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The Primacy of Institutions Reconsidered: The Effects of Malaria Prevalence in the Empirics of Development

by

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Abstract:
I reconsider the primacy of institutions over geography as an explanatory factor of cross-country differences in economic performance, which has recently been postulated by Acemoglu et al. (2001) and others. My estimates show that the reported missing direct performance effects of a measure of geography such as malaria prevalence are not robust to alternative specifications and samples. Unbiased estimates of the relative performance effects of institutions and malaria prevalence are difficult to obtain due to a lack of independent instrumental variables. Conditional on a restricted effect of institutions, my estimates suggest that malaria prevalence exhibits a large negative direct impact on economic performance, as postulated by Sachs (2003) and others.

Key Words: Economic development, institutions, malaria prevalence

JEL Classification: 01, 04

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1. Introduction

The vast differences in average income between the world's richest and poorest nations have been explained in many ways by economists, historians, and other social scientists. One respected strand of the literature has emphasized the preeminent role of physical geography in explaining cross-country differences in the level of development. Earlier studies along this line of reasoning include Lee (1957) and Karmack (1976), more recent contributions include Landes (1998) and, from outside of economics, Diamond (1997). By contrast, the vast empirical growth literature of the last two decades has largely neglected physical geography as a relevant dimension of analysis. What is more, some recent empirical studies that do consider measures of geography deny any direct impact of geography on the level of economic development (Hall and Jones 1999, Acemoglu et al. 2001, Easterly and Levine 2003, Rodrik et al. (forthcoming)). These studies emphasize the primacy of institutions over geography by suggesting that geography-related variables like disease ecology will not affect the level of development directly but only through their effect on institutions, if at all.

While development economists can easily agree on the relevance of good institutions for successful development, there is, however, no agreement on the role of geography in the recent empirical literature. Partly by highlighting the arguments of the older literature and partly by presenting new empirical evidence, Jeffrey Sachs and coauthors have argued in a series of papers that measures of geography such as malaria prevalence may directly impact on the level of economic development in addition to the impact of the institutional framework of a country (Bloom and Sachs 1998, Gallup et al. 1999, Gallup and Sachs 2001, Sachs 2001, McArthur and Sachs 2001, Sachs and Malaney 2002, Sachs 2003). The main disagreement in the present debate is about the robustness of the empirical evidence presented by Sachs and his coauthors, which has been questioned by the studies that favor the primacy of institutions.

I focus on this specific empirical aspect of the ongoing debate by reconsidering the evidence that has been presented in favor of the primacy of institutions relative to geographic factors. Using new data provided by Sachs (2003), I employ alternative samples of countries and various specifications of the estimation equation in order to assess whether the prevalence of malaria, which is obviously related to geographic and climatic conditions, has a statistically significant and economically important effect on economic performance once institutional quality is controlled for. A robust answer to this empirical question may have substantial implications for devising appropriate international development policies. For instance, foreign aid may mainly be targeted on initiating policy reform and on improving institutions in impoverished countries if no direct development effects of malaria prevalence can be identified empirically. But given that there are direct performance effects of malaria prevalence, foreign aid may also be spend on solving biophysical or technological problems, which, are specific to public health in tropical countries. Especially in Sub-Saharan Africa, poor countries may need something in addition to good institutions to overcome the constraints imposed on them by geography. They may actually require direct interventions, backed by donor assistance, to address disease prevalence and low technological productivity that trap them in poverty (Sachs et al. 2004).

Rodrik et al. (forthcoming) and Acemoglu et al. (henceforth AJR) (2001) a priori dismiss the possibility that a measure of geography like malaria prevalence could have a large effect on economic performance. They argue that tropical diseases like malaria are unlikely to be the reason why many countries in Africa and Asia are very poor today just because people in areas where malaria is endemic may have developed various types of immunities against such diseases. According to this view, strong performance effects of malaria are implausible because malaria is a debilitating rather than fatal disease, with the risk of malaria severity and death mainly limited to non-immunes such as children below the age of five and adults who grew up elsewhere, like European settlers.

But even if the health effects of malaria on the adult population cannot justify large performance effects, which is at least open to debate, one form of immunity against malaria also comes at a cost for the adult population. The sickle cell trait provides protection against malaria without serious health complications when inherited from one parent, but the same allele inherited from both parents is fatal, leading to sickle cell anemia.[1] Sickle cell anemia generates severe pain episodes and increasing infections, i.e. outcomes that are at least comparable to the direct negative health effects of malaria experienced by non-immunes. These considerations suggest that due to natural selection, areas with a high prevalence of malaria are likely to be areas with a high prevalence of sickle cell anemia. Some estimates appear to suggest that up to 40 percent of the population in tropical Africa may carry the sickle cell trait.[2] Hence given that a high degree of malaria prevalence reflects natural selection in favor of a high degree of prevalence of the sickle cell trait, there is at least an additional possibility that geography may affect economic performance directly through poor health and absenteeism of the workforce, and not only through its possible effect on the adoption of specific institutions.

2. Specification and Basic Results

In line with the empirical studies by AJR (2001) and Sachs (2003), I use the following cross-country regression equation to estimate the relative effects of institutional quality (*INSTITUTIONS*) and malaria prevalence (*MALARIA*) on economic performance, which is here measured by the logarithm of gross domestic product per capita (*LNGDPC*):

(1) $$LNGDPC_i = \beta_1 + \beta_2 \cdot INSTITUTIONS_i - \beta_3 \cdot MALARIA_i + \varepsilon_i \ ,$$

[1] For information on sickle cell anemia, see http://www.scinfo.org/ (April 2004).
[2] See http://www.pbs.org/wgbh/evolution/library/01/2/l_012_02.html (April 2004).

where ε_i is an error term with zero mean and common variance, and β_2 and β_3 are the coefficients of interest.

Controlling for the potential endogeneity of the measure of institutional quality, AJR (2001) find that β_3 is statistically not different from zero, which implies that there are no direct development effects of malaria prevalence. Using the same basic approach but partly different data, Sachs (2003) additionally controls for the potential endogeneity of the measure of malaria prevalence and finds that β_3 is statistically different from zero, negative, and quantitatively important.

