WORKING PAPERS IN ECONOMICS & ECONOMETRICS

ON THE CONSTRAINED CONTRIBUTION OF ADVANCES IN MEDICAL KNOWLEDGE TO THE ECONOMIC GROWTH OF DEVELOPING COUNTRIES

Alan Martina
School of Economics
College of Business and Economics
Australian National University

E-mail: alan.martina@anu.edu.au

JEL codes: I10, I18, O15, O43

Working Paper No: 504
ISBN: 086831 504 4

July 2009

Paper prepared for The International Conference on Science and Society
University of Cambridge, 5th to 7th August, 2009.

Abstract: The conjectures examined are that: (i) advances in the medical knowledge are likely to have comparatively little (resp. considerable) impact on the rate of the growth of gross domestic product per capita (GDPPC) in a poor developing country if economic institutions are weak (resp. adequate); (ii) apparently strong economic institutions will have comparatively little (resp. considerable) impact on this rate of economic growth in this country if previously the level of health had not been (had been) raised to a minimum threshold level. The (limited) evidence presented indicates that the contribution that advances in medical knowledge are likely to make, in raising the rate of growth of GDPPC in developing counties, appears to be constrained at least by the level of economic institutions present in the country concerned.

1. Introduction

A good case can be made for the view that one of the most important contributions made towards improving the level of well-being attained by the societies of the world in the last one-and-a-half centuries or so have been the major advances in the understanding of the causes of major killer diseases. The discoveries that were made in this area of scientific endeavour, from about 1850 on, lead to the prevention, or the containment and/or the treatment of many of these diseases. For instance, fundamentally important insights resulted from the scientific work by: John Snow and Robert Koch into the causes of water-borne intestinal diseases; Alphonse Laveran, Ronald Ross and Giovanni Grassi regarding the causes of malaria; Jesse Lazear, James Carol and Walter Reed with respect to the causes of yellow fever.[1] These various advances in medical knowledge each made a contribution towards increasing the level of life expectancy for members of the societies of the world.[2]

At this juncture the question may be posed immediately: did the application of these advances (and any relevant subsequent advances) in medical knowledge and the resulting increase in the level health in the last century and a half or so make a useful contribution towards increasing the level or the rate of growth of gross domestic product per capita (at constant prices) (GDPPC) in any developing country? The answer to this question clearly has some relevance for the design and implementation of science (or more particularly health) policy in developing and developed countries.

[In passing it is emphasised that this class of question is not new. For instance it was asked, implicitly at least, by Balfour and Scott (1924: Part 3, Ch. 4) in a chapter in their book (concerned with public health issues in the British Empire and elsewhere). The relevant chapter is entitled: 'The Financial Aspect of Public Health'.]

Naturally the potential answer to the question posed should not be the sole consideration that influences public health policy in developing countries. A community

[1] No doubt the names of others could be added to those just listed in the main text. For a series of articles, edited by Cunha (2004), that surveyed the history of the medical discoveries relating to the causes of a wide range of major killer diseases see *Infectious Disease Clinics North America*, Vol. 18.

[2] The improvement of the level of nutrition in the societies of the world also would have made a contribution to raising the level of health in these societies – as is argued, for instance, by McKeown (1976) and Fogel (2004). (How much of a contribution is open to debate. Grundy (2005) provides an assessment of this debate within the context of British demographic history.) This matter receives little attention in the main text, however.

may hold the view that, on ethical grounds, all of its members should have access to the basic preventative and curative health care that is required to ensure that, wherever feasible, all in this community attain a reasonable level of health. This ethical belief, no doubt, has contributed towards motivating the application of relevant medical knowledge in developing countries. That said the case for applying this knowledge in developing countries presumably would be strengthened if reliable empirical evidence could be identified that demonstrated that this action, and the resulting increase in the level of health also contributed towards raising the level of GDPPC for at least some developing countries.

On turning to consult the contemporary relevant literature that explicitly or implicitly addresses the question posed earlier, it is clear that there is no answer that receives broad support. Some have argued, implicitly at least, that these advances have made, *without qualification*, a positive and significant contribution (for instance Gallup and Sachs, 2001; Sachs, 2003; Bloom, Canning and Seville, 2004; Lorentzen, McMillan and Wacziarg, 2005; Carstensen and Gundlach, 2006; Bleakley, 2007, 2009).

There are, however, a number of grounds for challenging this unqualified point of view. The first challenge comes in the form of the general observation that while in one particular set of circumstances the application of relevant medical knowledge in a developing country most likely (but not definitely) will make a significant contribution to raising the level of GDPPC in this country, but if these particular circumstances are absent or are altered even in an apparently minor way, then the application of this medical knowledge may have little or no, or possibly even (over the long term) a negative influence on the rate of growth of GDPPC for the developing country concerned. These assertions imply that improving the level of health (through the application of relevant medical knowledge) in a developing country is likely only to be a component, albeit an important component, of an economic system that determines the level of GDPPC for this country. In this system there also needs to be present, however, other relevant complementary elements. If they are absent, or at an inadequate level then a marked rise in the level of health is unlikely to have significant influence on the level or rate of growth of GDPPC for this developing country. The opposite may be the case, however, if these complementary factors are present.

An initial statement of this particular line of argument is to be found in Martina (2007). This argument has been considerably refined and extended in Martina (2009) in order to provide a more complete justification for the assertions made in the previous paragraph.[3]

There is, however, another broad reason for challenging the unqualified view that the application of relevant advances in medical knowledge has made a positive and significant contribution toward increasing the level of GDPPC in developing countries. This particular challenge possibly had its beginnings with Vogt (1948) – who was then followed by a number of other authors ending with the general argument set out in Acemoglu and Johnson (2007) and Ashraf, Lester and Weil (2009).[4] Specifically it suggests that there are two broad economic consequences for a developing country flowing from the improvement in the level of health in this country. The one is to increase the level of GDP, while the other is to increase the size of the population for this country. The latter change may be so comparatively large in a representative developing country that the net effect is that the rate of growth of GDPPC declines in this country as a result of the assumed improvement in the level of health. These important matters are also addressed and considered in some detail in Martina (2009) – a discussion that contradicts this unqualified line of argument.

Given the comparative complexity of the range of issues at stake the discussion presented here can only provide a brief summary of aspects of the issues raised by the first challenge mentioned earlier. There are a number of reasons for this complexity, but one is that the economic system in a developing country is likely to be distinctly non-linear at an important stage in economic development process of this country. This non-linearity reflects, in part, the possibility that the influence of the level of health on the level of GDPPC varies at different stages in the economic development of this country. At one stage in this non-linear process application of relevant medical knowledge will have little or no influence on the aggregate economic performance of this country, while at some threshold or inflexion point the appropriate application of relevant medical knowledge appears to be of vital importance for assisting the economy of this country to attain a much

[3] Packard (2009) also, within the context of controlling malaria, has argued that a reduction in the incidence of this disease in a developing country may bring no immediate increase in economic activity in this country.

[4] The relevant literature has been surveyed to some degree from various perspectives by Jack and Lewis (2009: 12 – 19) and Packard (2007: 146 – 7; 2009).

higher level of performance. Attempting to identify, let alone attempting to measure the extent of this non-linear process requires that the available empirical evidence be analysed and assessed with some care.

In the light of this apparent complexity, certain components of the more complete argument will be omitted here for they would require an extended discussion of a range of relevant issues. Thus, for instance, there will only be a brief discussion in Section 10.1(ii) of the demographic issues mentioned earlier.[5] Nor will there be any empirical results presented here based on the econometric testing of empirical economic growth models. This is so for a range of reasons that are not gone into here except to assert that it is rather difficult (given the limited relevant contemporary data that are available) to provide a set of tests of these models that generates reliable statistical results.[6]

Expanding a little on these initial remarks, the argument to be sketched out and tested to a limited degree here indicates that the main factor that appears to have a marked influence on the likelihood of an increase in the level of health significantly influencing the rate of growth of GDPPC in a developing country is the level of economic institutions (to be defined later). In contrast, some of the evidence to be presented later also suggests that the level of health influences the likelihood of an increase in the level of economic institutions significantly influencing the rate of growth of GDPPC in this country. These observations imply that, in attempting to answer the question posed earlier, possibly as much attention needs to be devoted to determining the economic consequences of an increase in the level of economic institutions and how these institutions interact with the level of health, as with considering the influence of an increase in the level of health alone on the level of GDPPC for the developing country concerned. Put more generally, to determine the influence of an increase in the level of health alone on the level of GDPPC for this developing country special attention needs to be given to gaining a reasonably good understanding of the basic overall operation of the economic system for this country. No attempt is made here to address this issue in any detail.

---

[5] The relevant argument in Martina (2009: Chapter 8) also is framed around a non-linear economic model. Hence again the issues that appear to be at stake are comparatively complex.

[6] The assertion just made in the main text is justified in Martina (2009: Chapter 3) and in the references cited there.

The discussion that follows begins by noting that an elementary Bayesian analytical methodology is to be applied, where historical quasi-controlled experimental information is employed to test various prior beliefs. Attention turns in Section 3 to defining the measures of health and economic institutions to be employed throughout - such as in Section 4 where two of the initial Bayesian prior beliefs are presented. These prior beliefs are tested in Sections 5 and 6 where they are found to be wanting. The discussion in Section 7 indicates in broad terms how the analysis, based on historical quasi-controlled experimental information may proceed in order to provide a more through testing of relevant beliefs. The relevant conclusions or posterior beliefs derived from this suggested (but omitted) line of analysis are set out in Section 8. A limited additional test of these beliefs is provided in Section 9 by way of making use of some relevant contemporary data in the attempt to fathom, in very broad terms, why the world's GDPPC is distributed across countries in the way it is in the late 20th century. The posterior beliefs set out in Section 8 are also applied in Section 10 in the assessment of the results reported in some related literature. In this section there also is a brief discussion of the related demographic issues mentioned earlier. Some concluding remarks are made in Section 11.

In this conclusion the observation is made that increasing the level of health in a poor developing country needs to be part, but only a part of a spectrum of public policy actions directed at attempting to increase the rate of growth of GDPPC in this country. Increasing the level of health, by way of applying appropriate medical knowledge in a developing country, without regard to other relevant considerations, may well result in disappointing results in terms of influencing this country's economic performance.

2. Broad analytical technique employed

Throughout most of the subsequent discussion an elementary Bayesian approach is applied. The information that is employed to test certain prior beliefs and modification of these beliefs is drawn from a wide range of episodes in the relevant history of a number of countries or communities. Clearly these historical episodes need to possess certain basic properties or characteristics. First there needs to be a comparatively large change in the level of the relevant deep determinant (health or economic institutions) in a particular

community over a comparatively short period of time.[7] Such a change is likely to ensure that it is likely that all other relevant variables have remained unchanged (or more or less so) during the relevant time period – as is required in a standard controlled experiment. It also may be useful if this determinant then remains at or near its new level over an extended period of time. This situation will assist in determining the full extent (or the general equilibrium effect) of the influence of the change in the level of this determinant on the economy of the country or community concerned. While other relevant variables are more likely to change during this extended period of time, it is hoped that it is possible to take these changes into account when attempting to draw relevant inferences from the historical information being considered.[8] In addition, when considering a particular relevant piece of quasi-controlled experimental information ideally this information is not considered in isolation as a stand-alone piece of evidence. Rather each piece of relevant evidence should be considered as part of an overall system of tests that result from applying and comparing a range of relevant pieces of quasi-controlled experimental evidence. And these various tests of some relevant prior belief need to generate results that are consistent with one another. If they are then this increases the level of confidence in the reliability of the relevant probabilistic inferences being drawn from the experimental information being considered. If, however, these pieces of evidence are inconsistent with one another then the system of testing concerned possibly should be abandoned.

It also is emphasised that some of the natural experiments to be considered in reality imposed relatively large, and sometimes traumatic social and economic costs on the communities or the nations concerned. For this reason quasi-controlled experiments of the nature to be considered later would never, on ethical grounds, be contemplated in the designing of contemporary randomized controlled experiments or trials (RCTs) in the social or natural sciences. (These RCTs are considered briefly later in sub-Section 10.1(i).) In contrast some of the other quasi-controlled experiments to be considered here, that had the potential to benefit literally hundreds of millions of people, implicitly were carried out on

[7] A deep determinant is a variable that influences the level of the proximate determinants of economic growth - capital accumulation, labour supply and the level of technology.

