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The Impact of Poor Health on Total Factor Productivity

A number of recent studies have illustrated the link between health and economic growth. This paper argues that a key mechanism through which health affects growth is via total factor productivity (TFP). We first estimate TFP based on a production function and then estimate the determinants of TFP, paying particular attention to three indicators of health that are particularly problematic in developing regions: malnutrition, malaria and waterborne diseases. We find the impact of poor health on TFP to be negative, significant, and robust across a wide variety of specifications.

JEL classification: O47, I12

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I. Introduction

Disease and poor health represent a great burden to affected individuals. Whilst difficult to quantify, the welfare losses to the individual of being severely ill can be significant, particularly in those developing regions with limited social security provision and health care. Individuals suffering from illness may be weak, unable to work or study and generally unable to provide for children and other dependants. At a more aggregated level, however, it seems likely that a high disease burden may have an adverse impact on a country's productivity, growth and, ultimately, economic development. The many studies that have attempted to explain cross-country differences in economic growth and productivity rates have typically suggested that education, trade openness, savings, inflation and the initial level of income are amongst the key explanatory variables (Barro, 1991; Mankiw *et al*., 1992; Barro and Sala-i-Martin, 1995; Miller and Upadhyay, 2000). There are good reasons to suggest, however, that health is also an important determinant. Lvovsky (2001), for instance, estimates that the burden of disease in LDCs, expressed in disability-adjusted life years (DALYs) lost per million people, is approximately twice that in developed countries.[1] This results from the far higher incidence of disease and malnutrition in LDCs compared to developed regions. Whilst the burden of disease may be a function of poverty, a high disease burden is also likely to adversely affect a nation's development prospects.

Comparatively little attention, however, had been paid in the past to the impact of poor health, particularly in less developed countries (LDCs), on growth and productivity. These issues have begun to be addressed by more recent studies. The existing literature includes Wheeler (1980), Knowles and Owen (1995, 1997), McCarthy et al. (2000), Gallup and Sachs (2000), Bhargava et al. (2001), Arcand (2001), Mayer (2001), McDonald and Roberts (2002) and Webber (2002).[2] Our paper differs in two main and significant aspects from this literature. First, whilst existing studies mostly focus on life expectancy as a single aggregate measure of health, which only captures mortality, we look at three distinct and specific factors affecting health. These are malaria, malnutrition and waterborne diseases, all of which affect both morbidity and mortality and arguably morbidity in particular.[3] These measures capture three of the most serious threats to health in developing regions, another being the HIV/AIDS epidemic which remains a topic for future work. Second, the existing literature, for example, Wheeler (1980) and Knowles and Owen (1997) studies the effect of health on cross-national variation in income levels or economic growth. Arcand (2001) who looks at malnutrition and McCarthy et al. (2000) and Gallup and Sachs (2000) who look at malaria also estimate the effect of poor health on economic growth rates. Instead, we directly estimate the effect of health on total factor productivity.

If a disease has a fatal effect on individuals then it will lower the amount of labour supplied. However, in the vast majority of cases, the very common diseases and illnesses in the developing world such as undernourishment, malaria and waterborne diseases have non-fatal consequences, particularly on adults who participate in the labour force. Affected individuals remain in the labour force, but their productivity is severely impaired. Infectious diseases such as malaria, for instance, result in recurrent debilitating bouts of illness, which prevents individuals from supplying their labour productively. Human capital accumulation may also be adversely affected by poor health due to the higher levels of school absenteeism amongst those suffering from illness. However, as we shall argue in the next section, the economic impact of poor health is not restricted to a reduction in the productivity of labour. A high disease burden within a country can also have implications for foreign and domestic investment, tourism, the internal mobility of labour and land use. As the WHO (2001) claims, returns to investment in agriculture, mining, manufacturing and tourism, as well as investment in major infrastructure projects, are likely to be depressed by a high incidence of illness and disease.

Our central argument is therefore that poor health affects economic development primarily via total factor productivity, not as an additional factor of production or by affecting the productivity of one other factor of production only. If so, then including health as a direct determinant of growth is conceptually inaccurate since health is likely to affect output growth indirectly via total factor productivity. As far as we are aware, however, no study has directly examined the impact of poor health on cross-country aggregate productivity levels. That is the contribution of the present paper. We begin by estimating total factor productivity (TFP) from a parsimonious production function specification. We then examine the determinants of TFP paying particular attention to three key indicators of poor health in LDCs - the proportion of undernourished within a country, the incidence of malaria and the incidence of waterborne diseases. We examine a variety of functional forms and control for the potential endogeneity of poor health.

The paper is organized as follows; Section II begins by outlining the links between poor health and productivity; Section III examines the methodology used to estimate

TFP; Section IV discusses and estimates the determinants of TFP and Section V concludes.

II. Poor Health, Growth and Productivity

It is notable that the populations of many of the poorest countries in the world also suffer from the greatest degree of poor health. Murray and Lopez (1996: 259) estimate the per capita disability-adjusted life years (DALYs) lost in various regions of the world in 1990 due to premature mortality and years lived with disability, adjusted for severity. The estimated figures are lowest in developed countries at about 0.17 DALYs per capita, they range from 0.2 to 0.4 DALYs per capita in various regions of the developing world, and reach close to 0.6 DALYs per capita in Sub-Saharan Africa.

As Table 1 indicates, some of the world's lowest life expectancies, in many cases less than 50 years, are experienced in those sub-Saharan African countries that typically also suffer from extremely low levels of per capita income and often negative economic growth rates.[4] Although underdeveloped countries often lack the resources needed to invest in health care systems, it also seems likely that poor health will itself retard growth and hence income. Developing countries would therefore appear to be in a vicious cycle resulting in persistent underdevelopment.