In order to understand where the different results come from, I start with the following two premises, both suggested by AJR (2001). First, studying the impact of institutions on development has to focus on a sample of former colonies because only this sample provides the necessary exogenous variation in measures of institutions that can be exploited to estimate a causal effect. Second, the potential endogeneity of any measure of institutional quality should be controlled for by a measure that is correlated with the present variation in the institutional frameworks without being influenced by present economic conditions. In this context, European settler mortality in the early 19th century appears to be the most plausible instrumental variable that has been suggested to date.

Differences in early settler mortality across colonies, which were well known in Europe at the time of settlement, may explain the differences in institutional frameworks that were created by the colonizing powers. For instance, regions with low mortality were favored for settlement, and colonies of settlers implemented for themselves a set of institutions that resembled the institutions of their home countries by establishing property rights, the rule of law, and checks against government power. In regions were large-scale settlement was not feasible for Europeans due to an unfavorable disease ecology and high rates of mortality, the colonial powers imposed a different set of institutions that did not protect private property and did not provide protection against expropriation but instead mainly focused on the extraction of natural resources. Since early settler mortality is certainly independent from present economic conditions, and since early institutional frameworks have proved to be fairly persistent over time (AJR 2001), settler mortality across former colonies can be used as an instrumental variable that helps to identify the exogenous cross-country variation in present institutional frameworks.

Hence my sample of countries is limited to former colonies for which data on early settler mortality are available. AJR (2001, Tab. 7, p. 1392) estimate equation (1) for a sample of 62 countries. The first column in Table 1 replicates their result, with (a more recent estimate of) log GDP per capita in 1995 (*lngdpc*) as the dependent variable, an index of the protection against expropriation in 1985-95 (*exprop*) as the measure of institutional quality, and the prevalence of malaria falciparum in 1994 (*mfalajr*) as the measure of malaria prevalence.[3] The logarithm of settler mortality in the early 19th century (*lnmort*) is used to instrument for the measure of institutional quality.

For the case of single equation estimation, a rule of thumb by Staiger and Stock (1997) suggests that the empirical relevance of the chosen instrument should be assessed before the results of the instrumental variables (IV) estimates are to be considered in detail. According to the Staiger-Stock rule, an instrument can be considered as relevant if the first stage regression of the endogenous explanatory variable on the instruments produces an F-test statistic that is larger than 10. The first stage regression of *exprop* on *lnmort* produces an F-test value of 22.4, which confirms the statistical relevance of the chosen instrument.

With my first specification in Table 1 (column (1)), I estimate a coefficient of the measure of institutional quality that is statistically significant, positive (as expected), and quantitatively important. The point estimate of β_2 reflects the change in log out put per capita associated with a one-unit increase in measured protection against expropriation. Hence $\beta_2 = 0.69$ implies that a difference of 0.1 in the measure of protection against expropriation is associated with a 0.69 percent cross-country difference in output per capita. To see the potential magnitude of the estimated effect of the measure of institutions on economic performance, I compare two countries which represent about the 75th and the 25th percentile of the index of protection against expropriation in the sample, say

[3] See the appendix for the sources and a detailed description of all the variables that are used in the subsequent analysis.

Malta with an index value of 7.2 and Nicaragua with an index value of 5.2. This difference in protection against expropriation is predicted to result in a 1.4-log-point difference ((7.2 – 5.2) times 0.69) between the log per capita GDPs of the two countries. That is, the per capita GDPs of Malta and Nicaragua are predicted to differ by a factor of about 4 due to institutional differences, whereas their actual per capita GDPs differ by a factor of about 6 in my sample.

Since an OLS estimate of β_2 (not shown) turns out to be substantially smaller ($\beta_{2(OLS)} = 0.34$) than the IV estimate, this interpretation may overstate the performance effect of institutions due to measurement bias, which would imply that the 25th and 75th percentiles of the measured institution variable differ from the 25th and 75th percentiles of the true measure of institutions. One way to assess this possibility is to apply the IV estimate to the difference between the maximum and the minimum of the measured institution variable, as discussed in detail in Hall and Jones (1999). For the AJR sample of countries, the measured protection against expropriation ranges from a low value of 3.5 in Zaire to a high value of 10.0 in the United States. Hence by ignoring measurement error, one would predict a range of variation in GDP per capita by a factor of about 89 ($e^{0.69\cdot(10.0-3.5)}$), whereas the per capita GDP of the richest (United States) and the poorest (Tanzania) country of the sample only differs by a factor of about 60. Adjusting for the effect of measurement error by multiplying the IV estimate with the square root of the ratio of the OLS and IV estimates, one finds that differences in the measure of institutions can account for cross-country differences in GDP per capita by a factor of about 23 ($e^{\sqrt{0.34/0.69}\cdot 0.69\cdot(10.0-3.5)}$). This figure implies that the measure of institutions can probably account for about one third rather than two thirds of the observed inter-country difference in GDP per capita.

In a further twist of the argument, the institution coefficient may also be considered as downward biased. Since malaria prevalence can be expected to be an endogenous variable, controlling for it directly without instrumenting as in column (1) should result, all other things constant, in a downward biased standard error of the estimated coefficient and in a downward biased coefficient of the measure of institutional quality, as argued by AJR (2001). As column (1) shows, the coefficient of the measure of malaria prevalence (β_3) turns out to be statistically not different from zero, despite an expected bias towards statistical significance. This finding appears to provide strong support for the hypothesis of the primacy of institutions over geography.

The same conclusion emerges if a broader measure of institutional quality is used, namely an index of the quality of the social infrastructure of a country (*socinf*), which was suggested by Hall and Jones (1999). This index is defined as an average of an index of the quality of government and an index of the degree of trade openness. The index of the quality of government in turn averages five variables, including an index of the risk of expropriation (the other variables are law and order, bureaucratic quality, corruption, and government repudiation of contracts); the index of trade openness identifies the fraction of years in 1950-

1994 that an economy has been open, where openness applies if, among other things, trade restrictions and black market premiums for the exchange rate do not exceed certain thresholds.