[8] In the literature surveyed by Packard (2009: 63 – 69), of various historical case studies to determine the influence of a reduction in the incidence of malaria on the level of economic activity in a particular country or region, it also was recognized, not surprisingly, that there was a need to take into account the possible influence of all major pertinent variables on economic activity.

such an immense scale that their implementation required the extensive involvement of relevant governments. Again this class of experiment would never be contemplated in the designing of contemporary RCTs in the social sciences. One implication of these remarks is that the quasi-controlled experiments to be considered or are alluded to here have the potential to reflect general (as distinct from partial) equilibrium effects – which is not an unimportant potential benefit to be derived from considering this experimental information.

3. Some definitions

Before turning to begin the main analysis there is a need to provide two definitions; viz. that for the levels of health and economic institutions respectively.

(i) Health (H): The usual measures that are employed in the relevant literature are some appropriate measure of mortality, and/or the level of life expectancy at birth, and/or measures of morbidity. Information concerning some measure of mortality, such as total, adult and child mortality rates is comparatively easy to acquire within certain historical contexts whereas that for life expectancy is not. In other situations the only mortality measure available is a loose measure of the adult male mortality rate. It turns out that usually such an imprecise measure is adequate for the purposes of analysing the historical episode to be considered.

(ii) Economic Institutions (I): This determinant is far more difficult to define and hence measure since, ideally, it should incorporate a number of distinct dimensions. The main interest here is with how well or otherwise the relevant institution *functions*.[9] In particular ideally the measure of economic institutions should provide a fair indication how well these institutions function in assisting the community concerned to organise itself in the attempt to attain higher levels of economic (or Pareto) efficiency and technical efficiency (viz. attaining higher levels of technology).

With the measure of economic institutions being calibrated against this standard, there are at least three elements that such a measure should possess. The first is a measure of the ability of economic institutions to function in such a way (following Adam Smith, 1776; North, 1990, and others) as to constrain individual or group behaviour to the point where, in certain relevant circumstances, the community as a whole benefits. Thus

[9] The distinction between form and function of economic institutions has been emphasized by Chang (2007: 19 – 20).

the potential predatory behaviour of the state and/or other economic entities needs to be constrained and, thereby, provide protection for the property rights of individuals and/or any other relevant economic entities - viz. provide protected private property rights. Clearly such protection would reduce the level of economic uncertainty that, amongst other things, would reduce the costs associated with transactions. This changed set of circumstances in turn presumably would encourage a greater level of savings and investments in physical and human capital (education), and in the creation of new knowledge – subject to other considerations being satisfied (North, 1989).

The second element in a measure of economic institutions that should be allowed for is that, while some economic institutions may need to *constrain* behaviour to some socially desirable level, other economic institutions equally will be required in order to create suitable *incentives* to encourage the desired behaviour by members of a community. The means through which these incentives are put in place is the provision and implementation of appropriate government economic policies.

To explain, even if in law private property rights are protected and restricted to the required level (from society's point of view), if the economic policies implemented by the authorities severely reduce incentives to carry on economic activities then, equally, there will be few economic incentives to take advantage of these property rights. Indeed it is not difficult to conceive of situations where suitably protected private property rights would be near to worthless – as, for instance, in a community where little public basic education is available, a taxation system is imposed that severely distorts behaviour, the revenue raised is spent ineffectively and autarkic domestic and international trade policies are applied.[10] Alter these economic policies such that they reduce the level of economic distortions present in the economic system, and there now are more incentives to take advantage of private property rights. Indeed private property rights in a community may be relatively ill-defined and yet, because of the effectiveness of relevant economic policies in creating the incentives to take advantage of these property rights, the economy for this community may flourish. Thus the quality of the economic policies implemented probably has a

[10] Pande and Udry (2006: 364) come close to making a similar point to that just made in the main text - although within a different context. They note that the effectiveness of an economic institution (say a credit market) on the operation of the economy may be influenced by the presence of another unobserved institution (say the security of land tenure) in this community.

fundamentally important influence on the pace of economic expansion of a developing country.[11]

The third element that the definition of economic institutions may need to include is the level of education. The reason for allowing for this consideration is that no matter how well defined property rights may be in law and no matter how well economic policies may be designed, if the level of education in the country concerned is comparatively low these other aspects of economic institutions may have little influence on the level of GDPPC for this country. Within the present discussion the matter of the level of the level of education, and its interaction with other relevant variables is only touched upon in Section 9.

As for the precise measures of economic institutions, as defined here, they are not available in the relevant historical records to be considered. Nevertheless the historical information to be cited later provides qualitative (as distinct from quantitative) information that indicates adequately, for the purposes of the relevant argument being constructed, the direction of marked changes in the level of various relevant measures of economic institutions (as defined here).

(iii) Interactions: Finally, but not least, the level of economic institutions (I) may influence the level of health (H). Equally a certain level of H is likely to be required to allow a community to attain some level of I. Put differently, the capability of one particular deep determinant to function effectively may be influenced by the level of the measure of the other deep determinant. This important matter, of the interactions and complementarity between these two deep determinants, is considered in various contexts in the discussion that follows.

4. Two Prior Beliefs

Attention now turns to setting out two initial prior beliefs.

Prior Belief 1 (PB1): A significant exogenous rise in the level of health alone in a poor developing country, while all other things remain the same, will result in a marked and sustained rise in the level, and hence the rate of growth of GDPPC for this country.

[11] A similar point has been made by Lin (2009: 16) and Lewis (1955: 376).

This prior belief is derived from the cross-country empirical results presented in Gallup and Sachs (2001) and Lorentzen, McMillan and Wacziarg (2008: Table 7) where the possible influence of economic institutions on the level of, or rate of growth of GDPPC was ignored.[12] The measure of the level of health in the cross-country data set employed by Gallup and Sachs was the risk of contracting malaria whereas Lorentzen *et al*. applied the adult and infant mortality rates respectively.

In stark contrast others have emphasised the importance of raising the level of economic institutions alone as the route along which the level or rate of growth of GDPPC can be increased. This point of view is reflected in the following prior belief.

Prior Belief 2 (PB2): A significant exogenous rise in the level of economic institutions alone, while all other things remain the same, in a poor developing country will result in a marked and sustained rise in the level, and hence the rate of growth of GDPPC for this country.

This prior belief draws on the cross-country empirical results reported in Acemoglu, Johnson and Robinson (2001, 2005), Easterly and Levine (2003), Rodrik, Subramanian and Trebbi (2004) and a number of other references listed in Pande and Udry (2006). The references make no allowance for the possible influence of some measure of the level of health.

5. Some initial testing PB1

A comparatively recent period of economic history is employed to test the statement in PB1. The group of countries to be considered are the five listed in Table 5.1 and the period of interest is from about 1960 through to around 2000. This group of countries is rather special. Specifically, out of some one hundred non-rich countries in 1960 each of the countries listed in Table 5.1 – China, Malaysia, Republic of Korea (henceforth South

[12] In a limited subsequent econometric study based on cross-country data Sachs (2003) did find that both the levels of economic institutions and health respectively influence the level of GDPPC for a representative country in the late twentieth century. This general result was also derived by Carstensen and Gundlach (2006) and Martina (2007). In an extension of their initial results, Lorentzen, McMillan and Wacziarg (2008: Table 8) confirmed this result - although where the rate of growth of GDPPC is the dependent variable. Related results were presented in Batten and Martina (2007) where, instead of GDPPC, the level of the human development index was the dependent variable.

Korea), Taiwan and Vietnam – is one of only ten that experienced comparatively high rates of growth of GDPPC over a sustained period of time over the period leading up to 2000.[13]

Of initial interest is the behaviour of the rate of growth of GDPPC for each of these countries during this period. Specifically each experienced an initial period during which the rate of economic growth was comparatively low followed by a sharp and significant increase (of at least 2.6 percentage points) in its rate of growth of GDPPC. This significantly higher rate of growth of GDPPC also was sustained over an extended period of time; viz. of at least a decade and usually more.

Table 5.1 comes about here.

Turning next to assess the statement in PB1, this is done by considering the quasi-controlled experimental evidence that is concerned with identifying any possible influence significantly large, sudden changes in measures of the level of health are likely to have had on the rate of growth of GDPPC for each of the countries listed in Table 5.1. The measures of health employed here are both the under-five child mortality rate (U5MR) and the adult mortality rate (AMR). In assessing the relevant evidence, and to assist with the exposition the initial discussion will ignore two issues; viz. the possible presence of endogeneity in the evidence to be presented here and the matter of the speed with which changes in the level of health may influence the level of GDPPC. These two matters will be returned to and addressed, however, towards the end of this sub-section.

As for the relevant information set out in Table 5.1, it is noted that in the initial time periods specified for each country both the AMR and the U5MR rate declined by a comparatively significant proportionate amount. Considering each country in turn, in China the U5MR fell by 75 per cent between 1960 and the early 1980s, and the AMR declined by 74 per cent between 1960 and 1980. What is more the respective levels of the U5MR and the AMR (50 per thousand live births and 167 per thousand adults respectively) in 1980

[13] Most of the other countries – Hong Kong, Singapore, Botswana and Mauritius - all had populations of less than 6 million in the late 1990s. Given their comparatively small size, in terms of population, these countries are not considered in the main text. The exception is Egypt – again a country is not considered here.

were well below these measures of health for middle income countries (106 for the U5MR and 218 for the AMR) for that year.[14] Nevertheless, as the relevant information in Table 5.1 indicates, despite this marked improvement in the level of health in China over this twenty-year period the rate of growth of GDPPC for the 1960s and 70s remained low compared with the rate of growth attained by this variable in the subsequent decades. (A similar observation with respect to China was also made by Cutler, Deaton and Lleras-Muney, 2006: 110.)

On taking this new additional information into account, the statement in PB1 would appear to be less likely to be true than previously may have been thought.

This line of argument can also be applied to the data for each of the other countries listed in Table 5.1. In the instance of Malaysia, for instance, the U5MR rate fell by 38 per cent between the early 1960s and the early 1970s, while the adult mortality rate declined by 37 percent between 1960 and 1970. In addition, in Malaysia by 1970 the AMR (256) and the U5MR (around 52) were below that for middle income countries for that year. (For middle income countries around 1970 the AMR was 263 per thousand adults and the U5MR was 148 per thousand live births.) Yet, despite this apparently comparatively rapid rate of improvement that allowed the level of health to attain a relatively high level by 1970, the rate of growth of GDPPC was low during this initial period - compared with the economic growth rates attained by this country in subsequent decades.

Similarly in the instance of Vietnam there was a 46 percent reduction in the U5MR and a 53 per cent decline in the AMR from the 1960s or 1970s through to the early 1990s. Yet despite this improvement in the level of health, the rate of growth of GDPPC for this country remained comparatively low during this period when compared with what was to occur later regarding this variable.

South Korea and Taiwan also experienced comparatively rapid declines in their respective U5MRs over the initial periods set out in Table 5.1– 38 per cent and about 30 per cent respectively over about ten to fifteen year period.[15] The proportionate decline in the AMR was not as large, however, for these two countries. It was about 15 per cent for

[14] The relevant mortality rate data is drawn from World Bank (2006 – 2009).
[15] Some interpolation was applied to the mortality rate data for Taiwan.

South Korea and about 13 per cent for Taiwan over the relevant time periods. Nevertheless the U5MR for both countries had attained levels by 1960 that must have been well below this mortality rate for middle income countries for that year. (As indicated earlier in middle income countries the U5MR in 1970 was 148 per thousand live births.) These observations suggest that in these two countries, while the level of health for adults was improving at a comparatively slow pace in the relevant initial time periods, the level of health for the younger generations by the 1960s had attained comparatively high levels. And yet despite this improved situation (regarding the level of health in the early 1960s), the respective rates of growth of GDPPC for these two countries were low for the late 1950s and early 1960s compared to what was to follow in the subsequent decades. Apparently the improvement in the level of health in these two countries also did comparatively little to increase the rate of growth of GDPPC in the 1950s and early 1960s in the instance of Taiwan, and in the early 1960s in the case of South Korea.

