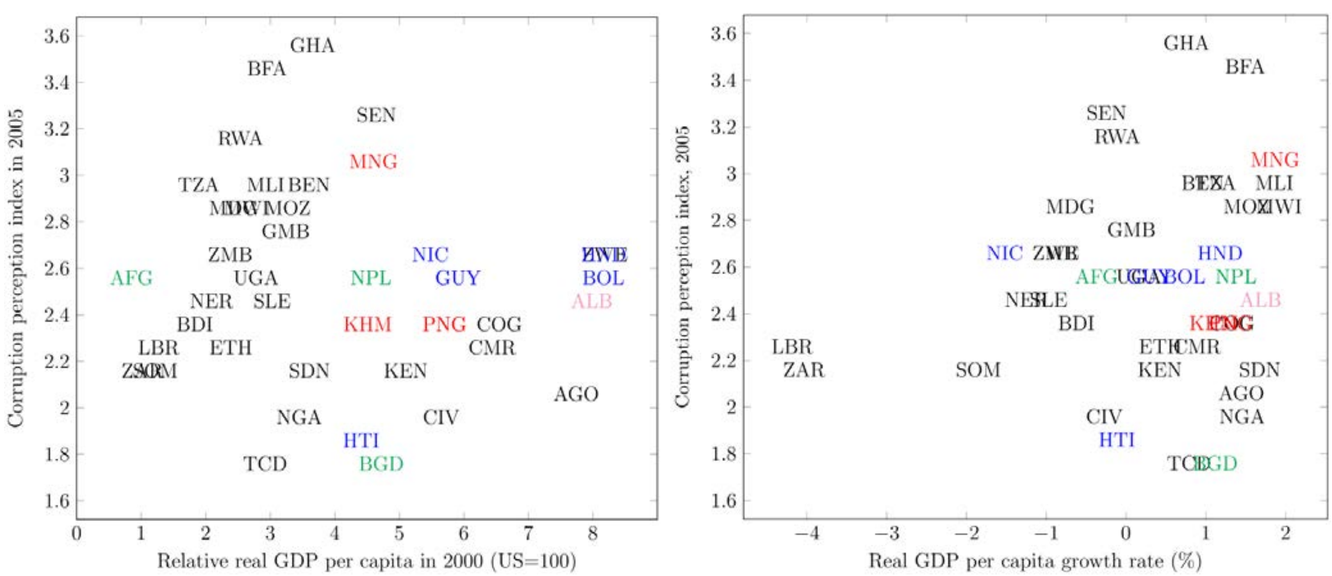


Source: The PWT 6.3 and the World Bank. The real GDP per capita growth rate is the average growth rate during 1970 to 2007; the average government health expenditure refers to the average of the available data during 1995-2010.

Figure 5. The Corruption Perception Index and economic performance

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

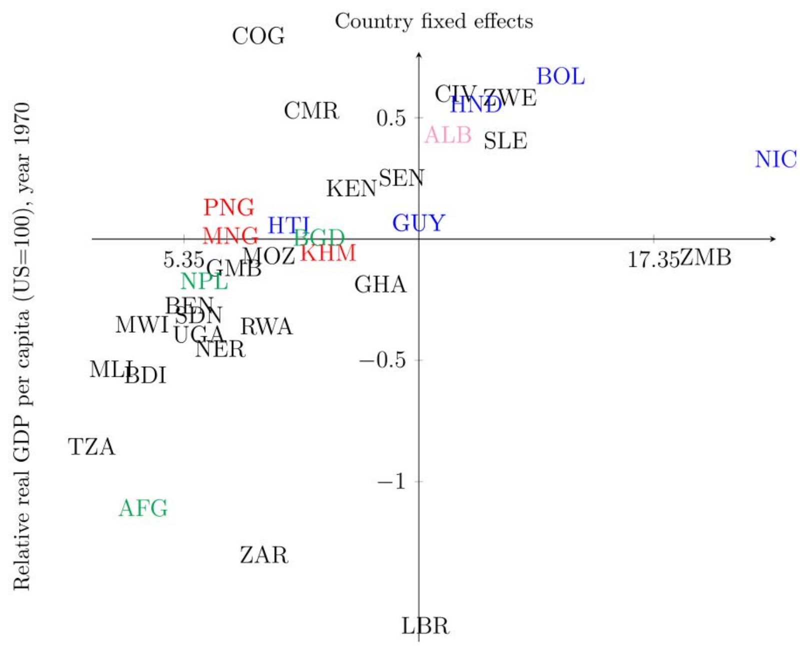
(b) The Corruption Perception Index vs. growth of real GDP per capita, 1970-2007