Table 1. Income, Health and Population Statistics 2002, By Income Group.

	Per Capita Y[b]	Life Expectancy	Under-5 mortality[c]	Population Growth	Per Capita Y growth[d]
Sub-Saharan Africa	$575	46	174	2.24%	0.02%
Low Y[a]	$484	59	121	1.79%	2.30%
Lower Middle Y	$1,687	69	40	0.75%	2.23%
Upper Middle Y	$4,638	73	22	1.21%	1.40%
High Y	$29,516	78	7	0.62%	1.65%

Notes:

[a] Low Y includes sub-Saharan Africa

[b] Per capita income in 1995 US $ [c] Deaths per thousand live births

[d] Average growth 1992-2002

Data from World Bank (2004)

Bhargava *et al*. (2001), Bloom *et al*. (1999) and Gallup *et al*. (1999) find life expectancy at birth to be a positive and significant determinant of economic growth rates. Typically, it has been suggested that a 10% increase in life expectancy is associated with a rise in economic growth of 0.3-0.4% per year (WHO, 2001). One of the problems with such estimations is that life expectancy is a measure of mortality rather than morbidity or poor health. Whilst the two are obviously correlated, it is morbidity and poor health rather than mortality which should have the greatest impact on economic development.

Furthermore, we contend that the most important mechanism by which poor health is likely to affect economic growth is via its impact on the productivity of inputs. In order to examine this mechanism we have to clarify what is meant by poor health. Health, by its very nature, is multidimensional and, as a result, is difficult to quantify. For the purposes of this paper we have focussed on some of the greatest threats to health facing the developing world: undernourishment (or malnutrition), malaria and waterborne diseases. Murray and Lopez (1996: 312) estimate that malnutrition is responsible for 18 per cent of the total burden of disease in developing countries (32.7 per cent in Sub-Saharan Africa). Lvovsky (2001: 6) suggests that safe water supply and sanitation account for another 7 per cent and malaria accounts for 3 per cent of the burden of disease in developing countries. In sub-Saharan Africa, these figures rise to 10 per cent for access to safe water and sanitation and 9 per cent for malaria.

We now examine the implications of our three indicators of health for growth and productivity.

(i) Undernourishment

Undernourishment remains widespread in the developing regions. In 1997, in the developing world as a whole, over 880 million people were classed as being undernourished, equivalent to 18% of the developing world's population. In sub-Saharan Africa, 34% were classed as undernourished, although this figure was over 60% for individual countries such as the Democratic Republic of Congo, Somalia and Burundi. Although the *proportion* of undernourished is falling in most developing regions, in sub-Saharan Africa, the Middle East and North Africa, the absolute number of undernourished is actually rising.[5]

Arcand (2001) estimates what he calls the efficiency cost of hunger: the growth-retarding effect due to undernourishment. Across a wide specification of models he finds that undernourishment has a statistically significant and substantively important negative impact on growth rates. His findings suggest that an elimination of undernourishment in Sub-Saharan African countries would raise the economic growth rate between 0.34 percentage points and as much as 4.63 percentage points.

The economic impact of malnutrition occurs largely through its effects on the labour force. Those suffering from malnutrition often feel weak and lacking in energy and are more susceptible to infection and other illnesses than those who receive the minimum dietary energy requirements (Dasgupta 1993, Chowdhury and Chen 1977). Furthermore, nutrient deficiencies, particularly in childhood, can retard physical and cognitive development and often undermine schooling due to absenteeism and early dropouts. In a review of the literature examining the impact of poor nutrition on the development of the brain, Lewis *et al*. (1986) and Politt (1997, 2001) conclude that most studies point to certain key nutrients, such as iron and Vitamin A, as being vital for cognitive development. Similarly, in a study of Tanzanian schoolchildren, Bhargava and Yu (1997) found that nutritional status was a significant predictor of educational test results.

In the light of these findings, a number of case studies have examined the impact of poor nutrition on labour productivity in LDCs. Wolgemuth *et al*. (1982), for example, found an increase in calories to increase the productivity of Kenyan construction workers, whilst Strauss (1986) also found a positive link between calorific intake and agricultural labour productivity in a study of farm households in Sierra Leone. Strauss and Thomas (1998) provide a thorough review of the links between nutrition, productivity and wages and conclude that there does appear to be a causal relationship between health and productivity. However, by examining the impact of nutrition on the productivity of an individual, or group of individuals, the studies reviewed by Strauss and Thomas fail to consider the macroeconomic impact of malnutrition.

In addition to its likely impact on aggregate labour productivity, poor health can have other macroeconomic implications. A country experiencing widespread malnutrition, or other forms of ill health, will find its national budget distorted. The increased demands on the health care system will mean that resources for other social services will be reduced, and perhaps donor resources that may have been used to meet other needs will have to be diverted.

(ii) Malaria

Gallup and Sachs (2000) and McCarthy *et al*. (2000) have estimated the impact of malaria on economic growth rates. Both papers find a significant negative relationship between malaria morbidity and economic growth rates, which proves to be robust across a variety of functional forms. Gallup and Sachs, for example, estimate that the effect of a country having intensive malaria in 1965 was to lower its economic growth rate by 1.3%, having controlled for other factors. McCarthy *et al.* find malaria to have a slightly smaller impact on growth, with the impact exceeding 0.25% per year for around one quarter of the sample.