Interestingly, in the instance of Taiwan there is some micro survey data that tends to increase the veracity of this conclusion. Specifically an economic assessment was carried out by Pletsch and Chen (1954) of a vigorous anti-malaria campaign implemented in that country in the early 1950s.[16] They came to the conclusion that this campaign had done little to increase the level of output per capita in rural Taiwan. (This apparently was due the prevalence of under-employment in that rural community. Hence those workers who were too ill to work were readily replaced, at no increased opportunity cost to the community, in the workforce by those who were not ill.) This conclusion tends to confirm the conclusion that has just been drawn from the relevant macro data for Taiwan in the 1950s and early 1960s.

Initial general conclusion: The probability that the statement in PB1 is true is reduced in size once the relevant quasi-controlled experimental evidence for the countries listed in Table 5.1 and that just cited for Taiwan is taken into consideration. This is especially so in the instance of the relevant information presented for China, Malaysia, and Vietnam respectively. This inference is given slightly less strong support by the relevant information provided for South Korea and Taiwan.

[16] Packard (2009: 63) provides a discussion of this study.

5.1 Two additional issues

The line of argument that has just been sketched out is made a little more complicated by returning to consider the issues, up to now left in abeyance, of endogeneity and the speed with which changes in the level of health may influence the level of GDPPC in a developing country. As for the endogeneity issue it is certainly likely that an increase in the level of GDPPC for a poor developing country will increase the level of health for this country by allowing individuals in this community to attain a higher level of nutrition. (For instance China between 1959 and 1961 experienced a severe famine. The subsequent economic recovery from this famine, reflected in the increase in the level of GDPPC in the 1960s, no doubt allowed an improvement in the level of nutrition in this community that in turn probably contributed to a decline in mortality rates in China in that decade.)

That said the available empirical evidence also points to the conclusion that a significant proportion of the improvement in the level of health in developing (as distinct from developed) countries after, say, 1960 was due to the applications of the exogenous advancements in medical knowledge from the mid- to late-19th century on, concerning preventative health care and some comparatively inexpensive curative procedures.[17] (These matters were alluded to in the introduction.) In addition it is emphasized that the per capita expenditures required to implement a number of these effective programs in developing countries are comparatively small – a point stressed, for instance, by Jones *et al*. (2003).[18]

The previous observations imply, therefore, that while an increase in the level of GDPPC in a representative developing country would assist with financing the deployment and application of this medical knowledge, this increase could not be seen as the main factor contributing to an improvement in the level of health in this country. Rather it seems reasonable to infer from the earlier remarks that at least fifty per cent of the improvement in

[17] In the instance of preventative health care the advances in medical science concerned the need for access to safe water supplies, improved sanitation, and public programs concerned with providing vaccinations, insecticide-treated bednets, and education in basic hygiene (such as promoting the benefits of breastfeeding) and preventative health care. As for inexpensive curative procedures this refers in particular to oral rehydration therapy for the treatment of gastroenteritis.

[18] After searching the relevant medical literature, Jones *et al*. (2003: 69) conclude: '[A]bout two thirds of the child deaths could be prevented by interventions that are available today and are feasible in low-income countries at high levels of population coverage.' And the cost of providing this medical intervention amounts to '… a few cents' worth of [insecticide-treated materials for bed nets], oral rehydration therapy, or efforts to promote breastfeeding.' (Jones *et al*., 2003, ibid.)

the level of life expectancy in this representative developing country in the period 1960 through to the early 1990s was due to the exogenous advances in the level of the relevant medical knowledge – much of which occurred many decades prior to 1960. This reasonable inference can also be drawn from the surveys of the relevant medical history and contemporary medical empirical evidence provided by Soares (2007: especially 258 – 61) and Jones *et al*. (2003). (Also see Cutler, Deaton and Lleras-Muney, 2006.)

Based on these observations it seems reasonable to assume that at best half of the 74 per cent reduction in the level of the AMR in the instance of China over the period 1960 to 1980 was due to the comparatively small increase in the level of GDPPC in this country during this period. [As the earlier argument suggests, this assumption almost certainly overstates the contribution of the rise of GDPPC. This point is in agreement with Halstead *et al*. (1985) and Banister (1987: Ch. 4) who observed, with respect to China during the relevant period, that the increase in the level of health was mainly the consequence of the application of inexpensive preventative medical knowledge.] Nevertheless this generous assumption still implies that the assumed size of the exogenous change in the level of health – about 32 per cent in the U5MR and AMR - in China could only have had a comparatively small impact on raising the rate of growth of GDPPC (2.8 per cent per annum) for this country over this period. A similar line of argument applies to Malaysia and especially Vietnam over the relevant respective initial time periods considered for these two countries.

In the instance of these three countries, therefore, over the relevant respective time periods the revised (but still significant) exogenous improvements in the level of health in these countries appear to have had little or no positive influence on the level or rate of growth of GDPPC for these respective countries. Matters are less clear cut with respect to Taiwan and South Korea due to the fact that the AMR and the U5MR rates for these two countries declined by comparatively small mounts in the initial time periods for both of these countries.

Next the point may be made that any improvement in the level of health in a developing country may only influence the rate of growth of GDPPC for this country with a time lag of a decade if not decades. This is especially so when demographic effects, resulting from the change in the level of health, are taken into account. Here is it simply

noted that the evidence presented elsewhere indicate that this argument does not seem to be valid - at least where there are significant reductions (or increases) in the level of the adult mortality rate within a particular context in a developing country. In sub-section 4.3 for instance it is indicated (amongst other things) that changes in this measure of the level of health, if it does influence the level of GDPPC for the community concerned, has an almost immediate and significant impact. (Longer-term demographic effects are being ignored here.)

It follows from the observations made in the last few paragraphs that the initial general conclusion reached in the previous sub-section still appears to apply and that the statement in PB1 is less likely to be valid once the relevant historical quasi-controlled experiment information presented earlier is taken into consideration in assessing that prior belief.

5.2 To be effective adequate health requires adequate economic institutions

If that is so then why did the improvements in the level of health in these countries, in the initial periods of interest here, not result in a significant and immediate increase in the rate of growth of GDPPC (in these respective countries)? Why were these rates of economic growth so comparatively low when they are compared with what was to come later in the countries concerned? The relevant evidence presented here in the attempt to answer these questions can only be brief. Specifically the answer appears to be found in considering the comparatively low level of economic institutions and the associated economic policies to be found in the various countries concerned and in the relevant initial time periods set out in Table 5.1. Subsequently the level of the quality of these economic institutions (as defined in Section 3) increased significantly – and associated with this change was a significant sustained increase in the rate of growth of GDPPC in each of the countries concerned.

To explain a little further, in the instance of China, for example, between at least 1960 and 1978 the economic institutions present in that country provided hardly any, if any, protection of private property rights.[19] In addition at that time there was a range of associated highly distorting economic policies in place – such as extreme restrictions on

[19] Some additional information regarding the evolution of economic institutions in China is set out in Table 5.1.

regional and international trade; comparatively high implicit tax rates imposed on producers of agricultural goods and comparatively generous implicit subsidies provided to urban consumers and heavy industry; exchange rates were highly distorted while labour migration was more or less banned (through the imposition of the ***hukou*** (registration) system). This institutional and economic policy milieu no doubt contributed to the headcount measure of poverty for the rural population of about 790 million for China around 1978 – 1980 reaching (depending on who you read and what poverty line is applied) between 75 and 100 per cent (Yao, 2000, 463 – 4 and Ravallion and Chen, 2007, 8). [At that time the rural population made up 81 per cent of the total population of China (World Bank, 2006 - 9).]

Perhaps in part because of this dire economic situation, significant changes in these economic institutional arrangements and associated economic policies were announced in December 1978 – the date of the Third Plenum of the Eleventh Central Committee of the Chinese Communist Party – and in the years immediately thereafter.[20] One consequence was the sharp and significant rise in the level of GDPPC in China between 1979 and 1988 that, in turn, contributed in a substantial way to the equally dramatic fall after 1978 in the headcount measure of rural poverty so that by the mid-1980s it was within the bounds of 10 to 25 per cent (Yao, 2000: 463 – 4, and Ravallion and Chen, 2007: 8).

Without providing the details, a similar line of argument, *mutatis mutandis*, can be applied to the relevant economic history of the other countries listed in Table 5.1. (Brief summaries of how the economic institutional framework altered over time in each of these countries are set out in Table 5.1.)

To summarise, it would appear that the application of medical technology, concerned mainly with containing diseases, of itself did little to increase the rate of growth of GDPPC in the countries concerned in an economic environment where the level of economic institutions was comparatively low. What also seems to have been required was a marked improvement in the level of economic institutions in these countries. Or was it just the significant improvements in the level of economic institutions alone in the countries concerned that induced the subsequent marked increase the rate of growth of GDPPC in

[20]The relevant historical factual details alluded to in the main text are to be found, for example, in Riskin (1987: Chs 9 to 14), Lin (1992), Lin, Cai and Li (2003), Chow (2002), Qian (2003), Liu (2005), Wu (2005: Ch 2) and Lin *et al*. (2007).

these countries? As will be indicated in the next sub-section the answer to this question probably is in the negative.

6. Some initial testing PB2

In the process of testing PB2 three historical episodes are considered: (i) the Panama Canal case from 1881 through to 1904; (ii) colonial Malaya and plantation agriculture from 1874 through to about 1901 and later, and (iii) colonial Northern Rhodesia and copper mining between 1924 and 1930 and later. Within these respective contexts the level of economic institutions was increased markedly in size over a comparatively short period of time in the communities concerned. It remains to determine what happened to the level of economic activity in these communities.

6.1 Attempts to build the Panama Canal:[21] Soon after Ferdinand de Lesseps had floated the Panama Canal Company in France, in order to raise the financial capital required for the construction of a canal across the Isthmus in Panama, work on this engineering project began in 1881. Those investing in this project, it seems reasonable to presume, believed that the private property rights regarding their investments in this project were adequately protected under French law as it applied along the canal corridor in Panama. (If not presumably this investment would not have taken place.) This behaviour therefore implies, amongst other things, that those investing in this project believed that the level of economic institutions (as defined in Section 3), as they applied along the canal corridor across the Isthmus, had increased significantly compared to the situation prior to say 1880. What is more this increase in the level of economic institutions was exogenous in the sense that French commercial law was already in place and was just being applied at least along canal corridor in Panama. The level of French commercial law clearly was independent of the level of GDPPC in Panama in the early 1880s.

Nevertheless, despite this exogenous marked increase in the level of economic institutions as they applied in this region after 1881, this engineering venture was abandoned in 1889 when the Panama Canal Company was declared bankrupt. It would

[21] The core reference employed in the main text is McCullough (1977). Other references drawn upon are Harrison (1978), Cook (1998), Hamoudi and Sachs (1999), Gallup and Sachs (2001), Keiser, Singer and Utzinger (2005), Speilman and D'Antonio (2001), Hutchinson and Ungo (2004) and Packard (2007).

appear, therefore, that the unqualified statement in PB2 is not given any empirical support by the relevant facts associated with this historical episode.

As for the reasons why the Panama Canal Company became bankrupt, besides there being some financial mismanagement, certainly there were weaknesses in the design of this engineering project. Nevertheless the central reason for the abandonment of this engineering enterprise was the exceptionally high adult mortality rate amongst the workforce employed on this project caused by the prevalence of yellow fever and malaria along the canal corridor. (The average adult mortality rate reached 333 per thousand in the mid-1880s. Along some sections of the canal corridor this mortality rate reached two out of every three workers.)

Once it was realized that these tropical diseases were undermining the economic viability of this civil engineering project there was nothing that de Lesseps and others could do to mitigate this situation. This was so since in the 1880s (and up to the late 1890s) there was no useful medical knowledge available that indicated how the tropical diseases of malaria and yellow fever could be effectively controlled. Hence there was little choice but to abandon this project – despite the apparent adequacy of the economic institutions in place to facilitate the building of this canal.

Thus, as noted earlier, the implication is that this historical episode contradicts the unqualified statement in PB2. Put differently, the new information provided by this quasi-controlled experiments suggests that the statement in PB2 is less likely to be correct than may have been thought previously.