Although I use a different sample of countries, a different dependent variable, and a different instrumental variable, my results in column (2) of Table 1[4] by and large reproduce findings by Hall and Jones (1999, Tab. VI, p. 111), who report a statistically significant coefficient of social infrastructure of about 5 and statistically insignificant coefficients of a number of separately included additional variables (malaria prevalence is not considered as an additional variable). To assess the magnitude of the estimated effect of the measure of institutions on economic performance, I again compare two countries, which represent about the 75th and the 25th percentile of the index of social infrastructure in the sample, says Venezuela with an index value of 0.46 and Angola with an index value of 0.21. This difference in the measure of social infrastructure is predicted to result in a 1.1-log-point difference between their log per capita GDPs. That is, the per capita GDPs of Venezuela and Angola differ by a factor of about 3 due to institutional differences, which is the same factor by which the per capita GDPs of the two countries differ in my sample.[5]

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[4] For this specification, the first stage F-test value equals 32.0. Hence *lnmort* can be considered as a statistically relevant instrument for *socinf*.

[5] This interpretation may substantially overstate the performance effect of institutions. Measured social infrastructure ranges from a low value of 0.113 in Zaire to a high value of 0.973 in the United States. Hence even by ignoring measurement error, one would predict a range of variation in GDP per capita by a factor of about 41 ($e^{4.33\cdot(0.973-0.113)}$), which accounts for about two thirds of the actual variation in GDP per person across the sample of

As before, I find a statistically insignificant coefficient of the measure of malaria prevalence. Thus the finding of the primacy of institutions over geography appears to be robust to alternative measures of institutional quality.

Next I consider alternative measures of malaria prevalence to check the robustness of the primacy of institutions. The specification in columns (3) of Table 1 uses an updated version of the measure of the risk of infection with malaria falciparum (*malfal*). Notwithstanding substantial revisions relative to the malaria data that were used by AJR (2001), the results in column (3) are still broadly in line with the initial AJR findings. Given that malaria prevalence should be treated as an endogenous variable and hence be instrumented, the statistically weakly significant coefficient cannot be interpreted as strong evidence in favor of a direct negative effect of malaria on economic performance.

The results presented in column (4) introduce a new measure of malaria prevalence (*malrisk*) suggested by Sachs (2003). The new measure is based on the prevalence of non-fatal species of the malaria pathogen (Plasmodium vivax, P. malariae, P. ovale). For international comparisons, the new malaria measure may provide a more accurate measure of the share of the population that is at risk of malaria infection than the measure used by AJR (2001). The reason is that the effects of previously used measures of malaria prevalence are difficult to

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countries. Adjusting for the effect of measurement error with $\beta_{2(OLS)} = 2.36$ (not shown), one finds that differences in the measure of social infrastructure can only account for less than a third of the actual sample variation in GDP per capita ($e^{\sqrt{2.36/4.33}\cdot 4.33\cdot(0.973-0.113)} = 15.6$).

separate from the effects of continental dummies because Sub-Saharan Africa has a high proportion of malaria falciparum cases, whereas a relatively higher proportion of malaria vivax is reported for the Americas, Europe, and much of Asia. However, I do not find a statistically significant performance effect of the new malaria measure based on the specification of column (4).

As a further robustness test, I consider a different dependent variable but otherwise the AJR specification for the sample of 62 former colonies. In column (5), I use GDP per working-age person in 1990 (*lngdpw*) instead of GDP per capita in 1995 as the dependent variable. I find a somewhat reduced coefficient of the measure of institutions and a statistically significant large negative effect of the measure of malaria prevalence. Abstracting from measurement error, my point estimate of β_3 would predict that the per worker GDPs of, say, Brazil and Pakistan, which roughly represent the 40^{th} and the 60^{th} percentile of the highly stratified distribution of the chosen measure of malaria (with percent values of 0.04 for Brazil and 0.54 for Pakistan), should differ by a factor of about 1.7 due to the differences in the proportion of the population that lives with the risk of infection with malaria falciparum, whereas the actual per worker GDPs of these two countries differ by a factor of about 2.4 in my sample. This finding should not be taken too seriously, however, because of the potential endogeneity of any measure of malaria prevalence. Nevertheless, it shows that the reported findings of insignificant malaria effects (AJR 2001, Rodrik et al. (forthcoming)) are not robust with respect to an alternative dependent variable.

A statistically significant coefficient of the malaria measure is also confirmed by my last individual robustness check, which considers the sample of countries. Instead of increasing the sample size as in previous papers that take issue with the AJR result of the primacy of institutions (McArthur and Sachs 2002, Easterly and Levine 2003, Sachs 2003, Rodrik et al. (forthcoming)), I delete all countries from the AJR database which are small (less than one million inhabitants in 1990), which depend mainly on oil production (Gabon), or which are known to provide unreliable statistics (rated as "D"-countries in Summers and Heston (QJE 1991)). Using the same specification as in column (1), column (6) reports the results for a sample of 45 former colonies that are neither small, nor dependent on oil production, nor statistical terra incognita. For this sample, I again find a large negative statistically significant coefficient of the measure of malaria prevalence.

Thus up to this point, my results show that the AJR finding of a statistically insignificant coefficient of the measure of malaria appears to be robust to an alternative measure of institutions and to two alternative measures of malaria prevalence, but it is apparently not robust to using an alternative dependent variable or an alternative sample of countries. Column (7) combines my four robustness checks of the basic AJR result in one specification: a different dependent variable, a different measure of institutional quality, a different measure of malaria prevalence, and a different sample. With this specification, I also find a large negative statistically significant coefficient of the malaria measure. However, the statistically significant coefficients reported in columns (5), (6), and (7) may only reflect the endogeneity of the measure of malaria prevalence and, therefore, are neither rejecting the AJR result nor confirming the Sachs result of a direct impact of malaria prevalence on economic performance.