Malaria is one of the most prevalent and challenging infectious diseases affecting developing countries. It is endemic in 91 countries, accounting for 40% of the world's population, and is responsible for over 1 million deaths per year (McCarthy *et al*., 2000). Clearly such deaths will affect the supply of labour. However, in the majority of cases, particularly in labour-supplying adults, malaria is non-fatal, but results in frequent recurrent attacks that affect the productivity of labour supply.

Like malnutrition, malaria is most common in the poorest regions of the world, especially sub-Saharan Africa. However, unlike malnutrition, the incidence of malaria appears to be only a weak function of income. Whilst communities can, to an extent, invest in antimalaria protection (such as bed nets) and also health care services to treat sufferers, the severity of malaria is determined mainly by climate and ecology. Eradication programmes since the 1940s and 50s have focussed on the control of mosquitoes and have been successful in low-incidence regions such as the Mediterranean, but have largely failed in high-incidence regions such as tropical sub-Saharan Africa. In this latter region eradication efforts were hindered by the far higher human and mosquito carrying rates, the prevalence of mosquito species particularly suited to malaria transmission, and climatic conditions that allow all year around exposure (McCarthy *et al.,* 2000). Large scale eradication efforts were scaled back in the 1960s to be replaced by local initiatives involving both prevention and treatment.

The most direct economic impact of malaria is in terms of reduced labour productivity. Hempel and Najera (1996) indicate that a bout of non-fatal malaria will typically last for 10-14 days including 4-6 days of total incapacitation with the remainder characterized by headaches, fatigue and nausea. A mild sufferer will experience 1 or 2 bouts per year. The extent to which this lost labour time will reduce output depends on whether it coincides with harvest time in agricultural areas, and whether other family members can compensate.[6] In common with malnutrition, malaria results in frequent absenteeism, particularly amongst school children, resulting in the reduced accumulation of human capital and associated lost productivity in adult life. However, the economic impact of malaria extends beyond the direct impact on labour productivity. A high malaria burden is likely to increase labour turnover resulting in increased hiring and training costs and reduced profitability for enterprises. Furthermore, a high malaria incidence within a particular area may reduce tourism, deter otherwise profitable foreign and domestic investment and prevent the use of land or other natural resources (WHO, 2001). Malaria may also limit the movement of workers due to the reluctance of both foreign and domestic labour to move to malaria infested regions. The quality of skill matching may suffer as a result. With regard to the internal mobility of labour, Gallup and Sachs argue that the better educated workers who often move to the largely malaria free cities are likely to lose their natural protection. As a result, they may be reluctant to return to rural areas or even to maintain contact with such areas. Thus, 'the transmission of ideas, techniques and the development of transportation systems may all be stunted by malaria' (Gallup and Sachs, 1999: 10). Finally, Conly (1975) has argued that attempts to change planting patterns to minimize the overlap between bouts of malaria and peak agricultural activity have often resulted in reduced agricultural productivity. In sum, a high incidence of malaria may mean that resources are not allocated efficiently and assets are not used as productively as they could be.

(iii) Waterborne diseases

Lack of access to sanitation and particularly to safe drinking water remains a great risk to health in developing countries. It is a strong determinant of waterborne diarrhoeal and other diseases such as amoebiasis, cholera, dysentery, schistosomiasis and typhoid fever as well as roundworm and guinea worm infections. It is estimated that diarrhoeal diseases alone (including dysentery) annually kill over 2 million children under the age of five (Warner, 1997). And yet, as with malnutrition and malaria, adults often survive the effects of waterborne diseases, but their labour productivity becomes severely impaired both during and after the period of disease. Furthermore, like malnutrition and malaria, lack of access to safe water and sanitation is most common in the poorest regions of the world. Indeed, it often exacerbates the incidence and effects of malnutrition and malaria as diarrhoeal and other diseases make it more difficult for individuals to retain consumed food and poor water conditions foster the spread of malaria contaminated mosquitoes.

Despite significant effort, access to safe water and sanitation has not considerably increased over the last two or three decades. The WHO estimated that in the mid-1970s some 1.9 billion people had no access to safe drinking water and some 2 billion had no access to adequate sanitation. Twenty years later more than 1.1 billion people worldwide were still deprived of access to safe water and the number of people without adequate sanitation actually rose to 2.5 billion (UN Ecosoc, 2000). This rather poor progress is despite a number of policy initiatives, starting with the launch of the International Drinking Water Supply and Sanitation Decade (1980–1990), which was initiated by the UN Water Conference in Mar del Plata, Argentina, in 1977. The extent of the health problem posed by a lack of access to safe water and sanitation meant that the issue featured prominently at the September 2002 UN Conference on Sustainable Development in Johannesburg, with the summit setting a target of reducing by half the proportion of people without access to safe drinking water and sanitation by 2015.

Unlike malaria, lack of access to safe water and sanitation appears to be a strong function of income. The so-called Environmental Kuznets Curve literature shows that such access improves unambiguously with rising income (Shafik (1994)). However, as with the other forms of ill health, there are also likely to be a number of negative feedback effects on economic development. Diarrhoeal disease, even when it is non-fatal as in the majority of cases with adolescents and adults, usually means that the affected individuals are rendered unproductive as they cannot attend either school or work. The economic impact is not limited to absenteeism, however, as the weakening effect on body functions further reduces the long-term ability of individuals to study or work. In addition, other individuals such as parents or spouses are also affected as they need to attend to sick individuals. In this respect, waterborne diseases are similar to malaria, as the affected individuals can become largely incapacitated and highly dependent on others. In comparison, undernourishment is a more chronic condition.