Extending the argument a little, it later was realised, implicitly, by some in the government of the United State from about 1903 onwards that providing an adequate level of *economic* institutions (as defined earlier) was never going to provide the *complete* institutional foundation that was required to allow the construction of an economically viable canal across the Isthmus. To explain, immediately following the United States government acquiring the legal right to build the canal in 1903 the question now facing President Theodore Roosevelt was how best to proceed with this engineering project. By this time, however, major scientific advances made in the late 1890s and early 1900s had demonstrated that certain classes of the Anopholes mosquito were the vectors that carried

the malaria parasite and that *Aedes aegypti* was the vector for yellow fever. It also had been demonstrated (by William Gorgas amongst others) that a rigorous sanitation program aimed at reducing the risk of these vectors biting humans would result in a significant decline in the incidence of malaria and yellow fever in the region concerned.[22] What is more, these rigorous sanitation programs had demonstrated that this could be achieved at relatively low cost - as long as they were confined to a comparatively small geographic area.

Fortuitously this (then) new medical knowledge was known to an advisor to Roosevelt - viz. Dr William David Lambert, a medical doctor. Based on this knowledge he made the follow observation to Roosevelt: 'If you fall back on the old methods of sanitation, you will fail, just as the French failed. If you back up Gorgas [who was in charge of sanitation issues in Panama] and his ideas and let him pursue his campaign against the mosquitoes, you will get your canal.' Roosevelt promptly accepted the advice provided (McCullough, 1977: 467 – 8).

In so doing Roosevelt implicitly agreed with the argument that the creation of public health institutions, directed at drastically controlling the populations of mosquito vectors along the canal corridor at comparatively low cost, was an essential component of the institutional foundations necessary for allowing an economically viable canal to be built. And this was so even though the United States government had already provided the other essential component of this foundation; viz. the economic institutions. The construction of the Panama Canal was completed in 1914. Its construction went on to provide a range of benefits to the United States economy. Indeed, based on their calculations of the net value of these benefits to the United States, Hutchinson and Ungo (2004) concluded that the investment in the Panama Canal possibly was 'the best investment the United States government has ever made based on the social benefit relative to the cost of building it.' (A similar conclusion was reached by Maurer and Yu (2006).)

6.2 Attempting to develop the economy of Malaya: The Malaya peninsula came under British colonial rule over the period 1874 through to 1908. During this period, therefore, there was a marked exogenous increase in the quality of economic institutions applying in

[22] See, for instance, Amorosa *et al*. (2005) and Harrison (1978) on the relevant medical history regarding malaria and Bryan *et al*. (2004) on yellow fever. Also see Packard (2007: Ch. 5).

Malaya – at least as perceived by potential foreign investors in this region. And yet around the turn of the twentieth century attempts to develop the economy of this region were floundering. And this was so even though Malaya apparently had a comparative advantage, for instance, in the production of raw rubber – a raw material for which there was a growing world demand at that time.

Again the impediment to expanding the level of economic activity in this region was the comparatively low level of health, reflected in the fact that there was a relative high adult morbidity and mortality rate amongst the work force in Malaya at that time due to the prevalence of endemic malaria. For instance, in the late 1890s and early 1900s in the commercial centre of Klang individuals were continuously ill and unable to work. In addition mortality rates in the early 1900s of around 300 per thousand were not uncommon amongst the workforce employed on plantations and engineering works (Watson,1943: 342). In short, in the early 1900s attempts to build profitable plantation and mining industries in Malaya were severely constrained by the prevalence of tropical diseases. And this was so even though there had been a marked improvement in the level of economic institutions – as probably perceived by potential investors – from 1874 on to 1908.

Again the unqualified statement in PB2 does not appear to be supported by the evidence provided by this historical episode.

The economic situation changed for the better soon after Malcolm Watson began to apply, from 1901 on, the newly discovered knowledge regarding the ways in which malaria was transmitted. Specifically, programs were devised and directed at controlling populations of types of mosquitoes.[23] A certain level of economic prosperity resulted such as to cause Eric MacFadyen to observe, based on his experience as a planter in Malaya: 'Had it not been for malaria control, British Malaya … could never have been realized. Its populous towns, its railways and roads which have unlocked its natural resources, the monster dredging plants representing an outlay of millions of sterling, which excavated its tin, its 300,000 acres of rubber … not a tithe of these developments could have been achieved had malaria remained uncontrolled.'[24]

[23] See Watson (1943) and Reid and Reid (1956).
[24] MacFadyen (1938) cited in Watson (1943: 343).

This statement rather exaggerates the contribution that the controlling of malaria made to the economic development of Malaya for, as the discussion in the previous section indicates, the level attained by economic institutions is likely also to have made a contribution to the economic development of Malaya after about 1901.

6.3 Mining copper ore in Northern Rhodesia: British colonial rule of Northern Rhodesia began in 1924. The resulting exogenous increase in the level of economic institutions, as seen by potential foreign investors in this new colony, no doubt encouraged some of these investors to think seriously about investing in the mining of the known copper ore deposits in this colony. (This raw material had become more valuable due to the expansion of the electrical and motor vehicle industries in the 1920s.)

Attempts to mine these deposits profitably in the late 1920s were threatened, however, by the fact that at the Roan Antelope mine, at least, the desertion rate amongst the African work force was around 640 per thousand in 1929 and 1930. This situation meant that there was a relatively high probability that any on-the-job training given to this labour would be lost due to desertion. In addition it was difficult to attract skilled European labour to work at this mine. And these various patterns of behaviour were mainly in response to the comparatively high risk, as perceived by potential employees at this mine, of experiencing debilitating malaria or dying from this disease contracted while working at this mine. This was a real possibility since at this mine in 1930 the adult mortality rate was thirty two per thousand while in it was not uncommon for thirty per cent of the European miners to be absent sick with malaria.[25] Again it follows that the unqualified statement in PB2 tends not to be supported by this piece of history for Northern Rhodesian for the period from 1924 through to 1930.

Extending the argument a little, from 1930 on efforts began to be made to find ways to reduce, significantly, and at relatively low cost, the populations of the malaria-carrying mosquitoes *Anopheles Gambiae* and *A. Funestus* at and near the mining areas (Watson, 1953). Variations of the preventative techniques applied in Panama and Malaya were re-applied on the Roan Antelope mine and elsewhere on the Copperbelt in Northern Rhodesia. The outcome was that the adult mortality rate on this mine fell to 9 per thousand

[25] See Spearpoint (1953), Perrings (1979: 260 – 1) and Parpart (1983: 30, 41 - 42).

in 1933 and then fell slightly over the next eight years (Perrings, 1979: 260 – 1). This change in turn contributed to the desertion rate falling sharply from the previous levels to about 34 per thousand in 1932 and averaged about 60 per thousand over the next eight years.[26] In addition European skilled labour became easier to hire at the going real wage rates. A similar pattern of change was experienced at the other copper mines on the Copperbelt over this period and beyond (Utzinger, Tozan and Singer, 2001: 683).

This controlling of malaria appears to have gone on to contribute towards making copper mining in this colony a profitable enterprise especially as the copper mining industry began to expand after the mid-1930s.[27] Nevertheless other things were changing around this time such as the sharp fall in the level of aggregated demand in the world economy associated with the Great Depression of the early- to mid-1930s – a change that played a part in making the labour supply more flexible in the copper mining industry (Parpart, 1983: 47 - 50).

6.4 General conclusion: It seems reasonable to infer by considering these three case histories that the statement in PB2 is less likely to be valid once this additional information is taken into account. This quasi-controlled experimental information also suggests, however, that a sufficient exogenous improvement in the level of economic institutions most likely needs to be accompanied by the presence of an adequate level of health before the combination of these two deep determinants of economic development is likely to have a significant impact on the rate of growth of GDPPC.

This conclusion clearly is the dual of the inferences that may be drawn from the quasi-controlled experimental information presented in the previous section.

7. A sketch of how the analysis may be extended[28]

The quasi-controlled experimental evidence presented and discussed in the previous two sections suggests the conjecture that an exogenous significant improvement in the level of: (i) health in a developing county will have little or no impact on the rate of growth of GDPPC for this country if the level of economic institutions (as defined in Section 2) is

[26] See Watson (1953: 13 and 15) and Perrings (1979: 260 – 1).
[27] See Utzinger, Tozan and Singer (2002) and Utzinger, Tozan, Doumani and Singer (2002).
[28] The ideas presented in this section were first presented in Martina (2007). An extended version of these ideas is provided in Martina (2009: Ch 3).

below some threshold minimum level; (ii) economic institutions in a developing county will have little or no impact on the rate of growth of GDPPC for this country if the level of health is not at least at some minimum threshold level. Expressed slightly differently, both a threshold minimum level of health (min H) and a threshold minimum level of economic institutions (min I) need to be in place in a developing country as necessary pre-conditions that need to be satisfied before this country is likely to be capable of experiencing sustained modern economic development as a consequence of an increase in the level of at least one of these two deep determinants (viz. economic institutions and health) of economic development.[29]

These inferences imply that there are at least two broad conjectures that need to be tested (in far more detail than was provided in the previous two sections) by applying quasi-controlled experimental information. First, under certain conditions health and economic institutions are likely to be distinct deep determinants of the level and pace of economic development. Second, threshold minimum levels of both health and economic institutions need to be attained before exogenous increases in the level of either of the presumed deep determinants begins to have a significant influence on the level and rate of growth of GDPPC for the developing country concerned.

Space does not allow the detailed testing of these conjectures. [30] All that is done here is to indicate what form this testing may take through the application of quasi-controlled experimental information. First it proves useful to set out a number of modified versions of the prior beliefs presented in the Section 4. Next it needs to be indicated how these modified prior beliefs (MPBs) form part of a theoretical framework that suggests how the initial testing needs to be structured and how, above all, the various initial tests relate to one another. The third step consists, based on this framework, of carrying out the initial tests based on historical quasi-controlled experimental information. The final results

[29] The term 'modern economic development' in a country refers to the economy for this country being based on a range of modern institutions that, amongst other things, provide the incentives for economic entities to save relatively large amounts of resources that are invested in physical capital as well as human beings and, through this means allows this country to be in a position to take full advantage of relevant modern technology. This economic system also encourages households to significantly reduce their demand for children – a change that results in a reduction in the rate of growth of population for this country.

[30] This discussion is to be found in Martina (2009: Chapters 4 and 5). There some twenty-five historical episodes, that provide quasi-controlled experimental information, are considered, assessed and compared in various ways.

obtained for a given test are compared in various ways with that for the other initial tests. These comparisons should generate a more robust set of results and, thereby, allow relevant inferences to be drawn with a reasonable degree of confidence.

To expand a little on how this may be done, use is made of the representation set out in Figure 7.1. The initial assumption applied there is that in a poor developing country, with both a threshold minimum level of health (min H) and a threshold minimum level of economic institutions (min I) having been attained, it is now possible to produce a minimum level of output per capita, min X (> 0), in the modern sector of the economy for this country. If the level of health is below the threshold min H then modern economic development does not take place (viz. X = 0). (This threshold, minimum, level of H is represented by the line AB in Figure 7.1.) And this is so even if the level of economic institutions is at least at min I. (The threshold, minimum, level for I is represented by the line CD in Figure 7.1.) Similar remarks apply if the level of economic institutions is below the threshold min I and the level of H is at least at min H. Expressed more formally, at min X (> 0) both H and I must have attained at least their respective minimum values. At min X these two deep determinants are combined with one another in a Leontief fixed-coefficient 'production function' where the two deep determinants are the two 'factor' inputs: viz. at

$$X = \min X = \min (H, I) \qquad (7.1)$$

whereas if H < min H, or I < min I, or both then X = 0.

Figure 7.1 comes about here.

When one of these deep determinants initially is at its minimum level and the other is at or above its minimum level then an increase in the level of at least one of these determinants is assumed to result in a significant increase level of X. This particular case is of no immediate interest here, however. What is of interest is the general situation where either the level of H, or the level of I moves across its particular threshold minimum level. There are six (6) cases that refer to this general situation. Each case in represented by an arrow in Figure 7.1.

The first two instances (marked by arrows 1 and 2) are closely related to the cases discussed and assessed in the previous two sections. The other cases are concerned with what occurs to the level of GDPPC when the level of level of health (or the level of economic institutions) crosses its particular threshold level given some adequate level of economic institutions (or health). The dashed arrows refer to situations where the level of health and the level of economic institutions may interact with one another.