3. Controlling for the Endogeneity of Malaria Prevalence

In the following, I continue with the specification of column (7) of Table 1 for my small sample of countries but now use alternative instruments to control for the potential endogeneity of the malaria measure. My first instrument is a new measure of malaria ecology (*maleco*), which was developed by Kiszewski and Sachs et al. (2004) and first used for cross-country regressions by Sachs (2003). Since this measure of malaria ecology is only built upon climatic factors and specific biological properties of each regionally dominant malaria vector, Kiszewski and Sachs et al. (2004) argue that *maleco* is exogenous to public health interventions and economic conditions, and thus can be considered as a valid instrumental variable in regressions of economic performance on malaria risk.

More specifically, the index of malaria ecology developed by Kiszewski and Sachs et al. (2004) is meant to measure the contribution of regionally dominant vector mosquitos to the *potential* transmission intensity of malaria. Hence it includes regions where malaria is not currently transmitted, but where it had been transmitted in the past or where it might be transmitted in the future. The construction of the index proceeds in two basic steps. First, the regionally dominant vector Anopheles is identified across countries in which malaria is or has been endemic. The criteria for the identification of the dominant vector are its longevity and its human-biting habit.

Abstracting from all detail, the index of malaria ecology is calculated in a second step according to

$$(2) \qquad \frac{a_i^2 p_i^E}{-\ln p_i} \ ,$$

where i is the identity of the dominant malaria vector, a is the proportion of vector i biting people [0,1], p is the daily survival rate of vector i [0,1], and E is the length of the extrinsic incubation period in days, which mainly depends on average temperature and differs between P. falciparum and P. vivax. Hence the index value for a specific country is measured as a function of climatic factors that determine the required habitat of the dominant vector and of specific biological properties of the region-specific dominant vectors. Since the region-specific dominant malaria vector only reflects the forces of biological evolution, it can be considered as independent from present economic conditions. That is, terms likely to be affected by economic conditions or public health interventions (like mosquito abundance, for example) do not enter equation (2). Overall, the calculated index shows that due to vector specific properties, a given malaria intervention is likely to have a smaller impact in the tropics than in more temperate climatic zones.

Column (1) of the first panel of Table 2 reproduces the principal finding by Sachs (2003) that conditional on a measure of institutional quality, the coefficient of the malaria measure turns out to be negative, economically important, and statistically significant, given that its potential endogeneity is controlled for by *maleco*.[6] Compared to the results of column (7) in Table 1, my estimated coefficient of the measure of institutional quality is now reduced to about two thirds of its size, and the coefficient of the measure of malaria prevalence is increased by about two thirds. The latter finding is quantitatively by and large in line with results reported by Sachs (2003) for a number of different specifications and samples. The former finding is unexpected because, all other things constant, controlling for the potential endogeneity of malaria prevalence should have increased the coefficient of the measure of institutional quality, not reduced it. Hence the question arises whether the Sachs result based on the new instrumental variable *maleco* stands up to similar robustness checks as the ones performed on the AJR result in the previous section.

For instance, Rodrik et al. (forthcoming) doubt that *maleco* is actually exogenous to present economic conditions. They criticize that Sachs (2003) does not go into the details of the construction of the index and point out that

[6] A regression of *malrisk* on *maleco* produces an F-test value of 25.5 for the small sample and of 46.7 for the large sample, which confirms the statistical relevance of the instrumental variable *maleco*.

Kiszewski and Sachs et al. (2004) do not discuss exogeneity at all.[7] While this critique is technically correct, I do not think that doubts regarding the exogeneity of *maleco* are justified, as explained above. Nevertheless, it would be reassuring if the finding of a statistically significant malaria coefficient could be replicated with other instrumental variables as well.[8]

I consider two alternative instruments that relate to the climatic preconditions for malaria, namely temperature and rainfall. Since a key part of the life cycle of the parasite depends on a high ambient temperature, malaria is intrinsically a disease of warm environments. Malaria also depends on adequate conditions of mosquito breeding, mainly pools of clean water, usually due to rainfall ending up in puddles and the like. Hence the prevalence of frost (*frost*), measured as the proportion of a country's land receiving five or more frost days in that country's winter, or the degree of humidity (*humid*), measured as the highest temperature during the month when average afternoon humidity is at its highest, may be considered as appropriate instrumental variables that are exogenous to economic conditions. Both variables happen to be correlated with

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[7] Online information on the construction of the malaria transmission index (malaria ecology) is available at http://www.earth.columbia.edu/about/director/malaria/index.html. A previous version of the text describing the construction of the index may have contributed to the impression that *maleco* is not purged of endogeneity because it stated that a measure of mosquito abundance is included in the calculation. However, observed mosquito abundance only enters the index of malaria ecology as a screen for precipitation data, where the independently identified dominant malaria vector is assumed to be absent from the specific site under consideration if precipitation falls below 10mm per month.

[8] For instance, AJR (2001) point out that their result validates using absolute distance from the equator as an instrument for a measure of institutions, as in Hall and Jones (1999).

my preferred measure of malaria prevalence and thus can be considered as statistically relevant instruments, at least for my larger sample of countries.[9] Columns (2) and (3) of the first panel of Table 2 show that using either *frost* or *humid* as an additional instrument results in statistically insignificant coefficients of both the measure of malaria prevalence and the measure of institutional quality. To exclude the possibility that this outcome is determined by the specific sample employed, columns (4)-(6) of the first panel of Table 2 repeat the specifications for a larger sample of countries. A similar pattern of results emerges. If either *frost* or *humid* is used as an instrument instead of *maleco*, both coefficients of interest are estimated to be statistically not different from zero. If *maleco* is used as an instrumental variable along with *lnmort* (column (4)), the point estimate of the coefficient of the measure of malaria prevalence remains statistically significant and of a size that is larger though broadly in line with my previous estimates, but the coefficient of the measure of institutions now becomes statistically insignificant. This finding for the larger sample reverses the basic result reported by AJR (2001).