III. Estimating Total Factor Productivity

In order to examine the impact of health on productivity we require a measure of total factor productivity. Although commonly estimated growth equations (Barro 1991, Barro and Sala-i-Martin 1995, Mankiw et al. 1992, Islam 1995) can be used to provide information on aggregate productivity, their primary focus is on income convergence and there is little consensus as to exactly which independent variables should be included. We therefore adopt what we believe to be the most commonly used and widely accepted method for calculating TFP, namely the estimation of a Cobb-Douglas production function. This is the approach used in many key productivity studies, such as Hall and Jones (1999), Bernard and Jones (1996) and Miller and Upadhyay (2000).

We therefore estimate TFP from a Cobb-Douglas production function specified as follows:

$$Y = A\,K^{\alpha} H^{\delta}\ L^{\beta} \text{ where } 0 < \alpha < 1,\ 0 < \delta < 1 \text{ and } 0 < \beta < 1 \qquad (1)$$

Y denotes real GDP, *A* represents an index of total factor productivity, *K* represents the total physical capital stock, *H* represents human capital and *L* denotes the total labour force. Note that the number of hours worked might be a better measure of the stock of labour, but lack of data prevents us from using it. We do not restrict ($\alpha + \beta + \delta$) to equal one and hence allow for the possibility of increasing or decreasing returns to scale.

To obtain equation (1) in per worker form, we divide by the labour force, *L*.

$$y = A\,k^{\alpha} h^{\delta}\, L^{\alpha + \beta + \delta - 1} \qquad (2)$$

where *y* represents real GDP per worker, *k* denotes the physical capital stock per worker and *h* denotes human capital per worker. Expressing equation (2) in natural logarithms provides equation (3):

$$\ln y = \ln A + \alpha \ln k + \delta \ln h + (\alpha + \beta + \delta - 1)\ln L \qquad (3)$$

Note that the nature of the production function's returns to scale can now be ascertained by the coefficient on ln$L$. Equation (3) then leads directly to equation (4), our equation to be estimated:

$$\ln y_{it} = \phi_i + \alpha \ln k_{it} + \delta \ln h_{it} + (\alpha + \beta + \delta - 1)\ln L_{it} + \varepsilon_{it} \qquad (4)$$

Where subscripts *i* and *t* denote country and year, respectively. Our measure of total factor productivity is then (ϕ_i + ε_{it}) which is equivalent to ln$A$ in equation (3). Equation (4) is estimated for a panel of 52 developed and developing countries using data at five yearly intervals for the period 1965 – 1995. The time series reflects the fact that our source of human capital data (Barro and Lee 2000) reports only five-yearly observations.[7] Data for *y*, *k* and *L* are provided by the World Bank (2004). More information on all data is provided in Appendix A. Appendix B lists the countries for which TFP can be estimated. Naturally, developed countries have better data availability, but 32 of the 52 countries in the sample are developing countries. Both fixed and random effects specifications are used to estimate equation (4). In the former, ϕ_i are treated as regression parameters, whilst in the latter they are treated as components of the random disturbance. Table 2 provides our fixed effects results. Random effects results yield the same signs and very similar coefficients as the fixed effects results. Since the Hausman test rejects the random effects assumption at the 5 per cent level, we only report the latter.

Table 2. Production Function Estimates (Fixed Effects)

*Dependent variable: income per worker (*ln*y)*	
ln*k*	*0.37****
	(0.022)
ln*L*	*0.013*
	(0.060)
ln*h*	*0.20****
	(0.029)
R^2	*0.95*
N	*364*
Hausman	*9.12*
(FE v. RE)	*(0.03)*

Standard errors in parentheses (p-value for the Hausman test).

Note: *** denotes significance at 99% confidence level.

Table 2 provides the estimated production function described by equation (4). The coefficient of ln*L* indicates that the production function exhibits close to constant returns to scale. The elasticity of output with respect to the capital stock is 0.37, whilst the equivalent elasticity for human capital is 0.20. Since the coefficient of ln*L* represents $(\alpha + \beta + \delta - 1)$, the implied elasticity of output with respect to the labour force (β) is 0.44. Using the estimates from table 2 as our measure of TFP, we now turn towards the determinants of TFP and the role of health therein.

IV. The Determinants of TFP

Having estimated TFP using the results in Table 2, we are now in a position to identify the determinants of TFP, beginning with variables relating to the health of a nation.[8]

(i) Indicators of Health

Since our primary concern is the impact of poor health on TFP in LDCs, we utilize data on three of the most common causes of ill health in developing regions. The first is undernourishment or malnutrition. Note that to capture this aspect of poor health we cannot use calorie, protein or fat supply data despite their quite good availability. The reason is that it has long been recognized that the need for calorie and protein intake depends partly on climatic conditions, with people in cold countries in greater need than people in warmer climates (FAO, 1974; Parker, 2000). As a consequence, for example, cold Mongolia has a higher calorie and protein supply despite its great poverty than the much richer Singapore, located in the tropics. For this reason, we prefer to consider undernourishment directly. The FAO defines undernourishment as 'food intake that is insufficient to meet dietary energy requirements continuously' where dietary energy requirements are 'the amount of dietary energy required by an individual to maintain body functions, health and normal activity.' (FAO, 2000). We use the proportion of the population that is undernourished, as reported by the FAO (2000). Data are provided for all of our 52 countries, although only for the years 1980, 1991 and 1996.The percentage of undernourished people is a better indicator of the actual health burden than the very close concept of relative food inadequacy (FAO, 1996: 3-5) and is now the FAO's preferred indicator of the extent of undernourishment. We note that Svedberg (1999) has raised doubts with respect to the reliability and suitability of these data. He argues in favour of using anthropometric measurements referring to body height and/or weight instead. The FAO (2002a) itself has rejected Svedberg's claim as have several experts of a FAO-sponsored Technical

Workshop (FAO, 2002b). Not being technical experts ourselves, we are uncertain as to the validity of Svedberg's claims. However, the availability of cross-country data on anthropometric measurements is rather poor for children before the 1990s and practically no data exist for adults. We therefore see no alternative to using the FAO data.