8. Some summarising conclusions

To facilitate the discussion presented in the subsequent sections it proves helpful to summarise the conclusions derived from the (omitted) detailed testing of the conjectures based on Figure 7.1. This is done by setting out the following set of posterior beliefs:

Posterior Belief (PB) 8.1: In a poor developing country if $I_t \geq$ min I and in the subsequent relevant period $I_{t+1} \geq$ min I then a significant exogenous increase in the level of health ($\Delta H > 0$) (due to a fall in the level of adult mortality rates), so that $H_t <$ min H moves to ($H_t + \Delta H =$) $H_{t+1} \geq$ min H, will increase the likelihood that this country will experience a significant and sustained increase in the rate of growth of GDPPC – other things remaining the same.

A dual statement of that just stated is the following:

Posterior Belief (PB) 8.2: In a poor developing country if $I_t <$ min I and in the later relevant period $I_{t+1} <$ min I an exogenous increase in the level of health, so that $H_t <$ min H moves to $H_{t+1} \geq$ min H (due to a fall in the adult mortality rate and/or fall in the under five child mortality rate), is unlikely to result in a significant increase in the rate of growth of GDPPC for this country – given that all other relevant variables remain the same.

To add weight to the argument that changes in the level of health do matter in certain circumstances in influencing the level of GDPPC in a country, the following also applies:

Posterior Belief (PB) 8.3: In a developing country initially $H_t \geq$ min H and $I_{t+1} \geq$ min I. Subsequently there is a significant exogenous decrease in the level of health ($\Delta H < 0$), so that $H_t \geq$ min H moves to ($H_t + \Delta H =$) $H_{t+1} <$ min H (due to a fall in the adult mortality rate). This decline in the level of H_t may have little impact on the level of I_t, or it has a negative

influence the level of I_t so that $I_{t+1} \leq$ min I. In either instance almost certainly this country will experience a significant decrease in the rate of growth of GDPPC, and the average rate of growth arrived at will remain around this comparatively low level for an extended period of time - all other relevant variables remaining the same.

In addition an adequate level of health, even though its level may not alter is size, can also act, as it were, as a catalyst in the sense of influencing the rate of growth of GDPPC for the developing country concerned.

Posterior Belief (PB) 8.4: In a poor developing country if $H_t \geq$ min H and $H_{t+1} \geq$ min H then a significant exogenous increase in the level of economic institutions ($\Delta I > 0$), so that $I_t <$ min I moves to ($I_t + \Delta I =$) $I_{t+1} \geq$ min I, will increase the likelihood that this country will experience a significant and sustained increase in the rate of growth of GDPPC – other things remaining the same.

If the level of health is not adequate, however, health appears to lose its property of being a catalyst in the sense just indicated. This is indicated by the following posterior belief:

Posterior Belief (PB) 8.5: In a poor developing country if $H_t <$ min H and $H_{t+1} <$ min H, an exogenous increase in the level of economic institutions, so that $I_t <$ min I moves to ($I_t + \Delta I =$) $I_{t+1} \geq$ min I, is unlikely to result in a significant increase in the rate of growth of GDPPC for this country – given that all other relevant variables remain the same.

It is emphasised that these various posterior beliefs are couched in the language of likelihoods – not certainties. The reason for applying this language is because it is not difficult to construct reasonable counter examples (or carry out thought experiments) that indicate that the posterior belief concerned may not apply in all (realistic) situations. For example, within the context of the statement in Posterior Belief 8.1, assume that the

developing country concerned (country A) is landlocked and is surrounded by hostile countries that refuse country A access by land to external markets. In these circumstances a marked improvement in the level of health in this country may have little impact on the level of its GDPPC even though the level of economic institutions in this country is at or above some threshold level. The important theme alluded to by this example is extended in Section 10.

9. An empirical test based on contemporary cross-county information

An inference that may be drawn from the statement of the posterior beliefs set out in the previous section is that the level of health, in combination with the level of economic institutions, across countries should go a good way towards explaining the distribution of the GDPPC for the world across countries at the end of the 20th century. If this is not the case then this would provide good grounds for questioning these posterior beliefs. This conjecture is tested here.

Before turning to developing a relevant test it is noted that in the 1970s through to the early 1990s the world's distribution of GDPPC across countries was bi-modal.[31,32] In order to indentify this income distribution, however, the GDPPC for each country needed to be ranked in order of its size. Thus it is this rank order of the GDPPC for each country that needs to be explained empirically. This will be done here by way of calculating Spearman rank order correlations coefficients for appropriate combinations of variables.

In constructing a suitable test of the conjecture of interest here first it is noted that the relevant posterior beliefs cited in the previous section suggest that the level of health in a country in a given year should have a positive influence, possibly with a lag (of say ten or more years), on the level of the GDPPC attained by this country. But the main reason for including this lag into the empirical analysis is that it will, to some degree at least, mitigate the possible influence of reverse causality. Similarly the relevant posterior beliefs cited

[31] See Bianchi, 1997; Quah 1997; Paap and van Dijk 1998; Fiaschi and Lavezzi 2003; Bloom, Canning and Sevilla 2003; Anderson 2004; Barro and Sala-i-Martin 2004: 7 – 8, Durlauf Johnson and Temple 2005: 593 – 595, Milanovic 2005: 51 – 3 and Sala-i-Martin, 2006. Recently it has been possible to take account of the distribution of personal or household incomes within countries as well when measuring the world distribution of GDPPC across countries. For the late 20th century the bi-modal distribution still emerges. See Edward (2006), for example, on this point.

[32] It is explained in Martina (2009: Chapters 3 and 9) that this fact is not inconsistent with the economic theory underlying the posterior beliefs stated in the previous section in the main text.

earlier suggest that possibly the level of economic institutions in this country is likely to have a positive influence on the lagged value of the GDPPC for this country. Finally, and most important of all these posterior beliefs clearly suggest that the level of the complementarity effect, created between the level of health and economic institutions respectively, for this country in a given year is likely to have a comparatively strong positive influence on the lagged level of GDPPC attained by this country. As for the measure of this complementarity effect for a given country in a given year, it is assumed here to take the form of the product of the levels for these two deep determinants for this country in this year.

The first conjecture to be tested, therefore, is that the rank ordering of relevant measures of health across countries should be reasonably closely correlated with the rank ordering of the lagged values of the level of GDPPC across countries. A similar conjecture applies with respect to economic institutions. The third conjecture to be tested is that the rank ordering of the measure of the complementarity effect across countries (for which relevant data is available) for the same year should be even more highly correlated with the rank ordering of the lagged values of the level of GDPPC across countries.

These rank correlation tests are applied by making use of relevant data for the late 20^{th} century to estimate the relevant Spearman rank correlation coefficients. The sources for the data and the definitions for the variables employed are set out in Table 9.1. The data for measures of health, economic institutions and education (which is a component of economic institutions as defined in Section 2) respectively are all for time periods or years prior to the years set to measure GDPPC by country (viz. 1995 and 2000 respectively). Thus the measures for economic institutions (excluding education) are for the early to mid-1980s, the measures for education are for 1980 and 1990, the levels of health are averages for the 1980s (for the child mortality rate) or the period 1960 to 2000 (for the adult and total mortality rate), while the measure for malaria is for 1994.

Tables 9.1 and 9.2 come about here.

The relevant Spearman rank correlation coefficient estimates set out in Table 9.2 all have the expected sign and are all statistically significant at the 1 per cent level and take comparative values more or less consistent with the previous conjectures. In particular, and as the previous conjectures indicated, the value of the estimated rank correlation coefficients for health and partial economic institutions (a measure that leaves out a measure of education) alone are distinctly smaller than that for the full complementarity measure (which is the product of measures of health, partial economic institutions and education). That said the values for the Spearman rank correlation coefficient estimates for all the explanatory variables are comparative large. Thus the estimates of the correlation coefficient for the various measures of health on the level of GDPPC for 1995 or 2000 are within the range – 0.72 (for total mortality) and -0.90 (for child mortality). Smaller rank correlations are estimated for partial economic institutions – viz. within the range 0.60 and 0.68. However, once these two deep determinants are combined, or either of these two deep determinants is combined with a suitable measure of education, then the relevant rank correlation coefficient estimates tend to take larger values (compared to those for health or economic institutions alone). Thus, for instance, the estimate of the rank correlation coefficient for the measure of full economic institutions on GDPPC(1995) is 0.90, or 0.88 when GDPPC(2000) is applied.[33] Most interesting of all, the relevant rank correlation coefficient estimates tend to take even larger values (compared to those for health or economic institutions alone) when some suitable measure full economic institutions is combined with a suitable measure of health (viz. the full complementarity measure). In this instance the relevant Spearman rank correlation coefficient is just over 0.93 in the instance of GDPPC (1995), and takes a value of 0.91 when GDPPC (2000) is applied. It seems fair to say that this last set of rank correlation coefficient estimates in particular is remarkably high given that many other factors, besides the full complementarity effect, also could influence the rank of order of GDPPC across countries at the end of the 20th century.[34]

[33] As indicated in Table 9.1, the term 'full economic institutions' is defined here as some relevant partial measure of economic institutions multiplied by number of years of education for some relevant age group for 1980 or 1990.

[34] The size of the data set employed for the full complementarity measure is distinctly smaller than that for the measures of health and (partial) economic institutions respectively. This is due the fact that the data sets for the measures of education are smaller than those for health and (partial) economic institutions respectively.

The results presented in Table 9.2 tend, therefore, not to contradict an implication of the posterior beliefs set out in the previous section. Thus while the level of health for a country tends to influence the level of GDPPC for this country, the empirical results set out in Table 9.2 also suggest that its full influence only comes into operation when it is combined with adequate levels of economic institutions (broadly defined to include the level of education) – as those posterior beliefs suggest.

The general line of argument developed in this section however, needs to be qualified. First this discussion has presumed that the direction of causation goes from the level of health, or economic institutions, or a composite of these variables through to the lagged level GDPPC for the country concerned. There is likely to be some reverse causality or endogeneity present, however. Within the present context, however, the relative importance of this possibility presumably has been mitigated by comparing lagged values of GDPPC with the relevant explanatory variables. In addition there is bound to be a range of other factors - besides just the deep determinants of health, economic institutions and a composite of these variables – that are likely to have had an influence on the level of GDPPC for any given country at the end of the 20th century. This matter is not considered here, however.

An implication of the last set of remarks is that the test provided here, of the posterior beliefs set out in the previous section, is not strong. Be that as it may, at least the empirical evidence provided by this test is not inconsistent with those qualified beliefs.

10. Brief comments on some related literature

(i) Comparable studies that applied a different methodology: Taken together, the qualifying remarks that have just been made and the statements in the Posterior Beliefs 8.1 and 8.2 tend to contradict the relevant findings presented in a recent literature that applies the methodology of randomized controlled trials (RCT) in the attempt to derive insights, at the micro level, into the influence that a significant increase in a particular dimension of health is likely to have on some component of economic development (such as school enrolment and attendance rates, future wage earnings and so on).[35] Before turning, however, to assess one of the relevant results generated by the application of this

[35] A survey of this literature is to be found in Jack and Lewis (2009). Also see Belli, Bustereo and Preker (2005), Miguel (2005) and Duflo, Glennerster and Kremer (2008).

methodology it is noted that in epistemology this methodology has been championed by some in the medical sciences and the economics of development (at least) as being superior to any other (methodology).[36] The argument supporting such a view is flawed, however, as Worrall (2007) has demonstrated at some length within the context of the medical sciences. Here essentially one of the main points presented by Worrall (2007: 994 – 5 and 1003 – 8) is applied in the assessment of a particular finding, based on the application of RCT, in the economic development literature.

This finding is that generated by Miguel and Kremer (2004) where was found that an intestinal de-worming program in western Kenya reduced student school absenteeism by at least a quarter in the treated (compared to the control) group of primary schools. No other beneficial effects were observed. Most important of all no mention was made of the level of economic institutions present in the community concerned or, for that matter, any other potential confounding variable.