An apparent problem that bedevils the estimates in the first panel of Table 2 is that the instruments *lnmort*, *frost*, and *humid* are all proxies for geographic and climatic conditions and thus may not be able to identify independent

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[9] A regression of *malrisk* on *frost* produces an F-test value of 6.0 for the small sample and of 15.1 for the large sample; a regression of *malrisk* on *humid* produces an F-test value of 8.7 for the small sample and of 20.1 for the large sample. The stronger correlation between *malrisk* and *maleco* is probably due to the additional inclusion of the specific biological properties of the dominant malaria vector in the index.

exogenous variation between measures of institutional quality and measures of malaria prevalence. A priori, the same should hold for *maleco*. For instance, early settler mortality is likely to reflect early disease prevalence, including the prevalence of malaria, which in turn should be related to *maleco* because this measure is only based on climatic and biological factors that did not change substantially over the last 200 years. Put differently, *lnmort* could probably also be used as an instrument for a measure of malaria prevalence: an OLS regression of *malrisk* on *lnmort* yields an F-statistic of 66.7.

By reversing the basic AJR (2001) approach, the second panel of Table 2 considers a specification where the measure of malaria prevalence is instrumented by alternative variables, but the measure of institutions is not instrumented. Taken at face value, my results now seem to suggest that malaria prevalence rather than institutional quality matters for explaining international differences in output per worker. With one exception (column (5)), I find that the coefficient of *socinf* is not different from zero, whereas the coefficient of *malrisk* is always estimated to be statistically significant and larger than before. This result should of course not be interpreted as evidence against the relevance of institutions for economic performance. But it reveals that by the same reasoning, the AJR (2001) results should not necessarily be interpreted as evidence against the relevance of malaria prevalence for economic performance. In my reading, both sets of results only demonstrate that statistically significant robust IV estimates of the two coefficients of interest are difficult to come by, due to the high correlation of the available instrumental variables.

In light of this reinterpretation, it may be useful to consider an OLS estimate of equation (1) as a point of reference for assessing the relevance of measurement error relative to endogeneity bias and omitted variable bias in the interpretation of the coefficients of interest. As noted before, Hall and Jones (1999) and Acemoglu et al. (2001) report a substantial difference between their OLS estimates and their IV estimates of the performance effect of institutions and interpret this difference as indicating the dominance of measurement error over endogeneity bias. The third panel in Table 2 shows that an alternative interpretation is possible.

The first column of the third panel of Table 2 reports the results of an OLS estimate of the same specification and sample as in the first panel. In contrast to the findings reported in the literature, I do not find a large discrepancy between my IV estimates and my OLS estimates: the coefficients of the measures of institutions and malaria in column (1) of panel 1 are not statistically different from the coefficients in column (1) of panel 3, hence measurement error and endogeneity bias appear to cancel out or may not be quantitatively important. The same holds at least with respect to the malaria coefficient for my larger sample of countries (column (4)).

Column (2) and column (5) of panel 3 drop the measure of malaria from the OLS specification. By definition, an omitted variable bias results in a larger coefficient of the remaining variable, in this case the measure of institutions. If the measure of institutions is instrumented by a variable that is highly correlated with the omitted variable, the estimated coefficient of the measure of institutions will increase further. This is shown in columns (3) and (6) of panel 3, where *lnmort*, which is highly correlated with *malrisk* as noted before, is used as an instrument for the measure of institutions. The estimated coefficients of about 3 (OLS) and 5 (IV) by and large resemble the findings reported by Hall and Jones (1999) for a different sample and a set of different instrumental variables, where at least one of their instruments is highly correlated with a measure of malaria prevalence.[10] My reading of the results of panel 3 is, therefore, that omitted variable bias rather than measurement error is a plausible explanation for the positive difference between IV estimates and OLS estimates of the coefficient of institutions.

My reinterpretation of reported results in the literature in light of an omitted variable bias is in line with the hypothesis that a measure of geography like malaria prevalence could possibly affect economic performance directly in addition to the direct performance effects of institutions. However, a clear-cut interpretation of the empirical evidence appears to be constrained by the lack of independent instrumental variables. Therefore, I turn to imposing restrictions on

[10] For a sample of 127 countries, Hall and Jones (1999) report a coefficient of about 5 of the measure of social infrastructure for a specification where absolute distance from the equator is used as one of the instrumental variables; they report a coefficient of about 3 as their OLS estimate (their Table II, p. 104). For my samples with 45 and 68 observations, a regression of *malrisk* on distance from the equator produces F-test values of 11.7 and 30.9.

one of the two coefficients of the basic estimation equation. With this approach, I am avoiding the problem of correlated instruments at the cost of independent estimates of the coefficients of interest.

4. Estimating Conditional Coefficients

There is general agreement in the literature that a cross-country measure of institutional quality can, if instrumented appropriately, explain a substantial part of the international variation in economic performance as measured by per capita income or by output per worker. Given that the quantitative effect of institutional quality on economic performance is known, equation (1) can be revised in such a way that only the measure of malaria prevalence remains as a right-hand-side variable:

(3) $$LNGDPW_i - \beta_2 \cdot INSTITUTIONS_i = \beta_1 - \beta_3 \cdot MALARIA_i + \varepsilon_i \ ,$$

where the log of GDP per worker (*lngdpw*) is now used on the left-hand-side instead of the log of GDP per capita as in equation (1).

My previous estimates and estimates from the literature can be used to derive a plausible range of values for the coefficient β_2. For instance, the estimate based on the specification of column (1) of the first panel of Table 2, which is conditional on malaria prevalence, can be considered as a lower bound of the effect of institutions on economic performance. On the other hand, the estimate based derived by Hall and Jones (1999, Tab. VI, p. 111), which is conditional on a different measure of geography (distance from the equator) and based on a different sample, can be considered as an upper bound of the effect of institutions on economic performance. That is, a plausible range of values for restricting the coefficient β_2 is given by the interval [1.9, 5.1].