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

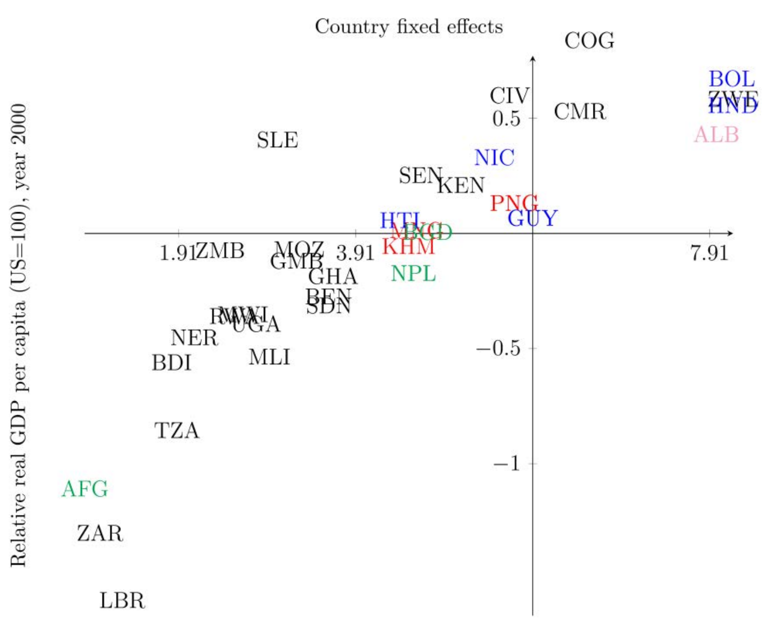
Figure 6. Country fixed effects and relative income levels

(a) Country fixed effects and relative real GDP per capita in 1970 (US=100)



Source: Panel regression result and the PWT 6.3.

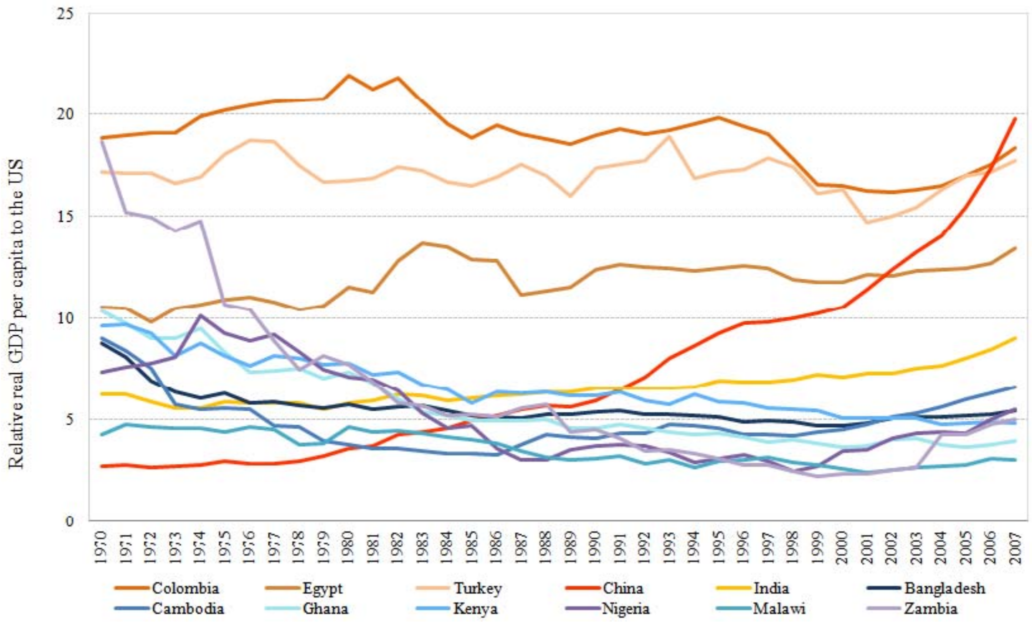
(b) Country fixed effects and relative real GDP per capita in 2000 (US=100)