Presuming that the Miguel-Kremer finding is correct,[37] the previously-stated posterior beliefs and their associated qualifying remarks clearly imply that this finding may well not be applicable in other developing countries. This is easily seen by applying the thought experiment that the level of economic institutions in western Kenya next falls to an extremely low level (as would be the case if, for example, social and political anarchy became prevalent). Alternatively, or in addition, this thought experiment may take the form of assuming that teacher absenteeism rises to such a high level that parents do not bother to send their children to school – even though their children have been treated for worms. Within any of these contexts the Miguel-Kremer result most likely would cease to apply.

[36] Worrall (2007: 983 for instance) cites sources that, in the past have strongly recommended the use of RCT, instead of the use of any other methodology, in the experimental medical sciences. Within the context of development economics Deaton (2009: 24, 43) cites a number of sources that suggest that RCT methodology sets the benchmark against which other methodologies should be judged.

[37] There is room for doubt regarding this matter as Deaton (2009: 39 - 40) has pointed out. First, in the Miguel and Kremer (2004) study the sample of schools included in the treated and control groups respectively in fact were not randomly. Instead they where selected in alphabetical order. Hence the balance of the basic before-treatment characteristics for each of these two groups of schools may be influenced by this method of selection. Second, only the mean school absentee rates were provided for these two groups of schools. No information is provided regarding the distribution of the absentee rates across each group. Hence there is no way of knowing if the mean level of the school absentee rate for the treated group is statistically significantly different (at the normal level of significance) from that for the control group. Hence the difference in the mean absentee rates between the two groups may just be the result of chance.

This observation actually points to a deeper more general weakness with the Miguel-Kremer finding, and that is that in all likelihood there is some confounding factor – that may be unanticipated – that emerges or applies in certain communities that has the consequence of ensuring that the Miguel-Kremer result just does not apply in these communities. Put differently, the only guarded conclusion that can be drawn from the Miguel-Kremer finding is that it is likely to hold in a particular developing country if the general set of circumstances, or the general context that applies in this country is very similar (if not identical) to that which applied in western Kenya at the time when the relevant RCT, reported by Miguel and Kremer, was performed. Alter (possibly not too drastically) these circumstances in the developing county concerned and the Miguel-Kremer result may no longer apply in this country.[38]

While these general comments apply to the Miguel-Kremer result, the same broad comments also can be applied with respect to a number of historical quasi-controlled experimental (not RCT) studies - such as those by Utzinger *et al.* (2002) and Bleakley (2007, 2009) respectively – that assess the impact that increases in the level of health have on some partial measure of economic performance. In the instance of both of the studies just cited no allowance was made for the level of economic institutions present in the particular communities being studied. More generally, these studies made no reference to, and made no allowance for possible confounders that, if present, had the potential to completely undermine the conclusions that these authors drew from their respective historical studies. (This theme is developed in more detail in Martina, 2009: Chapter 5.)

(ii) The demographic transition issue: The matter of the channels along which improvements in the level of health, in combination with an adequate level of economic institutions will influence the level of GDPPC for a developing country is far too complex an issue to be considered here.[39] Nevertheless it is noted in passing that, and as was mentioned in the introduction, it has been argued that while an improvement in the level of health in a developing country may increase its level of GDP, this improvement also will induce such a marked increase the rate of growth of population that the rate of growth of

[38] Also see Deaton (2009: 41 – 43) for a slightly different perspective regarding the issues addressed in the main text.
[39] A detailed discussion of these matters is provided in Martina (2009: Chapter 8).

GDPPC will decrease in this country. Some empirical evidence (based on highly aggregated data) to support this neo-Malthusian argument was provided by Acemoglu and Johnson (2007) and Ashraf, Lester and Weil (2009).

As a broad empirical generalization this evidence is misleading. Above all it does not take account of the wide range of demographic changes experienced by developing countries since the 1960s on. This point is explained in some detail in Martina (2009: Chapter 8).[40] Thus, as pointed out there, this statement has tended to be contradicted by the relevant empirical evidence for those developing countries that in the past have experienced the process of moving through the demographic transition. Thus in the instance of those countries listed in Table 10.1 each, in the respective relevant time period, experienced a significant fall in the child mortality rate (or rise in life expectancy in the instance of Japan) which was associated with a fall (not rise) in the total fertility rate and the rate of growth of population. During this demographic transition there also was a significant and sustained rise in the rate of growth of GDPPC.

Table 10.1 comes about here.

What is more there appear to be a satisfactory theoretical argument why a developing country will tend to experience a decline – not an increase - in the rate of growth of population as a consequence of an increase in the level of health when complemented by the presence of an adequate level of economic institutions.[41] Naturally, and not surprisingly, by altering this set of circumstances - such that the relevant complementarity effect does not come into operation since, for example, the level of economic institutions is well below their threshold level - and the outcome may well be quite different as a consequence of an increase in the level of health. (This seems to be the particular, but

[40]The argument developed in Martina (2009: Chapter 8) in fact draws heavily on Martina (1996).

[41] Specifically when the complementarity effect, between adequate levels of health and economic institutions, comes into operation this tends to create a range of new and profitable economic opportunities that provides the incentive for (altruistic) parents to expend significantly more on the education of their children in order that they may take advantage of these opportunities. To attain this end, however, parents will need (due to the limiting budget constraints that households are faced with) to reduce the number of children they desire. This change in behaviour is also encouraged by the fact that the presumed expanding economic prospects will increase the opportunity cost for mothers of acquiring and raising children. In this set of circumstances the relevant, albeit limited, empirical evidence for developing countries indicates that the total fertility rate may fall appreciably.

only, situation considered implicitly by Acemoglu and Johnson (2007) and Ashraf, Lester and Weil (2009).)

11. Conclusions

It would be an error to drawn the conclusion from the previous discussion that no attempt should be made in a poor developing country to increase the level of health in this community up to at least a threshold level in the attempt to raise the rate of growth of GDPPC in this country. On the contrary clearly that discussion indicates that raising the level of health in this community almost certainly needs to be a component, but only one, of a number of components in a range of public policies directed at achieving this end. Thus not only should the level of health be raised to at least the required threshold level but also the level of the various elements of economic institutions (as defined in Section 2) needs to be raised at least to some threshold level. Failure to implement this combination of complementary public policies (assuming that the level of economic institutions is below its threshold level), by only expending additional resources on attempting to raise the level of health, is likely to end in disappointing results being achieved regarding raising the rate of growth of GDPPC in the poor developing country concerned.

REFERENCES

Acemoglu, D., S. Johnson, and J. A. Robinson (2001). "The Colonial Origins of Comparative Development: An Empirical Investigation," *The American Economic Review* 91, 1369-1401.

_____(2005). "Institutions as the Fundamental Cause of Long-Run Growth." In Philippe Aghion and Steven N. Durlauf (Eds), Chapter 6.s

Acemoglu, D. and S. Johnson (2007). "Disease and Development: The Effect of Life Expectancy on Economic Growth," *Journal of Political Economy*, 115, 925 – 985.

Aghion, P. and S. N. Durlauf (Eds) (2005). *Handbook of Economic Growth, Vol. 1A*. Amsterdam: Elsevier.

Ahmad, O.B., A. D. Lopez, and M. Inoue (2000). "The Decline in Child Mortality: A Reappraisal," *The Bulletin of World Health Organization Bulletin* 78, 1175 – 1191.

Anderson, G. (2004). "Making Inferences About the Polarization, Welfare and Poverty of Nations: A Study of 101 Countries 1970 – 1995," *Journal of Applied Econometrics* 19, 537 – 550.

Ashraf, Q.H., A. Lester and D.N. Weil (2009). "When Does Improving Health Raise GDP?" In D. Acemoglu, K. Rogoff and M. Woodford (Eds), *National Bureau of Economic Research Annual 2008*, Vol. 23. Chicago: Chicago University Press.

Balfour, A. and H. H. Scott (1924). *Health Problems of the Empire: Past, Present and Future*. London: W. Collins Sons and Co. Ltd.

Banerjee, A. V. (2007*). Making Aid Work*. Cambridge, Mass.: MIT Press.

Banister, J (1987). *China's Changing Population*. Stanford, Stanford University Press.

Barro, R.J. and X. Sala-i-Martin. (2004). *Economic Growth* (Second Edition). Cambridge, Mass.: MIT Press.

Batten, A. and A. Martina (2007). "Diseases Dominate." In William R. Garside (Ed.), *Institutions and Market Economics*. Basingstoke, United Kingdom: Palgrave.

Belli, P.C., F. Bustereo and A. Preker. (2005). "Investing in Children's Health: What are the Economic Benefits? *Bulletin of the World Health Organization* 83, 777 – 784.

Bianchi, M. (1997). "Testing for Convergence: Evidence from non-Parametric Multimodal Tests," *Journal of Applied Econometrics* 12, 393 – 409.

Bleakley, H. (2007). "Disease and Development: Evidence from Hookworm Eradication in the American South," *Quarterly Journal of Economics* 122, 73 – 117.

_____ (2009). "Economic Effects of Childhood Exposure to Tropical Disease," *American Economics Review: Papers and Proceedings* 99, 218 – 223.

Bloom. D.E., D. Canning and J. Sevilla (2004). "the Effect of Health on Economic Growth: A Production Function Approach," *World Development* 32, 1 – 13.

Bloom. D.E., D. Canning and J. Sevilla (2003). "Geography and Poverty Traps," *Journal of Economic Growth* 8, 355 – 378.

Carstensen, K. and E. Gundlach (2006). "The Primacy of Institutions Reconsidered: Direct Income Effects of Malaria Prevalence." *The World Bank Economic Review*, 20, 309 – 339.

Chang, H.J. (2007). "Understanding the relationship between institutions and economic development – some key theoretical issues." In Ha-Joon Chang (Ed.), *Institutional Change and Economic Development*. London: Anthem Press.

Chow, G.C.(2002). *China's Economic Transformation.* Oxford: Blackwell.

Cohen, D. and M. Soto (2007). "Growth and Human Capital: Good Data, Good Results," *Journal of Economic Growth* 12, 51 -76. Associated web site for by-country levels of education is: http://www.iae-csic.uab.es/soto/data.htm.

Cook, N.B. (1998). *Born to Die: Disease and the New World Conquest, 1492 – 1650*. Cambridge: Cambridge University Press.

Cunha, C.B. (2004). "Historical Aspects of Infectious Diseases Part 1 and II," *Infectious Disease Clinics of North America* 18 (1 and 2), xi – xv and xi.

Cutler, D.M., A.S. Deaton and A. Lleras-Muney (2006). 'The Determinants of Mortality,' *Journal of Economic Perspectives* 20, 97 - 120.

Deaton, A.S. (2009). "Instruments of Development: Randomization in the Tropics, and the Search for the Elusive Keys to Economic Development." *National Bureau of Economic Research*, Working Paper 14690.

Duflo, E., R. Glennerster, R. and M. Kremer (2008). "Using Randomization in Development Economic research: A Toolkit." In T. P. Schultz and J. Strauss (Eds), *Handbook of Development Economics*, Vol. 4. Amsterdam, Elsevier, 3895 – 962.

Durlauf, S.N., P. A. Johnson and J. R. W. Temple (2005). "Growth Econometrics." In Philippe Aghion and Steven N. Durlauf (Eds), Chapter 8.

Easterly, W. and R. Levine (2003). "Tropics, Germs and Crops: How Endowments Influence Economic Development," *Journal of Monetary Economics* 50, 3 – 39.

Edward, P. (2006). "Examining Inequality: Who Really Benefits from Global Growth?" *World Development*, 34, 1667 – 1695.

Fiaschi, D. and A. M. Lavezzi (2003). "Distribution Dynamics and Nonlinear Growth," *Journal of Economic Growth* 8, 379 – 401.

Fogel, R. W. (2004). *The Escape from Hunger and Premature Death 1700 – 2100*. Cambridge, Cambridge University Press.

Gallup, J. L. and J. D. Sachs (2001). "The Economic Burden of Malaria," *American Journal of Tropical Health and Hygiene* 64, 85-96.

Grundy, E. (2005). "Commentary: The McKeown Debate: Time for a Burial," *Journal of Epidemiology* 34, 529 – 533.

Halstead, R., J.A. Walsh and K.S. Warren (Eds) (1985). *Good Health at Low Cost* New York: Rockefeller Foundation.