Imposing the restriction $\beta_2 = 1.9$ on equation (3) and using the alternative instrumental variables *frost* and *humid*, I find that the coefficient of *malrisk* turns out to be statistically significant, negative, and economically important in both of my samples, with a lower bound of the point estimates of β_3 of about –1.5 (Table 3, columns (1) and (2) in panels 1 and 2). At least for my larger sample of countries, the first stage F-test statistics indicates that both instrumental variables can be considered as statistically relevant. [11] If β_2 is restricted to 5.1 (the Hall-Jones result), the coefficient of *malrisk* turns out to be statistically insignificant (columns (3) and (4)). Yet by restricting β_2 to an intermediate value of 3.2, I again find statistically significant negative coefficients of *malrisk*, with point estimates of β_3 ranging from about 1.5 to 1 in absolute value for both samples (Table 3, columns (5) and (6)). These empirical results support the view that for given intermediate effects of institutions, the cross-country evidence points to statistically significant and quantitatively important direct negative effects of malaria prevalence on economic performance. Notwithstanding my somewhat smaller (in absolute terms) point estimates, this finding confirms the results reported by Sachs (2003) for a

[11] For my large sample (n=68), separate regressions of *malrisk* on *frost* and on *humid* produce F-test values of 15.1 and 20.9; the corresponding F-test values for my small sample (n=45) are 6.0 and 8.7.

different measure of institutions, a different instrumental variable, and different samples.

The third panel of Table 3 considers how my result is affected by the introduction of continental dummies. For instance, Rodrik et al. (forthcoming) argue that because malaria variables are highly correlated with location in Sub-Saharan Africa, it may be difficult to tell their effects from those of regional dummies. In their specification, the same malaria measure that I am using (*malrisk*) drops very far below statistical significance once regional dummies are included (their Table 5, column (10)). Such a finding should come as no surprise, simply because malaria is mainly a tropical disease and Sub-Saharan countries are on average closer to the tropics than other regional groups of countries. For instance, the absolute distance from the equator of the average Sub-Saharan country of my sample is 9.46 degrees latitude, with a standard deviation of 6.97. By comparison, the absolute distance from the equator of the average Asian country of my sample is 15.42 (11.02) degrees latitude, that of the average Latin American country is 15.63 (9.20).

For my preferred specification with the intermediate restriction $\beta = 3.2$, I also find that the statistical significance of the malaria coefficient declines substantially if a dummy for Sub-Saharan African countries is included (columns (1) and (2) of panel 3), which itself is statistically insignificant. If dummies for Asian and Latin American are included (columns (3) and (4)), the coefficient of the measure of malaria prevalence remains statistically significant and very similar in size as compared to columns (5) and (6) of panel 1. In the last two columns of panel 3, I add a dummy which combines Sub-Saharan and North African countries (*africa*) and again find statistically significant malaria coefficients of a size which is in line with previous estimates, whereas all of the coefficients of the three continental dummy variables are statistically not different from zero. This also holds if only the *africa* dummy is included (not shown). Given the restrictions imposed on my estimation equation, these findings appears to indicate that the chosen measure of malaria prevalence represents a genuine explanatory factor, which is tightly related to a tropical location but as such cannot be considered as a proxy for some otherwise unidentified cross-continental differences. Put differently, the statistical significance of any continental dummy is likely to disappear once a measure of malaria prevalence is included in the estimation equation.

As a final robustness check, which is symmetrical to imposing the coefficient of the institution variable, I restrict the coefficient of the malaria variable (β_3) such that

(4) $$LNGDPW_i + \beta_3 \cdot MALARIA_i = \beta_1 + \beta_2 \cdot INSTITUTIONS_i + \varepsilon_i \ ,$$

which leaves a measure of institutions as the only right-hand-side variable. In line with results reported by Sachs (2003), I consider the restrictions $\beta_3 = -1.5$ as an upper bound for the direct performance effects of malaria (in absolute terms) and $\beta_3 = -1.0$ as a lower bound, which is also broadly in line with the results presented in Tables 1-3. Imposing these restrictions on equation (4), I find statistically significant coefficients of the chosen measure of institutions in all specifications reported in Table 4, which include alternative samples and alternative measures of malaria prevalence. Depending on the presumed performance effect of malaria, my point estimates of β_2 range from about 2 to about 3, which reproduces results reported in Tables 2 and 1 for different specifications and different estimation techniques. In my reading, this result again indicates that both institutions and malaria appear to have substantial direct effects on economic performance.

5. Conclusion

My general conclusion is that it proves to be difficult to come up with a clear-cut answer to the question regarding the primacy of institutions relative to measures of geography such as malaria prevalence. The main reason appears to be a lack of plausible independent instrumental variables that could be used in a cross-country analysis to disentangle the exogenous effects of institutions and malaria prevalence on economic performance. With a new instrumental variable developed by Kiszewski and Sachs et al. (2004) and first used by Sachs (2003), one does find important direct effects of malaria in addition to the effects of institutions. The exogeneity of the new instrument variable has been questioned by Rodrik et al. (forthcoming), which appears to be unjustified, but the new instrument variable is highly correlated with other geography-based instruments and hence cannot generally be expected to identify independent variation between measures of institutions and malaria prevalence.

This somewhat agnostic result aside, I find that the Sachs hypothesis of direct performance effects of malaria prevalence cannot be dismissed as easily as claimed in recent studies by Acemoglu et al. (2001) and Rodrik et al. (forthcoming), quite the contrary. For given effects of institutions, my findings indicate quantitatively important direct negative effects of malaria prevalence on economic performance. There are multiple channels by which malaria may confine economic development, most obviously including its direct and indirect effects on various elements of human capital formation such as health, education, nutrition, and fertility. The protective effect of the sickle cell trait, which in itself can have fatal consequences, may also explain to some extent the large estimated performance effect of malaria. Nevertheless, more empirical research appears to be necessary to quantify the potential direct and indirect effects of malaria prevalence on measures of factor accumulation.