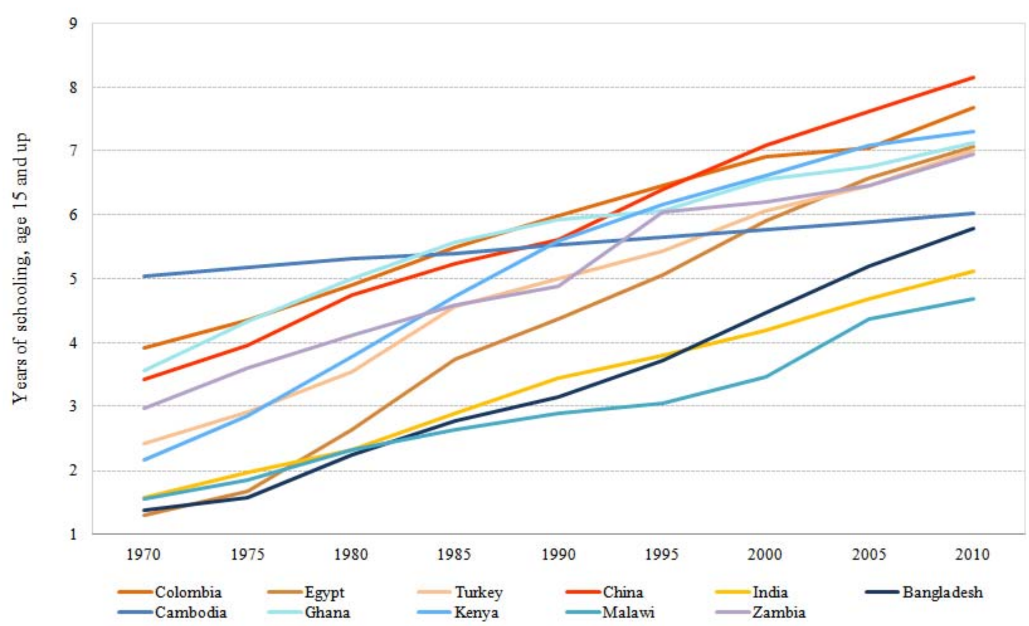
Source: Panel regression result and the PWT 6.3.

Figure 7. The economic performance, educational attainment and health performances for selected middle-income-low and trapped countries