Hamoudi, A. and J.D. Sachs (1999). "The Changing Global Distribution of Malaria: A Review," *Centre for International Development*, Harvard University, CID Working Paper no. 2.

Harrison, G. (1978). *Mosquitoes, Malaria and Man: A History of the Hostilities Since 1880*. London: John Murray.

Heston, A.; R. Summers and B. Aten (2006). *Penn World Tables Version 6.2*. Centre for International Comparisons at the University of Pennsylvania (CICUP).

Hutchinson, W.K. and R. Ungo (2004). "Social Saving of the Panama," *Department of Economics, Vanderbilt University*, Working Paper no. 04-W23.

Jack, W. and M. Lewis (2009). "Health Investments and Economic Growth." Washington, D.C., World Bank, Policy Working Papers 4877.

Johansson, S. R. and C. Mosk (1987). "Exposure, Resistance and Life Expectancy: Disease and Death during the Economic Development of Japan, 1900 – 1960," *Population Studies* 41. 207 – 235.

Jones, G. *et al*. (2003). "How Many Child Deaths Can We Prevent this Year?" *The Lancet* 362, 65 – 71.

Keiser, J., B. Singer and J. Utzinger (2005). "Reducing the Burden of Malaria in Different Eco-Epidemiological Settings with Environmental Management: A Systematic Review," *Lancet Infectious Diseases* 5, 695 – 708.

Lewis, A. (1995). *Theory of Economic Growth*. London: Allen and Unwin.

Lin, Y.F. (1992). "Rural Reforms and Agricultural Growth in China," *American Economic Review* 82, 34 – 51.

Lin, Y.F. (2009). *Economic Development and Transition: Thought, Strategy and Viability*. Cambridge: Cambridge University Press.

Lin, Y.F., F. Cai and Z. Li (2003). *The China Miracle: Development Strategy and Economic Reform.* Stanford: Stanford University Press.

Lin, Y.F., M. Liu, S. Pan and P. Zhang (2007). "Development Strategy, Viability and Economic Institutions: The Case of China." In G. Mavrotas and A. Shorrocks (Eds), *Advancing Development: Core Themes in Global Economics*. Basingstoke U.K.: Palgrave Macmillan.

Liu, Z. (2005). "Institutions and Inequality: The *hukou* System in China," *Journal of Comparative Economics* 33, 133 – 157.

Lopez-Casasnovas, G., B. Rivera and L. Currais (Eds) (2005). *Health and Economic Growth: Findings and Policy Implication.* Cambridge, Mass.: The MIT Press.

Lorentzen, P., J. McMillan and R. Wacziarg (2008). "Death and Development," *Journal of Economic Growth* 13, 81 – 124.

MacFadyen, E. (1938). "Address to the Manson-Ross Luncheon." Annual Report, London School of Hygiene and Tropical Medicine, 1937 – 38, p. 98.

McCullough, D. (1977).*The Path Between the Seas: The Creation of the Panama Canal 1870 – 1914*. New York: Simon and Schuster.

McKeown, T. (1976). *The Modern Rise of Population*. New York, Academic Press.

Martina, A. (1996). "The Quantity/Quantity of Children Hypothesis in Developing Countries: Testing by Considering Some Demographic Experiences in China, India and Africa", *Health Transition Review*, 6 (supp.), 191 – 212. Also to be found at http://dspace.anu.edu.au/bitstream/1885/40193/1/Martina1.pdf.

Martina, A. (2007). "A Class of Poverty Traps: A Theory and Empirical Tests." http://ecocomm.anu.edu.au/research/papers/pdf/wp482.pdf

Martina, A. (2009). *Moving out of Poverty: Health and Economic Institutions and the Capability of Developing Countries to Traverse Out of Poverty Traps – Testing Various Conjectures*. Unpublished manuscript.

Maurer, N. and Yu, C. (2006). "What Roosevelt Took: The Economic Impact of the Panama Canal, 1903 – 37." Harvard Business School, Working papers 06 – 041.

Miguel, E. and M. Kremer (2004). "Worms," *Econometrica* 72, 159 – 217.

Miguel, E. (2005). "Health and Education and Economic Development." In Guillan Lopez-Casasnovas, Berta Rivera, and Luis Currais (Eds).

Milanovic, B. (2005). *Worlds Apart; Measuring International and Global Inequality*. Princeton, Princeton University Press.

North, D.C. (1989). "Institutions and Economic Growth: An Historical Introduction," *World Development* 17, 1319 – 1332.

North, D.C. (1990) *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Press.

Ohkawa, K. and Rosovsky, H. (1973). *Japanese Economic Growth: Trend Acceleration in the Twentieth Century*. Stanford, Stanford University Press.

Paap, R. and R. K. van Dijk (1998). "Distribution and Mobility of Wealth of Nations," *European Economic Review* 42, 1269 – 1293.

Packard, R. M. (2007) *The Making of a Tropical Disease: A Short History of Malaria*. Baltimore: The Johns Hopkins University Press.

Packard, R.M. (2009). " 'Roll Back Malaria, Roll in Development?': Reassessing the Economic Burden of Malaria", *Population Development Review* 35, 53 – 87.

Pande, R. and C. Udry (2005). "Institutions and Development: A View from Below." In R. Blundell, W.K. Newey and T Persson (Eds), Advances in Economics and Econometrics, Theory and Applications, Ninth World Congress, Vol 2. Cambridge: Cambridge University Press.

Parpart, J.L. (1983). *Labor and Capital on the Africa Copperbelt*. Philadelphia: Temple University Press.

Perrings, C. (1979). *Black Mineworkers in Central Africa: Industrial Strategies and the Evolution of an African Proletariat in the Copperbelt, 1911 – 41*. London: Heinemann Educational.

Pletsch, D.J. and C.T. Chen (1954). "The Economic and Social Effects of Malaria Control with Some Specific Instances from Taiwan," WHO/Mal/108, Taipei Conf./ 7.

Qian, Y. (2003). "How Reform Worked in China." In D. Rodrik (Ed), *In Search of Prosperity: Analytic Narratives on Economic Growth.* Princeton: Princeton University Press.

Quah, D. T. (1997). "Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs," *Journal of Economic Growth* 2, 27 – 59.

Ravallion, M. and S. Chen (2007). "China's (Uneven) Progress Against Poverty," *Journal of Development Economics* 82, 1 – 42.

Reid, J.W. and J. A. Reid (1956). "Malaria Control in Malaya: An Appreciation of the Work of Sir Malcolm Watson," *Journal of Tropical Medicine and Hygiene* 59, 23 – 27.

Republic of China (various years), *Statistical Yearbook of the Republic of China*. Directorate General of Budget, Accounting and Statistics, Republic of China.

Riskin, C. (1987). *China's Political Economy: the Quest for Development since 1949*. Oxford, Oxford University Press.

Rodrik, D.; A. Subramanian and F. Trebbi (2004). "Institutions Rule: The Primacy of Institutions Over Geography and Integration in Economic Development," *Journal of Economic Growth* 9, 131-165.

Sachs, J. D. (2003). "Institutions Don't Rule: Direct Effects of Geography on Per Capita Income." *National Bureau of Economic Research* (Cambridge MA), Working Paper No. 9490.

Sala-i-Martin, X. (2006). "The World Distribution of Income: Falling Poverty and … Convergence Period", *Quarterly Journal of Economics* 121, 351 – 397.

Smith, A. (1776). An Inquiry into the Nature and Causes of the Wealth of Nations, 2 volumes. London: W. Strahan and T. Cadell.

Soares, R. R. (2007). “On Determinants of Mortality Reductions in the Developing World”, *Population and Development Review* 33, 247 – 287.

Spearpoint, C.F. (1953). “African Labour Affairs at the Roan Antelope Mine, 1927 – 1950”. In Watson (1953).

Spielman, A. and M. D'Antonio (2001). *Mosquito: The Story of Man's Deadliest Foe*. London: Faber and Faber.

United Nations (1997). Demographic Yearbook 1997 – Historical Supplement. To be found at http://unstats.un.org/unsd/demographic/sconcerns/natality/nat2.htm

United Nations (1999). Demographic Yearbook 1999 – Natal Statistics: to be found at http://unstats.un.org/unsd/demographic/products/dyb/DYBNat/NatStatTab03.pdf

Utzinger, J., Y. Tozan and B. H. Singer (2001). “Efficacy and Cost-Effectiveness of Environmental Management for Malaria Control,” *Tropical Medicine and International Health* 6, 677 – 687.

Utzinger, J., Y. Tozan, F. Doumani, F. and B. H. Singer (2002). “The Economic Payoffs of Integrated Malaria Control in the Zambian Copperbelt Between 1930 and 1950”, *Tropical Medicine and International Health* 7, 657 – 677.

Vogt, W. (1948). *Road to Survival.* New York, William Sloane Associated.

Watson, M. (1943). *The Geographical Aspects of Malaria*. Washington, D.C: United States Printing Office.

Watson, M. (1953). *African Highway: The Battle for Health in Central Africa*. London, John Murray.

World Bank (2006-9). World Bank Development Indicators. Available at: http://publications.worldbank.org/ecommerce/catalog/product?item_id=631625.

Worral, J. (2007). “Evidence in Medicine and Evidence-Based Medicine,” *Philosophy Compass*, 2, 981 – 1022.

Wu, J. (2005). *Understanding and Interpreting Chinese Economic Reform*. Mason, Ohio, Thomson, South-Western.

Yao, S. (2000). “Economic Development and Poverty Reduction in China over 20 Years of Reform,” *Economic Development and Cultural Change*, 49, 447 – 474.

Table 5.1

Various relevant pieces of data for China, Malaysia, Korea, Malaysia and Taiwan.

Country	Time Periods	Average growth rate of GDPPC	Average under 5 mortality rate per 1000 Live births	Adult mortality rate per 1000 adults	Institutional Change
(People's Republic of) **China**[(a)]	1960 – 77 1979 – 88 1989 – 2005	2.8 8.7 8.9	194 (1960-64) 104 (1970-74) 50 (1980-84) 38 (1995 - 99)	661 (1960) 215 (1970) 167 (1980) 135(2000)	End of Great Leap Forward. Cultural Revolution begins 1966 and ends 1978. Institutional reform begins at end of 1978 and continues up to the present. It is associated with a wide range changes in economic policy.
Malaysia[(a)]	1961 - 1969 1972 – 84 1985 – 97	3.4 6.0 5.0	86 (1960 - 64) 53 (1970 - 74) 26 (1980 - 84) 15 (1995 - 99)	404 (1960) 256 (1970) 190 (1980) 141 (2000)	Riots in 1969. New economic policy announced in 1971. Initially import-substitution polices. Later export-orientation policies also followed. Comparatively rapid expansion of the level of education from 1957 on.
(Republic of) **Korea**[(a)]	1961 – 65 1966- 79 1980 – 2005	3.0 7.1 7.0	114 (1960 - 64) 71 (1970 - 74) 12 (1995 - 99)	374 (1960) 318 (1970 213 (1980) 141(2000)	Strictly planned centralized administrative guidance program prior to early-1960s. Subsequently series of policy changes aimed at encouraging exports (in 1960s) and heavy and chemical industries in the 1970s. Comparatively rapid expansion of the level of education form 1950s on.
Vietnam[(a)]	1985 – 91 1992 – 2005	2.8 6.7	74 (1970 – 74) 65 (1980 - 84) 40 (1995 - 99)	408(1960) 233(1980) 184(1990) 135(2000)	Institutional/economic reform begins with Doi Moi program in 1986. Civil code introduced in 1995. Institutional and economic reform still in progress.
Taiwan[(b)] (Republic of China)	1953 – 62 1963 – 79 1980 – 96	3.57 7.84 6.05	45 (1957) 38 (1960) 20 (1970) 12 (1980) 6 (1990)	458(1957) 415(1960) 336(1970) 301(1980) 212(2000)	Centrally planned economy prior to 1959 with emphasis on import substitution. From early 1960s on this policy maintained along with also encouraging exports and heavy and chemical industries. Comparatively rapid expansion of the level of education for 1950s on.