My results can be summarized by a reduced-form equation that describes the cross-country evidence on the performance effects of institutions and malaria as

(5) $$LNGDPW_i = \beta_1 + 2.5 \cdot INSTITUTIONS_i - 1.25 \cdot MALARIA_i \ .$$

This equation implies that the primacy of institutions claimed by AJR (2001), Easterly and Levine (2003), and Rodrik et al. (forthcoming) does not hold. However, it should be noted that the coefficients of my equation have not been estimated independently and thus may reflect, at least to some extent, measurement by assumption. Yet given that the plausible instrumental variables that are discussed in the literature all more or less reflect geographic factors and are therefore not independent as well, there appears to be no obvious alternative to restricted IV estimation. As it stands, my equation suggests that the maximum difference in the measure of institutions would account for differences in output per worker across my (large) sample of countries by a factor of 8.6, and the maximum difference in the measure of malaria prevalence would account for differences in output per worker by a factor of 3.5. Taken together, the effects of institutions and malaria would account for about 60 percent of the actual difference in output per worker across my sample of countries.[12]

In contrast to hypotheses that favor the primacy of institutions, my results tend to suggest that emphasizing the importance of good governance will, even if accepted and implemented in poor countries, probably not suffice to achieve improved economic performance. As argued by Sachs and his coauthors in various papers, subsidized research on tropical diseases and also direct assistance from foreign donors for interventions against diseases may indeed be necessary to advance the development of poor countries, which otherwise are unlikely to escape the restrictions imposed on them by adverse geographic

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12 For my sample of 68 countries, the maximum and the minimum values for institutions (*socinf*) are 0.973 and 0.113; for malaria (*malrisk*), the values are 0 and 1; for log output per worker (*lngdpw*), the values are 6.57 and 10.51. It follows that the maximum difference in institutions accounts for differences in output per worker by a factor of 8.6 ($e^{2.5\cdot(0.973-0.113)}$), the maximum difference in malaria prevalence accounts for differences in output per worker by a factor of 3.5 ($e^{1.25\cdot(1-0)}$), and output per worker differs by a factor of 51 ($e^{10.51-6.57}$).

factors. All this is certainly not to deny that good institutions would make such interventions possible in the first place or at least would make them more productive, but my results point out that good institutions and a favorable disease ecology both appear to be necessary though not necessarily sufficient recipes for economic success.

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Appendix: Definitions and Sources of Variables

africa
Dummy variable, equals 1 for North African and Sub-Saharan countries and 0 otherwise.

asia
Dummy variable, equals 1 for Asian countries and 0 otherwise.

distance
Distance from the equator as measured by the absolute value of country-specific latitude in degrees.
Source: Hall and Jones (1999).

exprop
Index of protection against expropriation in 1985-1995; limited to 64 countries but includes Bahamas and Vietnam, which are not included in *socinf*; measured on a [1,10] scale.
Source: Acemoglu et al AER (2001), p. 1398.

frost
Proportion of a country's land receiving five or more frost days in that country's winter, defined as December through February in the Northern hemisphere and June through August in the Southern hemisphere; measured on a [0,1] scale.
Source: Masters and McMillan (2001).

gdpc
GDP per capita, adjusted for purchasing power parity (PPP), 1995; measured in international dollars; the logarithm (ln) of GDP per capita (*lngdpc*) is used in the empirical analyses.
Source: World Bank, Development Indicators CD-ROM, 2002.

gdpw
Real GDP per worker, 1990 or latest available year before 1990 (estimate for Vietnam based on World Bank data for GDP per capita and for the age structure of the labor force, which indicate a value comparable to Bangladesh); measured in international dollars; the logarithm (ln) of GDP per worker (*lngdpw*) is used in the empirical analyses.
Source: PWT 5.6 (1994).

humid
Highest temperature during the month when average afternoon humidity is at its highest; measured in degrees Celsius.

Source: Parker (1997).

latinam
Dummy variable, equals 1 for Latin American countries and 0 otherwise.

maleco
Combines climatic factors and specific biological properties of the regionally dominant malaria vector into an index of the stability of malaria transmission, which is called malaria ecology; the index of malaria ecology is measured on a highly disaggregated sub-national level, and then averaged for the entire country and weighted by population; the index ranges from 0 to 31.5 (Burkina Faso); for details see text; dataset as of 27 October 2003.
Source: Kiszewski and Sachs et al. (2004), here taken from http://www.earth.columbia.edu/about/director/malaria/index.html#datasets.

malfalajr
Proportion of a country's population at risk of falciparum malaria transmission in 1994 (used by Acemoglu, Johnson, Robinson (2001)); measured on a [0,1] scale.
Source: Gallup, Sachs, Mellinger (1999), here taken from McArthur and Sachs (2001).

malfal
Revised version of *malfalajr*; dataset as of 27 October 2003.
Source: Sachs (2003), here taken from http://www.earth.columbia.edu/about/director/malaria/index.html#datasets.

malrisk
Proportion of each country's population that live with risk of malaria transmission, involving three largely non-fatal species of the malaria pathogen (Plasmodium vivax, P. malariae, P. ovale); measured on a [0,1] scale; dataset as of 27 October 2003.
Source: Sachs (2003), here taken from http://www.earth.columbia.edu/about/director/malaria/index.html#datasets.

mort
Settler mortality rates in colonies in the early 19th century, fourth mortality estimate (72 countries, excluding France and UK); measured as death rate among 1,000 settlers where each death is replaced with a new settler; in the empirical analyses, the logarithm (ln) of settler mortality (*lnmort*) is used, with values ranging from 1.7 to 6.2.
Source: Acemoglu, Johnson, Robinson (2001, p. 1398), and Acemoglu, Johnson, Robinson (2000).

socinf
Index of social infrastructure defined as an average of an index of the quality of government and an index of the degree of trade openness (includes Barbados, Central African Rep., Chad, Mauretania, Mauritius, Myanmar, Rwanda, and Surinam, which are not included in *exprop*); measured on a [0,1] scale; the index of the quality of government averages five variables constructed by Political Risk Services (law and order, bureaucratic quality, corruption, risk of expropriation, government repudiation of contracts) based on averages for 1986-1995; the index of trade openness is constructed by Sachs and Warner (1995) as the fraction of years in 1950-1994 that an economy has been open, where openness is given if all of the following criteria apply: non-tariff barriers cover less than 40 percent of trade, average tariff rates are less than 40 percent, any black market premium was less than 20 percent during the 1970s and 1980s, the country was not classified as socialist, and the government does not monopolize major exports.
Source: Hall and Jones (1999).

sub-saharan africa
Dummy variable, equals 1 for Sub-Saharan African countries and 0 otherwise.