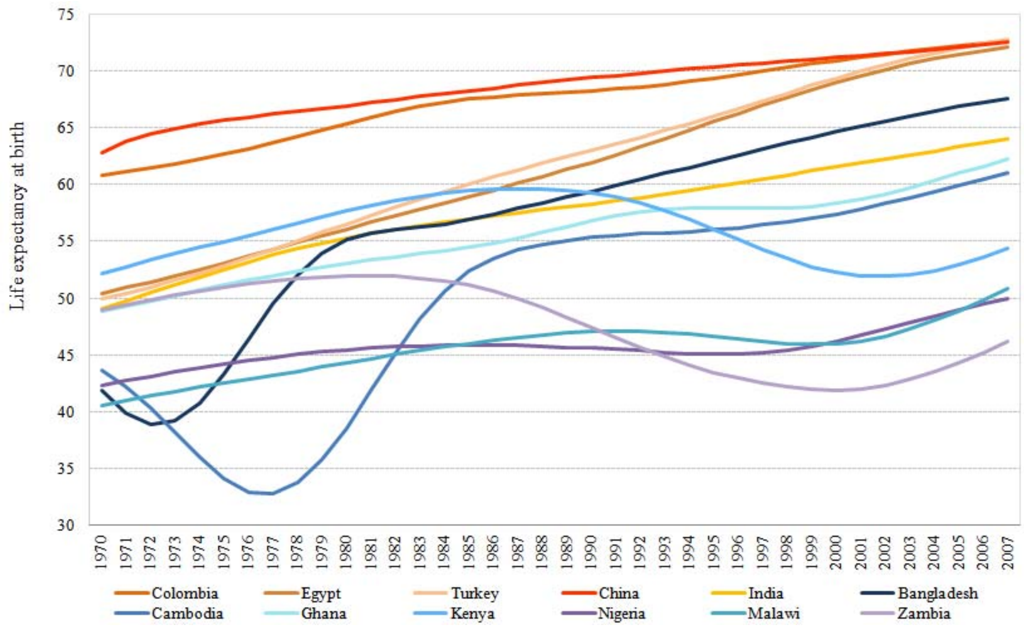
(a) Relative output per capita



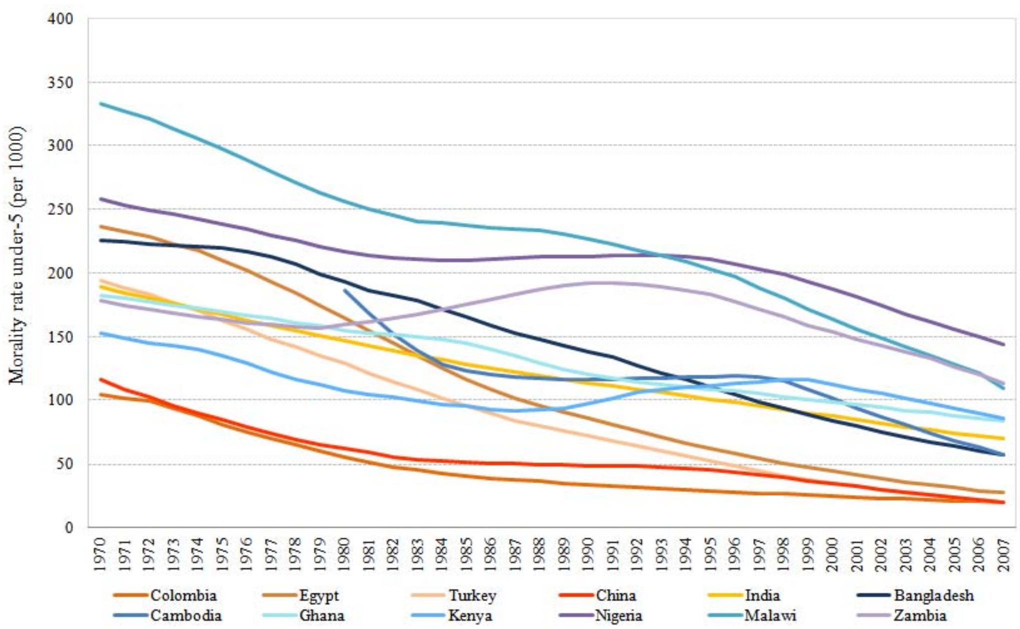
(b) Years of schooling



(c) Life expectancy at birth



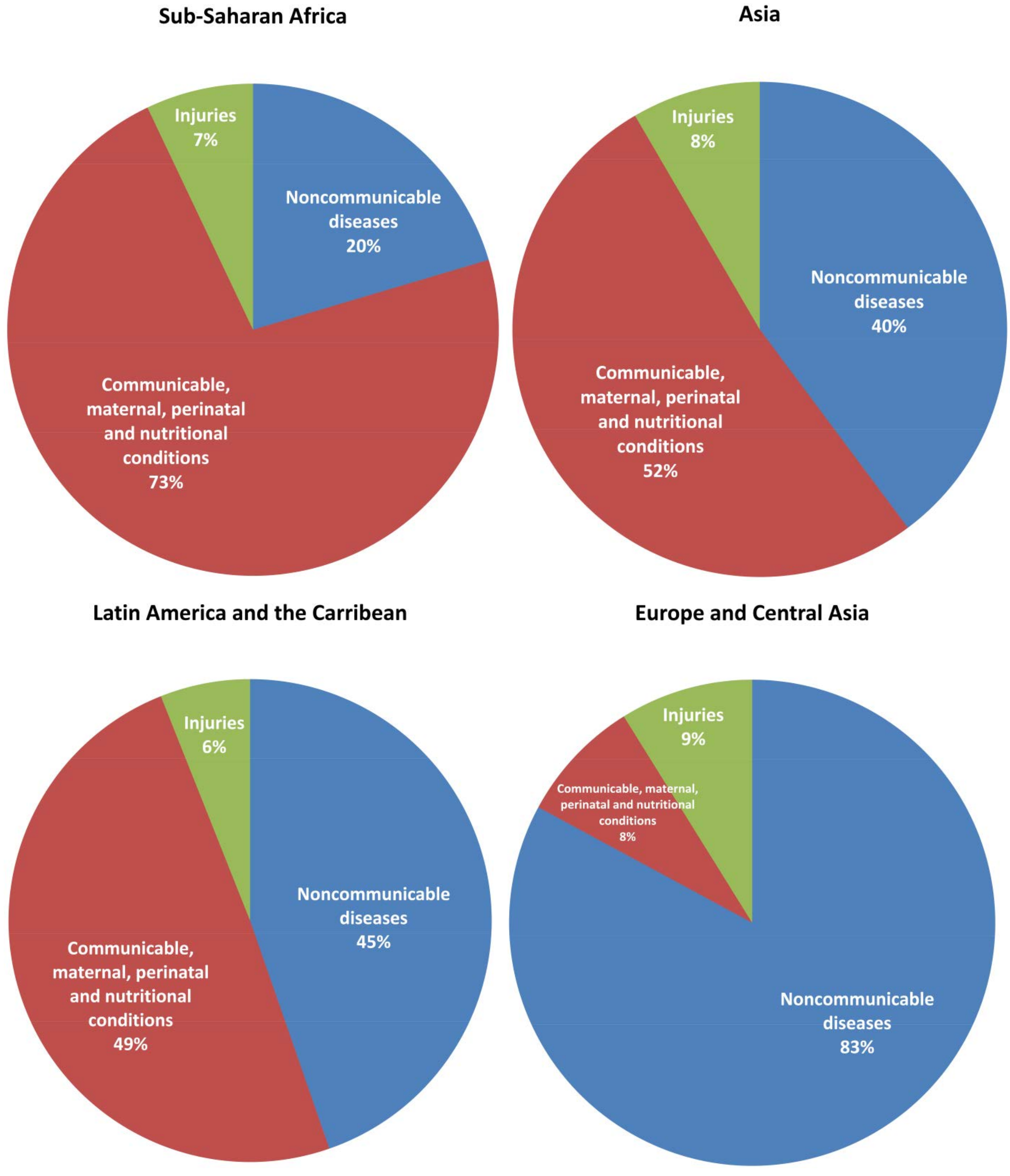
(d) Mortality rate under 5



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

Figure 8. Causes of death in the trapped countries by region