Sources: (a) Data on U5MR Ahmad et al. (2000). The rest of data is from World Bank (2006), World Development Indicators as of December 2006

(b) Various years of the Statistical Yearbook of the Republic of China (Directorate General of Budget, Accounting and Statistics, Republic of China).

Figure 7.1

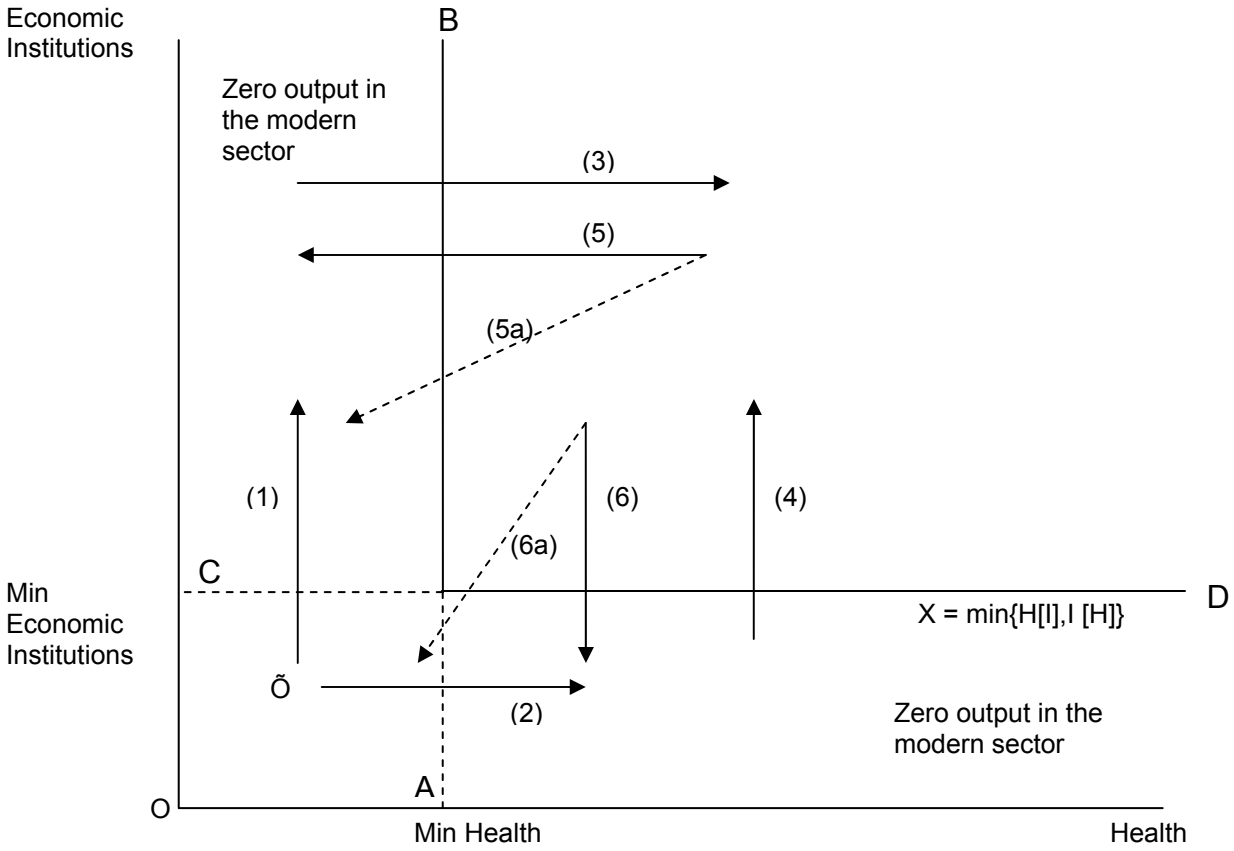
Economic Institutions
B
Zero output in the modern sector
(3)
(5)
(5a)
(1)
(6)
(4)
(6a)
C
Min Economic Institutions
D
X = min{H[I],I [H]}
Õ
(2)
Zero output in the modern sector
A
O
Min Health
Health

Table 9.1

Variables, definitions, sources and summary statistics

	Dependent Variables	Definition and Sources	Number of obs.	Mean	Std Dev.	Min	Max.
1	GDPPC (PPP) 1995	PPP ($US) adjusted per capita GDP in 1995 (constant prices: chain price series) Source: Heston, Summers and Aten (2006)	164	8084.661	8150.638	170.55	32091.43
2	GDPPC(PPP) (2000)	PPP ($US) adjusted per capita GDP in 2000 (constant prices: chain price series) Source: Heston, Summers and Aten (2006)	165	9431.127	9693.365	359.15	48217.27
	Other Variables or Regressors utilizes in various forms of regressions						
3	Malaria	Proportion of the population at risk of contracting malaria in 1994 multiplied by an estimate of the proportion of the fraction of Plasmodium falciparum cases. Sources: Gallup and Sachs (2001)	165	0.3608	0.4349	0	1
4	Under-Five Child Mortality Rate Average 1980s	Number of deaths for children under the age of five years per thousand children live births. Average for 1980 – 1989. Source: Ahmad, Lopez and Inoue (2000)	152	89.461	79.148	7.5	331.5
5	Adult Male Mortality Approx. early-1980s	Adult Male Mortality Rate (age 15 – 60). Number of male deaths per thousand in this age group. Average for 1960 – 2000 Source: Lorentzen et al. (2005)	148	0.3129	0.1361	0.126	0.573
6	Total Mortality Rate approx early- 1980s	Total Mortality Rate. Average for 1960 – 2000. Source: Lorentzen *et al*. (2005)	145	0.0128	0.0055	0.005	0.029
7	Rule of Law for early 1980s (without education)	Measure of the soundness of political institutions. A rise in the index indicates an increase in the level of the rule of law. Source: International Country Risk Guide (ICRG) Data, IRIS-3 file. Average 1982 – 1985	120	3.114	1.6167	1	6
8	Repudiation for early 1980s (without education)	Risk of Repudiation of contracts by government. Index 0 to 10. An increase in index denotes a reduction in the risk of repudiation. Source: International Country Risk Guide (ICRG) Data, IRIS-3 file. Average 1982 – 1985	120	5.6971	2.0507	2.1	10
9	Expropriation for early 1980s (without education)	Risk of expropriation of private investment. Index 0 to 10. An increase in index denotes a reduction in the risk of expropriation. Source:	120	6.171	2.0716	1.99	10

		International Country Risk Guide (ICRG) Data, IRIS-3 file. Average 1982 – 1985.					
10	Education 1	Number of years of education for 15 years of age plus for 1980. Source Cohen and Soto (2007)	93	5.5080	3.4447	0.23	12.65
11	Education 2	Number of years of education for 15 years of age plus for 1990. Source Cohen and Soto (2007)	93	6.4329	3.4230	0.44	13.21
12	Education 1	Number of years of education for 25 years of age plus for 1980. Source Cohen and Soto (2007)	93	4.7021	3.3015	0.105	11.853
13	Education 1	Number of years of education for 25 years of age plus for 1990. Source Cohen and Soto (2007)	93	5.6580	3.4019	0.218	12.444
14	Education combined with Health	[The measure of education for 1980 or 1990] multiplied by [the inverse of some relevant mortality rate for early 1980s]					
15	Full Economic Institutions: Partial Economic Institutions combined with Education	[Some relevant economic institution for early 1980s] multiplied by [the measure of education for 1980 or 1990]					
16	Partial complementarity measure	[Some relevant economic institution for early 1980s] multiplied by [the inverse of some relevant mortality rate for early 1980s]					
17	Full complementarity measure	[Some relevant economic institution for early 1980s] multiplied by [the measure of education for 1980 or 1990] multiplied by [the inverse of some relevant mortality rate for early 1980s]					

Table 9.2

Spearman Rank Correlations

Relevant Variable against GDPPC 1995 and 2000

Class of Explanatory Variable	Explanatory Variable	GDPPC 1995[1]	GDPPC 2000[1]
Measures of Health	Malaria	-0.7259* (150)	-0.7402* (152)
	Child mortality	-0.8956* (147)	-0.8846* (148)
	Adult mortality	-0.8088* (141)	-0.7993* (144)
	Total mortality	-0.7440* (139)	-0.7217* (142)
Measures of Partial Economic Institutions (viz. without education)	Rule of Law	0.6400* (116)	0.6303* (118)
	Repudiation	0.6261* (116)	0.6025* (118)
	Expropriation	0.6849* (116)	0.6569* (118)
Measures of Education	Number of years of education 25 years plus in 1990	0.8731* (92)	0.8476* (92)
	Number of years of education 15 years plus in 1980	0.8716* (92)	0.8470* (92)
Partial Complementarity Measure: Partial Economic Institutions (viz. without education) combined with Health	(Rule of Law) / (Child mortality 1970 - 89)	0.8404*	0.8350*
	(Expropriation)/(Child mortality 1970 – 89)	0.8601*	0.8549*
Education combined with health	(Number of years of education 15 years plus 1980) / (Child mortality rate 1970 - 89)	0.9101* (91)	0.8945* (92)
	(Number of years of education 15 years plus 1980) / (Total mortality rate)	0.9049* (87)	0.8799* (91)

Full measure of Economic Institutions: Economic Institutions combined with education	(Number of years of education 15 years and above in 1980) x repudiation	0.9040* (86)	0.8807* (87)
Full Complementarity Measure: Partial Complementarity Measure Combined with some measure of education	[Rule of Law / child mortality 80-90] x (Number of years of education 15 years and above in 1980)	0.9301* (85)	0.9122* (86)
	[Repudiation / child mortality 80-90] x (Number of years of education 15 years and above in 1980)	0.9320* (81)	0.9073* (86)
	[Repudiation / total mortality rate] x (Number of years of education 15 years and above in 1990)	0.9365* (81)	0.9128* (86)

*Correlation coefficient significant at the one per cent level.
[1]Data in brackets refers to the number of observations.

Table 10.1

Various relevant pieces of data for Japan, China, Malaysia, Korea, Vietnam and Taiwan.

Country	**Time Period**	**Average growth rate of GDPPC**	**Adult mortality rate per 1000 adults**	**Average under 5 mortality rate** per 1000 live births	**Life expectancy at birth**	**Total fertility rate**	**Average population growth Rate per annum (%)**
Japan[(a) (d)]	1937- 1956 1955 1956 1956 - 1969	0.53 9.0 8.6 11.31		49 (1955 – 59) 35 (1960 – 64) 22 (1965 – 69)	46.9 (1935-36) 23.9 (1945) 42.6 (1946) 61.9 (1952) 63.6 (1956) 65.5 (1960)	 3.638(1950) 2.365 (1955) 2.006 (1960) 2.011 (1961 – 65) 2.008 (1966-70)	1.3 1.02
(People's Republic of) **China**[(b) (d)]	1960 – 77 1979 – 88 1989 – 2005	2.8 8.7 8.9	661 (1960) 215 (1970) 167 (1980) 135(2000)	194 (1960-64) 104 (1970-74) 50 (1980-84) 38 (1995 - 99)		6.06 (1968) 3.32 (1978) 2.5 (1983) 1.95 (1.993)	2 1.5 1
Malaysia[(b) (d)]	1961 1972 – 84 1985 – 97	3.5 6.0 5.0	404 (1960) 256 (1970) 190 (1980) 141 (2000)	86 (1960 - 64) 53 (1970 - 74) 26 (1980 - 84) 15 (1995 - 99)		6.83 (1953) 5.59 (1968) 4.76 (1978) 4.00 (1988) 3.62 (1993)	3 2.5 2.5
(Republic of) **Korea**[(b) (d)]	1961 – 65 1966- 79 1980 – 2005	3.0 7.1 7.0	374 (1960) 318 (1970 213 (1980) 141(2000)	114 (1960 -64) 71 (1970 - 74) 12 (1995 - 99)		6.07 (1958) 4.52(1968) 2.59 (1978) 1.7 (1985)	3 2 1
Vietnam[(b) (d) (e)]	1985 – 91 1992 – 2005	2.8 6.7	408(1960) 233(1980) 184(1990) 135(2000)	74 (1970 – 74) 65 (1980 - 84) 40 (1995 - 99)		5.85 (1973) 4.69 (1983) 3.30(1985 - 90) [(e)] 2.60 (1990 – 95) [(e)]	2 1