Our second indicator is the incidence of malaria, as provided by Gallup *et al*. (1999) for all of our 52 countries for the years 1966 and 1994. Gallup *et al*. used World Health Organization (WHO) data to calculate the fraction of a country's land area subject to malaria. They then collected WHO data on the percentage of malaria cases that are the malignant *falciparum* species of malaria. Of the four species of malaria, *falciparum* is the most severe, being the most resistant to drugs and responsible for almost all malaria mortality. The malaria index is then the product of the percentage of land area and the percentage of *falciparum* cases.

Finally, the World Bank (2004) provides our third indicator, the percentage of the population without access to safe water.[9] This variable is used as a proxy for the variety of waterborne diseases that are prevalent in unclean water supplies. The World Bank (2004) defines access to safe water 'as the share of the population with reasonable access to an adequate amount of safe water (including treated surface water and untreated but uncontaminated water, such as from springs, sanitary wells, and protected boreholes). In urban areas the source may be a public fountain or standpost located not more than 200 meters away. In rural areas the definition implies that members of the household do not have to spend a disproportionate part of the day fetching water. An adequate amount of water is that needed to satisfy metabolic, hygienic, and domestic requirements, usually about 20 litres of safe water a person per day.' This variable is available for our 52 countries, for the years 1970, 1975, 1985, 1988, and 1993.

(ii) Other Determinants of TFP

In addition to our health variables, we include a number of other determinants of TFP, although relatively few have been suggested within the growth/productivity literature. Miller and Upadhyay (2000) suggest a determinant of TFP in the form of trade openness. Although the impact of trade on growth has generated a large, sometimes conflicting, volume of literature (see for example, Greenaway *et al*., 2002; Rodriguez and Rodrik, 1999; Harrison, 1996), it is widely accepted that increased openness is likely to result in countries deepening their specialization in those sectors in which they enjoy a comparative advantage. The resultant efficiency gains are likely to manifest themselves in the form of increased TFP which, in turn, should raise growth rates. Miller and Upadhyay's (2000) findings would support this assertion. Our preferred measure of trade openness is the share of trade in GNP, although our results are insensitive to the use of the share of exports in GNP. Both of these variables are provided by the World Bank (2004).

It has often been argued that productivity growth in the agricultural sector is lower than that in the manufacturing sector, an assumption often implicit in the works of development economists such as Lewis and Prebisch (e.g. Lewis, 1954; Prebisch, 1984). Although more recent studies have challenged this assertion (Martin and Mitra, 1999), we include the share of agricultural value added in total GNP to assess whether agrarian economies have lower levels of TFP. Finally, since Miller and Upadhyay (2000) find the inflation rate to be a negative determinant of TFP, we too include this variable. Data on the GNP share of agricultural valued added and inflation rates are provided by the World Bank (2004).

(iii) Methodology and Results

Our equation to estimate the determinants of TFP is as follows:

$$\ln tfp_{it} = \gamma_{i} + \delta_{t} + \theta_{1}\ln X_{it} + \theta_{2}\ln TRAD_{it} + \theta_{3}\ln INFL_{it} + \theta_{4}\ln AGR_{it} + \varepsilon_{it} \qquad (5)$$

Where, X denotes an indicator of health (either malaria, malnutrition or access to safe water), *TRAD* is trade openness, *INFL* is the rate of inflation and *AGR* is the share of agriculture in GNP. Subscripts i and t continue to denote country and year, respectively. Note that data for X are not available on an annual basis.

Table 3 provides a variety of estimations based on equation (5), using malnutrition as our indicator of health. It reports fixed effects results since Hausman tests suggested that, in most models, the country effects are correlated with the independent variables and hence the random effects model cannot be estimated consistently.[10] Nevertheless, we report random effects results in the appendix C.

Table 3. The Determinants of TFP, (X = Undernourishment, Fixed Effects)

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
		Dummy X	*Africa*	*Non-Africa*	*Lagged X*	*2SLS IV*
X	*-0.17****	*-0.34****	*-0.26****	*-0.18****	*-0.17****	*-0.21***
	(0.023)	*(0.064)*	*(0.054)*	*(0.022)*	*(0.025)*	*(0.10)*
TRAD	*0.062**	*0.087***	*0.25***	*0.066**	*0.074**	*0.00072*
	(0.034)	*(0.041)*	*(0.12)*	*(0.035)*	*(0.041)*	*(0.00063)*
INFL	*-0.040***	*-0.039**	*0.017*	*-0.046***	*-0.067****	*-0.036**
	(0.018)	*(0.020)*	*(0.052)*	*(0.021)*	*(0.020)*	*(0.021)*
AGR	*-0.41****	*-0.44****	*-0.73****	*-0.32****	*-0.40****	*-0.40****
	(0.044)	*(0.041)*	*(0.077)*	*(0.038)*	*(0.050)*	*(0.044)*
R^2	*0.67*	*0.63*	*0.70*	*0.68*	*0.72*	*0.67*
n	*152*	*152*	*29*	*123*	*100*	*152*
Sargan test						*0.51*
(p value)						*(0.47)*

Standard errors in parentheses.