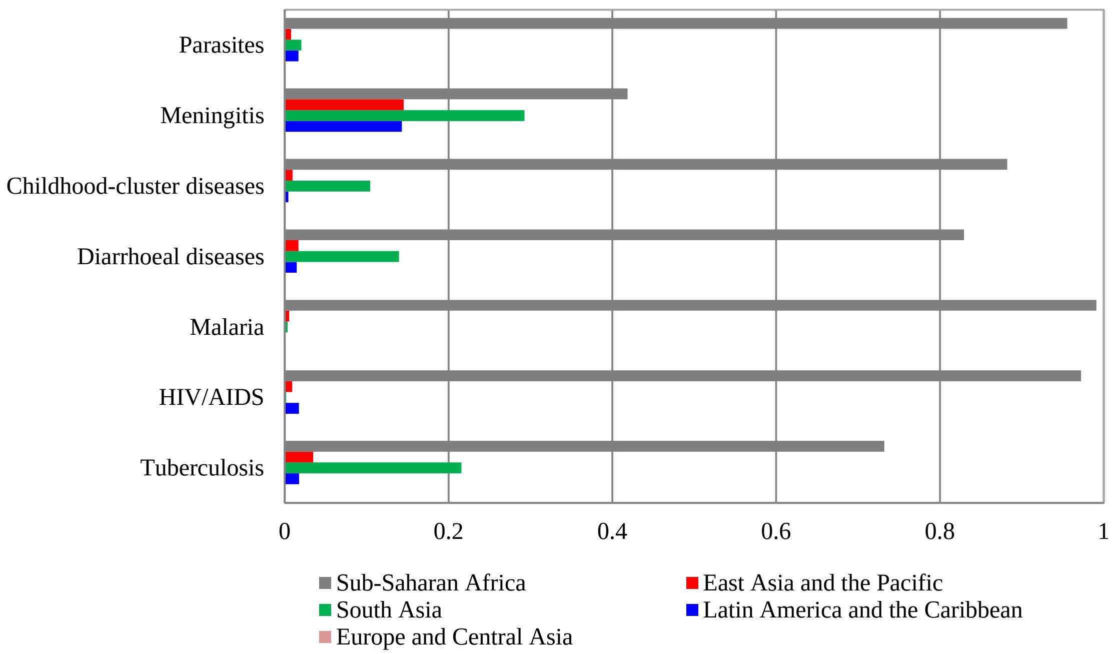
(a) Causes of death by major category



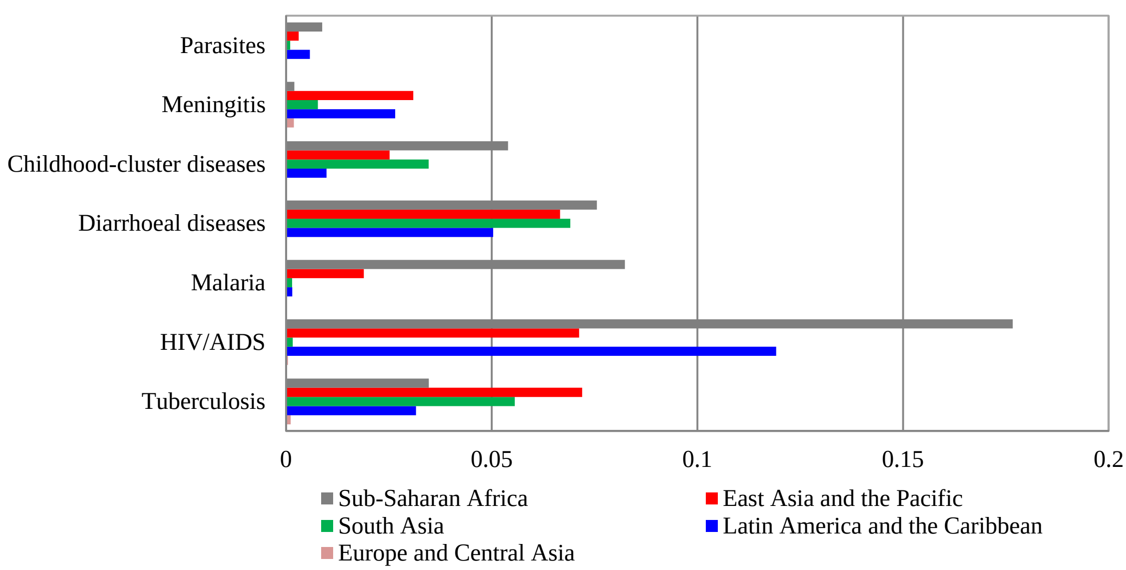
Source: Computed using Table 1: Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), the World Health Organization. The region Asia includes East Asia and the Pacific and South Asia.