Table 1: Robustness of the AJR-Results

	Dependent variable:						
	lngdpc (1)	*lngdpc* (2)	*lngdpc* (3)	*lngdpc* (4)	*lngdpw* (5)	*lngdpc* (6)	*lngdpw* (7)
exprop	0.69 (0.23)	-	0.62 (0.21)	0.77 (0.29)	0.50 (0.19)	0.51 (0.10)	-
socinf	-	4.33 (1.39)	-	-	-	-	3.22 (0.79)
malfalajr	-0.66 (0.44)	-0.67 (0.41)	-	-	-1.05 (0.35)	-1.22 (0.25)	-
malfal	-	-	-0.78 (0.38)	-	-	-	-
malrisk	-	-	-	-0.46 (0.55)	-	-	-0.98 (0.28)
n	62	61	62	62	62	45	45

Note: All estimates based on instrumental variables (IV) regressions, where the measure of institutional quality is instrumented by a measure of log settler mortality in the early 19th century (*lnmort)*; standard errors in parentheses.

Table 2: Controlling for Endogenous Malaria Prevalence and Omitted Variable Bias

	Dependent variable: *lngdpw*					
	(1)	(2)	(3)	(4)	(5)	(6)
	1. Alternative instruments for malaria prevalence					
socinf	1.91 (0.79)	-4.70 (19.51)	3.33 (13.55)	0.97 (1.09)	-5.98 (18.08)	1.60 (4.97)
malrisk	-1.69 (0.41)	-5.29 (10.64)	-0.91 (7.45)	-1.92 (0.42)	-4.77 (7.28)	-1.67 (2.07)
n	45	45	45	68	67	68
Instruments	*lnmort, maleco*	*lnmort, frost*	*lnmort, humid*	*lnmort, maleco*	*lnmort, frost*	*lnmort, humid*
	2. Ignoring the potential endogeneity of institutions					
socinf	0.86 (0.64)	0.09 (1.52)	0.67 (1.20)	1.28 (0.52)	0.38 (0.94)	1.23 (0.80)
malrisk	-2.26 (0.50)	-3.03 (1.41)	-2.45 (1.12)	-1.79 (0.34)	-2.50 (0.70)	-1.83 (0.60)
n	45	45	45	68	67	68
Instruments	*socinf, lnmort*	*socinf, frost*	*socinf, humid*	*socinf, lnmort*	*socinf, frost*	*socinf, humid*
	3. Measurement error vs. omitted variable bias					
socinf	1.76 (0.37)	3.13 (0.47)	5.01 (0.79)	1.78 (0.37)	3.48 (0.42)	5.76 (0.86)
malrisk	-1.36 (0.19)	-	-	-1.39 (0.17)	-	-
n	45	45	45	68	68	68
Instruments	OLS	OLS	*lnmort*	OLS	OLS	*lnmort*

Note: Standard errors in parentheses.

Table 3: Performance Effects of Malaria for Restricted Effects of Institutions

	Dependent variable:					
	*lngdpw-1.9*socinf*		*lngdpw-5.1*socinf*		*lngdpw-3.2*socinf*	
	(1)	(2)	(3)	(4)	(5)	(6)
	1. Small sample (n=45)					
malrisk	-2.18 (0.59)	-1.74 (0.42)	-0.67 (0.79)	0.10 (0.71)	-1.56 (0.59)	-0.99 (0.46)
Instrument	*frost*	*humid*	*frost*	*humid*	*frost*	*humid*
	2. Large sample					
malrisk	-1.95 (0.37)	-1.53 (0.29)	-0.81 (0.50)	-0.07 (0.44)	-1.49 (0.39)	-0.94 (0.32)
Instrument	*frost*	*humid*	*frost*	*humid*	*frost*	*humid*
n	67	68	67	68	67	68
	3. Continental dummies (large sample) Dependent variable: *lngdpw-3.2*socinf*					
malrisk	-1.54 (0.80)	-0.62 (0.47)	-1.51 (0.35)	-0.96 (0.27)	-1.87 (0.59)	-0.85 (0.39)
sub-saharan africa (ssa)	0.07 (0.12)	0.52 (0.33)	-	-	-	-
africa (af)	-	-	-	-	0.63 (0.59)	-0.18 (0.43)
asia (as)	-	-	-0.05 (0.26)	0.04 (0.22)	0.42 (0.50)	-0.09 (0.38)
latin america (la)	-	-	0.09 (0.23)	0.34 (0.19)	0.49 (0.41)	0.22 (0.32)
Instruments	*frost, ssa*	*humid, ssa*	*frost, as, la*	*humid, as, la*	*frost, af, as, la*	*humid, af, as, la*
n	67	68	67	68	67	68

Note: Standard errors in parentheses.

Table 4: Performance Effects of Institutions for Restricted Malaria Effects

	Dependent variable:			
	*lngdpw+1.5*malrisk*		*lngdpw+1.0*malrisk*	
	(1)	(2)	(3)	(4)
socinf	2.26 (0.48)	2.02 (0.52)	3.18 (0.53)	3.26 (0.57)
Instrument	*lnmort*	*lnmort*	*lnmort*	*lnmort*
n	45	68	45	68
	Dependent variable:			
	*lngdpw+1.5*malfal*		*lngdpw+1.0*malfal*	
socinf	2.12 (0.41)	1.78 (0.48)	3.08 (0.48)	3.10 (0.54)
Instrument	*lnmort*	*lnmort*	*lnmort*	*lnmort*
n	45	68	45	68

Note: Standard errors in parentheses.