***, ** and * denote significance at 99%, 95% and 90% confidence levels, respectively.

Model (1) begins by estimating TFP as a function of our four determinants, undernourishment (*X*), trade openness (*TRAD*), inflation (*INFL*) and agricultural share (*AGR*). We find all variables to be signed and statistically significant in accordance with our prior expectations in almost all cases. Most notably, the proportion of undernourished within a country is a negative determinant of that county's TFP. As a general check on the robustness of this result, to see whether it is driven by outliers for example, model (2) replaces our undernourishment variable with a dummy variable. This variable is set equal to one for the one-third of the sample with the highest proportion of population suffering from undernourishment. This technique gives equal weighting to all those observations for which the dummy variable is set equal to one, thereby reducing the possibility that the result in model (1) is driven by a handful of extreme observations. This technique is also used by McCarthy et al. (2000). Signs and significance remain very similar to those in model (1). To see whether the coefficient on undernourishment is simply picking up a TFP retardant 'sub-Saharan Africa effect', model (3) is estimated using Sub-Saharan African countries alone, whilst (4) uses only non-Sub-Saharan African countries.[11] Again, the signs and significance of our estimated coefficients remain very similar to those from models (1) and (2). The inflation coefficient becomes insignificant for our African sample although, with only 29 observations, perhaps not too much weight should be placed on this finding.

Models (5) and (6) address the potential endogeneity of undernourishment. It is, of course, likely that an increasing level of TFP within a country could increase that country's income and hence reduce the proportion of undernourished. As a first step towards addressing this potential problem, model (5) uses a lagged value of X.[12] We can see that, although the coefficient on undernourishment falls in size, it remains statistically significant. Lagging X mitigates the endogeneity problem, but it does not solve it if there is persistence in the country-specific error term over time. To address the issue of endogeneity more comprehensively, we use instrumental variables for undernourishment. Such instrumental variables need to fulfil two conditions: First, they must not be endogenous since otherwise they would suffer from the very same problem they are supposed to remedy. Second, they need to be partially correlated with the endogenous variables in the sense that the correlation persists after all other exogenous variables are controlled for (Wooldridge, 2002: 84). The stronger the correlation the better. Instrumental variable estimation effectively rules out endogeneity bias since estimations use only that part of the endogenous variable that is uncorrelated with the error term and is therefore exogenous. We use two instrumental variables which are correlated with the proportion of undernourished yet are arguably exogenous with respect to TFP. In addition, they pass standard Sargan over-identification tests. These variables are the proportion of a country's population living in Koppen-Geiger climate zone B ('Dry'), and the proportion of a country's area within this same climate zone.[13] These variables capture one specific cause of undernourishment. Dry regions are more vulnerable to fluctuations in rainfall, particularly those that do not have the infrastructure or the resources necessary to facilitate large scale irrigation and the transportation of water from other regions. Hence countries with high values of our two instruments are likely to experience food shortages, thereby contributing to undernourishment.[14] Appendix A provides more information on our instruments and the sources of these data. The results in Table 3 indicate that undernourishment remains a negative, significant determinant of TFP even when instrumented.

Random effects results in Appendix C (Table C1) can also be seen to be very similar to those in Table 3 in terms of sign and significance. The proportion of undernourished remains a negative, significant determinant of TFP.

We can now turn to our results estimated using the incidence of malaria as our measure of a nation's health. Again, we estimate six models using fixed effects.

Table 4. The Determinants of TFP, (X =Malaria, Regional Fixed Effects)

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
		Dummy X	*Africa*	*Non-Africa*	*Lagged X*	*2SLS IV*
X	*-0.58****	*-0.34***	*-1.04****	*-0.16*	*-0.52****	*-1.06****
	(0.11)	*(0.11)*	*(0.15)*	*(0.22)*	*(0.085)*	*(0.27)*
TRAD	*0.087*	*0.18***	*-1.64****	*0.20***	*0.11**	*0.035*
	(0.090)	*(0.090)*	*(0.32)*	*(0.089)*	*(0.061)*	*(0.12)*
INFL	*0.033*	*-0.054***	*-0.025*	*0.043***	*-0.018*	*-0.038*
	(0.029)	*(0.021)*	*(0.047)*	*(0.020)*	*(0.029)*	*(0.030)*
AGR	*-0.41****	*-0.40****	*-0.16**	*-0.36****	*-0.40****	*-0.40****
	(0.043)	*(0.042)*	*(0.081)*	*(0.052)*	*(0.023)*	*(0.066)*
R^2	*0.57*	*0.59*	*0.85*	*0.49*	*0.63*	*0.55*
n	*97*	*97*	*19*	*81*	*49*	*97*
Sargan test						*0.17*
(p value)						*(0.68)*

Standard errors in parentheses.

***, ** and * denote significance at 99%, 95% and 90% confidence levels, respectively.

The sign and significance of the results on the health variable in Table 4 can be seen to be very similar to those in Table 3. The incidence of malaria has a strong negative impact on TFP, which is robust across specifications with one notable exception. Since the malaria sample contains 52 countries, but only two time series observations, we conserve degrees of freedom by using region-specific, rather than country-specific, fixed effects. Thus, dummies are included for the EU, sub-Saharan Africa, South Asia, transition economies, Latin America and South East Asia. The sub-Saharan Africa dummy therefore controls for possible negative effects on TFP that may be specific to this region, thus the malaria coefficient should not be picking these up. We find TFP to be negatively determined by the presence of malaria and a high share of agriculture in GNP. Neither the inflation rate nor trade openness are consistently statistically significant. Model 3 contains no country or region dummies due to the small sample size and provides a further check on whether there is an effect specific to sub-Saharan Africa which is driving our results. We estimate a negative, significant coefficient on malaria within the African sample, but not the non-African sample (models 3 and 4). This does not necessarily mean that malaria has no impact on TFP outside Africa as the random-effects regression suggests a statistically significant coefficient for the non-African sample (Appendix C, Table C2).