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

(i) Distribution of deaths from selected communicable diseases in trapped countries by region



(ii) Causes of death from selected communicable diseases within regions



Source: Upper panel: Table 1: Estimated total deaths ('000), by cause and WHO Member State, 2002 (a), the World Health Organization. Lower panel: Table 1: Estimated total deaths ('000), by cause and WHO 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 9. Parents' genetic transmission to children's health and the optimizing level of health investment and education investment

(a) The optimizing level of health investment: MB_x and MC_x

(b) The optimizing level of parental time devoted to educating children: MB_e and MC_e

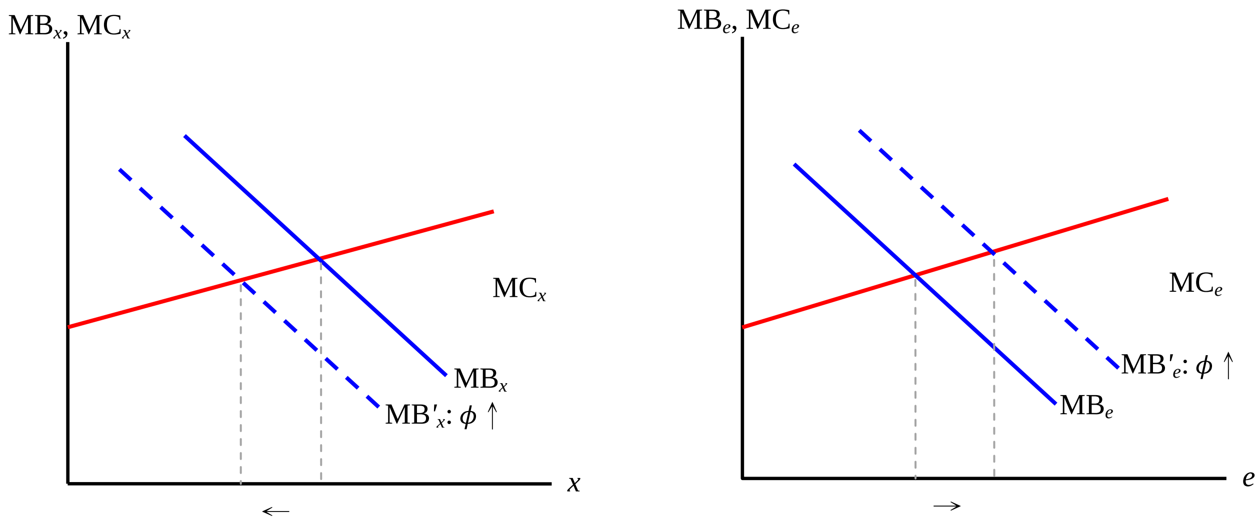


Figure10. Equilibrium determination of parental time devoted to educating a child

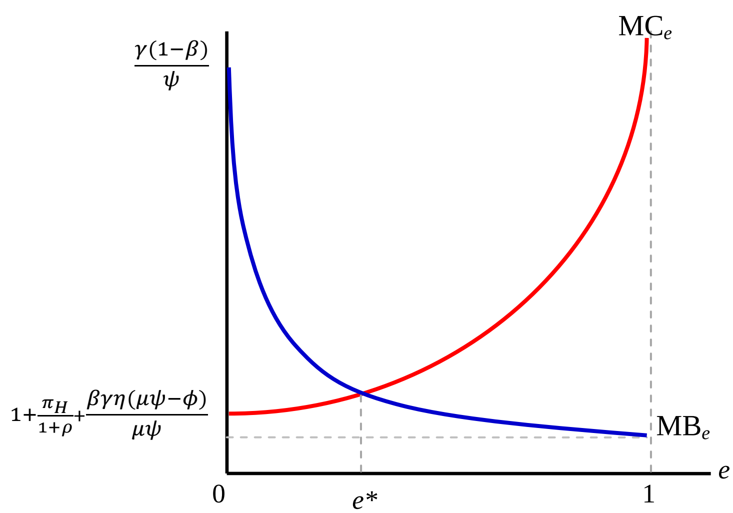


Figure 11. Equilibrium child health investment and capital accumulation, institutional changes, and traps

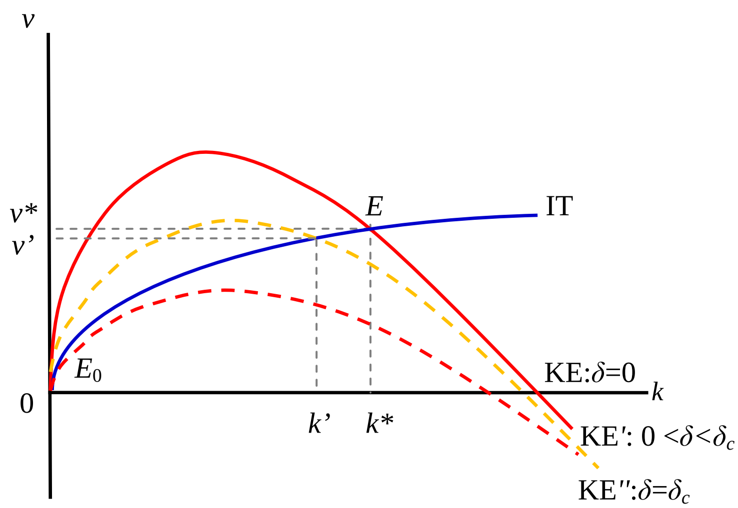


Figure 12. Comparative statics with respect to preferences and health technology changes