Model 5 uses a lagged value of malaria and finds results broadly similar to those estimated using current values of malaria.[15] Model 6 uses a two stage least squares (2SLS) procedure that instruments malaria using three variables capturing the proportion of a country's land area that is tropical or sub-tropical and a country's malaria ecology. Malaria incidence is highly correlated with these land area and ecology variables, yet they should be exogenous with regard to TFP. The Sargan over-identification test fails to reject the null hypothesis that these are valid instruments The 2SLS estimates are very similar to those from models 1 to 5. These findings are reinforced by the random effects results in Appendix C (Table C2). The negative impact of malaria on TFP is therefore robust across a variety of specifications.

Finally, we consider the impact on TFP of our third indicator of health, lack of access to safe water. Table 5 and Appendix C present the results of our models.

Table 5. The Determinants of TFP, (X = Lack of Access to Safe Water, Country Fixed Effects)

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
		Dummy X	*Africa*	*Non-Africa*	*Lagged X*	*2SLS IV*
X	*-0.090****	*-0.19****	*-0.17**	*-0.074**	*-0.14****	*-0.63****
	(0.035)	*(0.052)*	*(0.088)*	*(0.040)*	*(0.037)*	*(0.17)*
TRAD	*0.016*	*0.0061*	*-0.24***	*0.015*	*0.0029*	*0.056*
	(0.015)	*(0.016)*	*(0.12)*	*(0.015)*	*(0.015)*	*(0.045)*
INFL	*0.0098*	*0.054*	*0.30*	*0.017*	*0.027*	*-0.053*
	(0.027)	*(0.029)*	*(0.25)*	*(0.027)*	*(0.034)*	*(0.067)*
AGR	*-0.50****	*-0.51****	*-0.82****	*-0.45****	*-0.47****	*-0.33****
	(0.025)	*(0.028)*	*(0.093)*	*(0.029)*	*(0.029)*	*(0.075)*
R^2	*0.54*	*0.58*	*0.64*	*0.53*	*0.55*	*0.48*
n	*249*	*249*	*43*	*195*	*190*	*233*
Sargan test						*2.37*
(p value)						*(0.12)*

Standard errors in parentheses.

***, ** and * denote significance at 99%, 95% and 90% confidence levels, respectively.

Model (1) again estimates coefficients with signs in accordance with prior expectations, with lack of access to safe water a negative determinant of TFP and significant at a 99% confidence level. Model (2) replaces lack of access to safe water with a dummy set equal to one for the 13 countries in which, on average across the time period of our sample, under 50% of the population had access to safe water. This variable is highly significant as well. Model (3) uses only African countries and finds the estimated coefficient on safe water to increase. For non-African countries (model 4), safe water is also statistically significant. With regard to model (6), identifying suitable instrumental variables for lack of access to safe water proved very difficult. We use the level of urban and rural population density, which are negatively and positively correlated with lack of access to safe water, respectively. Contrary to the instruments used for under-nourishment and malaria incidence, we are far less confident that these instruments are truly exogenous. The 2SLS estimation results must therefore be treated with some care, although the Sargan test reported in Table 5 supports our use of these instruments, by finding them to be uncorrelated with the error term. Whether this is because our instruments are truly exogenous or because of the potentially low power of the Sargan test to detect their endogeneity, we do not know. In both estimations of model (6) (i.e. in Tables 5 and Appendix C, Table C3) instrumented lack of access to safe water is a negative, significant determinant of TFP with a larger estimated coefficient than in our non-instrumented model (1).

(iv) Summary and Discussion of Results

In general, we find the impact of poor health on TFP to be negative, significant, and robust across a wide variety of models and specifications. Furthermore, we generally find the share of agriculture in GDP to be a negative, significant determinant. Although the estimated coefficient on trade openness and inflation are frequently positive and negative, respectively, they are often not significant and in few cases even contrary to expectations.

Returning to our health variables, our econometric results yield a number of insights. Firstly, we find that the negative, significant impact of health on TFP occurs both *within* Africa and *outside* Africa (i.e. models 3 and 4), at least for undernourishment and lack of access to safe water. We are therefore confident that our full-sample results are not being driven by African countries alone. Finally, across the vast majority of our estimations, we find the elasticity of TFP with respect to health to be larger in Africa (model 3) than elsewhere.

Table 6 provides a comparison of the estimated elasticities for our three health variables, from our standard model (model 1) and our instrumental variables model (model 6). Both fixed and random effects results are reported. For each health variable we find that the estimated elasticity of TFP with respect to health is smaller in our standard model compared to our instrumented model. For malaria, for instance, our fixed effects estimation suggests that a 1% increase in the incidence of malaria will reduce TFP by 0.41% in model (1) and 0.70% in model (6). The same pattern is found for undernourishment and lack of access to safe water, whichever of our three specifications is used.