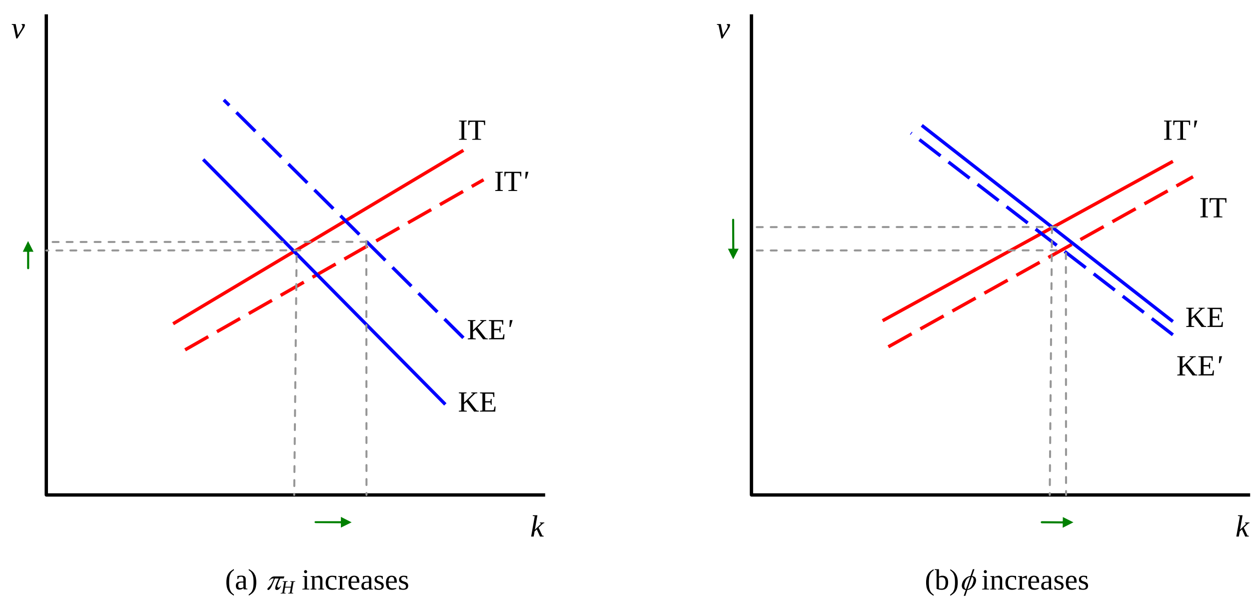
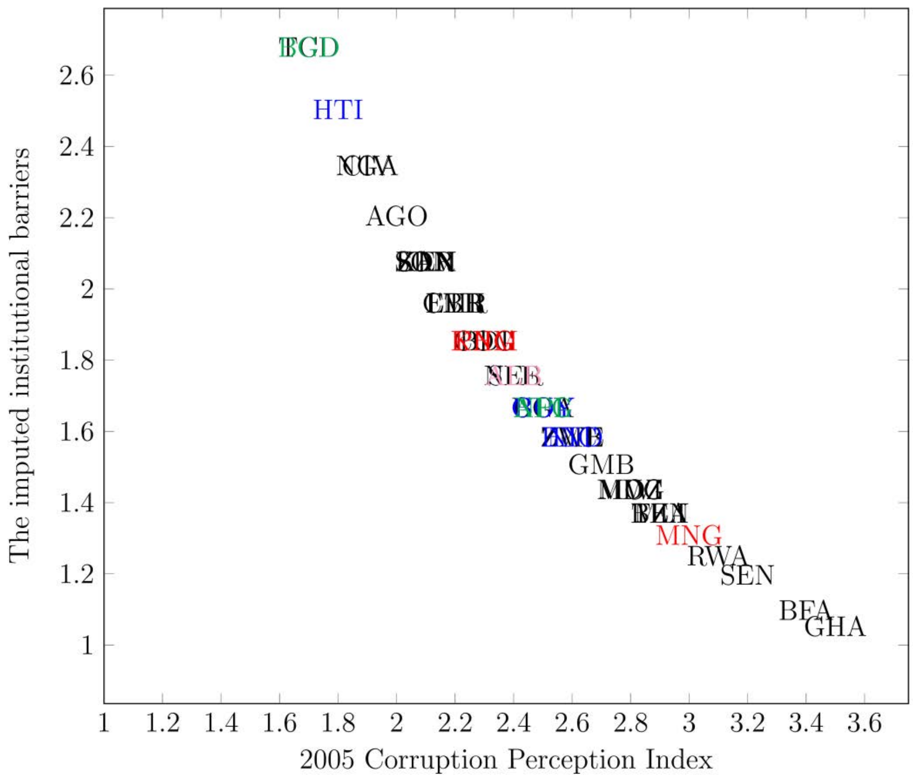
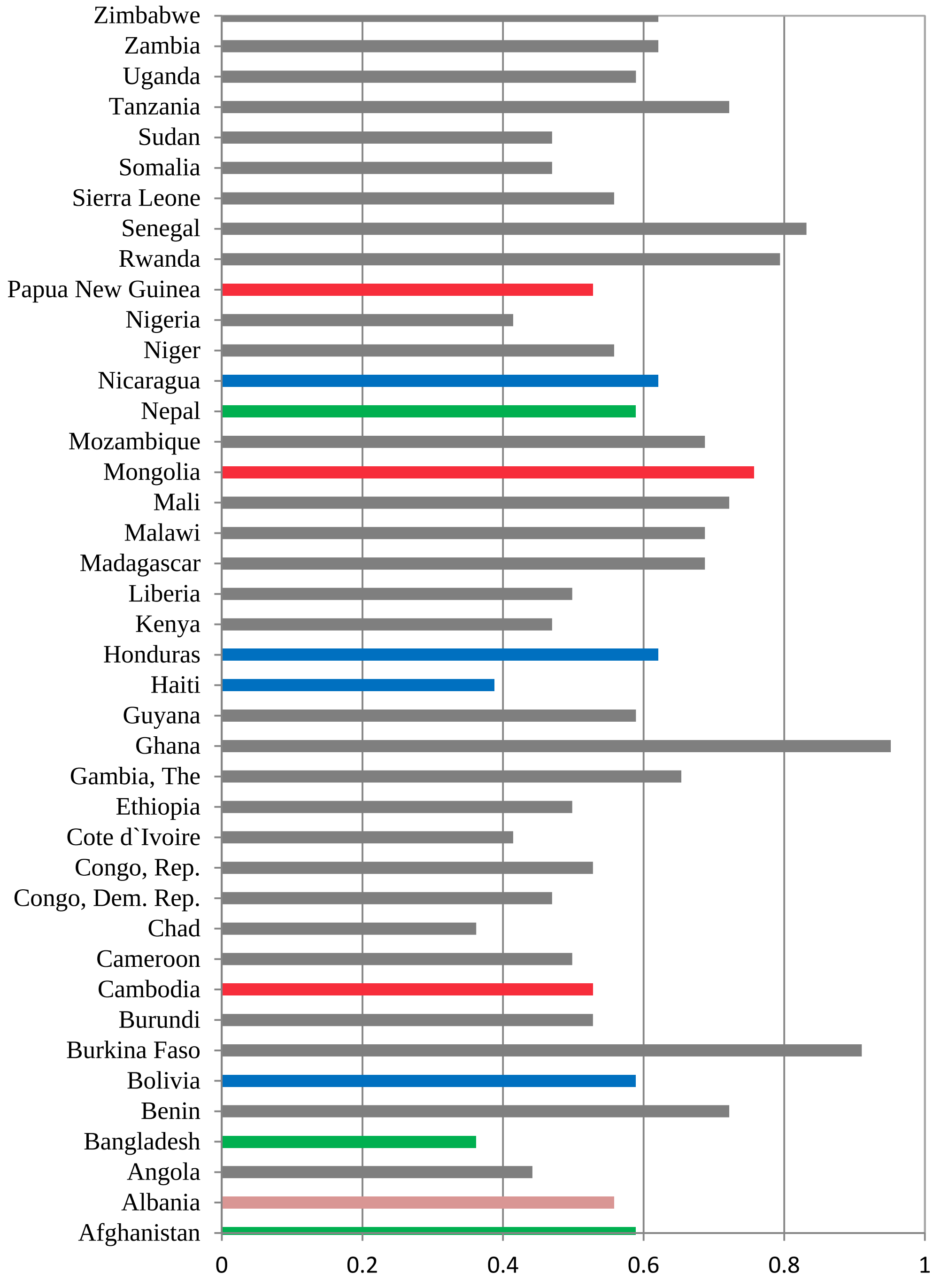


Figure 13. The Corruption Perception Index and the institutional barriers of the trapped economies



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

Figure 14. Chance of pull-out



Note: Gray: African countries; red: Asian countries; blue: Latin American countries; pink: East European country; green: Middle East countries.