Table 6. A Comparison of Estimated Health Elasticities

Health variable	*Model*	*Fixed Effects*	*Random Effects*
Undernourishment	*(1)*	*-0.17*	*-0.22*
	(6) IV	*-0.21*	*-0.33*
Malaria	*(1)*	*-0.58*	*-0.75*
	(6) IV	*-1.06*	*-1.06*
Lack of Access to Safe	*(1)*	*-0.09*	*-0.13*
Water	*(6) IV*	*-0.63*	*-0.63*

Although the elasticities in Table 6 do vary across fixed effects and random effects, in general we can see that the elasticities for malaria are larger in magnitude than those for undernourishment and lack of access to safe water in model (1) estimations. A 1% increase in *falciparum* malaria incidence will reduce TFP by between 0.58% and 0.75% whilst, for undernourishment and lack of access to safe water the estimated range is between 0.17% and 0.22% and 0.09% and 0.13%, respectively. However, once we control for potential reverse causality (model (6)), lack of access to safe water has the highest estimated elasticities at 1.06%. However, this result needs to be treated with some care, given the concerns expressed above about the true exogeneity of our instruments for lack of access to safe water.

Section II described some of the possible mechanisms via which poor health can affect total factor productivity, although their detailed examination is outside the remit of this paper. Nevertheless, our analysis does provide some insights. It is plausible that a significant proportion of the impact of health on TFP occurs through an impact on labour productivity. However, in addition to this linkage, Section II suggested that poor health may also reduce productivity by undermining schooling. Other potentially quantifiable linkages between health and TFP include the fact that labour and capital may avoid certain disease infested areas, the rate of return on large scale public investment projects may be depressed and health budgets may be distorted by a high disease burden. Unfortunately, data limitations significantly hamper the investigation of these linkages. But the variety of ways in which health can affect economic development supports our argument that health is best modelled as affecting TFP.

V. Conclusion

In the light of a number of recent studies showing the adverse impact of poor health on economic growth (Bhargava *et al*., 2001; Gallup and Sachs, 2000; McCarthy *et al*., 2000; Arcand, 2001), the aim of this paper has been to illustrate that a key mechanism through which health affects growth is via TFP. Our results suggest that poor health can indeed reduce aggregate productivity. It would therefore appear that poor health is a key factor in explaining the existence of persistent underdevelopment in many regions of the world. It has long been known that poverty and underdevelopment play a significant role in the prevalence of malnutrition, the lack of access to safe water and sanitation and the resultant profusion of waterborne diseases, and the general lack of medical services and preventative medicine. However, a reversal of this relationship, with poor health itself contributing to poverty and underdevelopment, has generally not been quantified at a macroeconomic level until relatively recently. We have tried to improve on the existing literature by looking at three specific aspects of poor health rather than the aggregate measure of life expectancy and by directly estimating the effect of health on total factor productivity, rather than economic growth.

The recent creation of the World Health Organization's (WHO) Commission on Macroeconomics and Health, chaired by Jeffrey Sachs, suggests that interest in the macroeconomic implications of poor health is increasing. The Commission's report, published in December 2001 (WHO, 2001), firmly states that poor health within a nation can have severe implications for that nation's macroeconomic performance. With a clear link between health and productivity emerging, the report calls for a global commitment to tackle health issues. This commitment must come from low-income countries themselves, but also increased financial commitments from donor countries will be needed. It would appear that only increased and re-prioritised investment in health care, on a global scale, will release the developing world from the vicious cycle that links poor health and poverty.

Endnotes

[1] DALYs are a common measure of disease burden and combine life years lost due to premature death with fractions of years of healthy life lost as a result of illness.

[2] There are two more studies, which have included life expectancy at birth in their estimations without focussing on health directly; see Bloom *et al.* (1999) and Gallup *et al.* (1999).

[3] Webber (2002) uses calorific intake as a proxy for human health instead of life expectancy. Further below we argue that this is a flawed indicator and we measure undernourishment directly.

[4] We would have liked to have included DALYs by income group in Table 1, but data only exist at a regional level.

[5] Data from FAO (2001).

[6] Hempel and Najera (1996) claimed that bouts of malaria often coincide with the planting season in Spring.

[7] Appendix B lists the countries in our sample. The number of countries is constrained by the availability of capital stock data, particularly for the 1960s. Although several techniques could be used to estimate missing values, we believe these to be of questionable accuracy, and hence prefer to use a smaller, although we believe still representative, selection of countries.

[8] Appendix B provides a ranking of our 52 countries by TFP.

[9] We use the lack of access to safe water, as opposed to sanitation, due to the larger number of observations reported by the World Bank (2004). The two variables are highly correlated.

[10] All estimations in this paper utilize heteroscedastic-robust standard errors. A lagged dependent variable ($lntfp_{it-1}$) was not favoured on the grounds that both $lntfp_{it}$ and $lntfp_{it-1}$ will be functions of γ_i, our country characteristics. Since γ_i is part of the unobserved error term, it means that $lntfp_{it-1}$, an independent variable, is correlated with the error term and hence OLS estimates will be biased. A solution to this problem is to follow Arellano and Bond (1991) and to estimate a dynamic panel using $lntfp_{it-2}$ as an instrument for $lntfp_{it-1}$ and to first difference all variables. However, our limited time series makes such an approach inappropriate. Furthermore, we note that Miller and Upadhyay (2000) do not include a lagged dependent variable in their estimations of TFP.

[11] Note also that the signs and significance of estimated coefficients in Table 3 (models (1), (2), (5) and (6)) were virtually unaffected by the inclusion of a sub-Saharan Africa dummy.

[12] Lagging our undernourishment variable means that one year of data is lost.

[13] The Koppen-Geiger climate system classifies the world into six major climate regions, based on average annual precipitation, average monthly precipitation, and average monthly temperature. Climate zone B denotes ‘dry’ regions and includes many African and Middle Eastern countries, parts of India, Pakistan, the Southern ex-Soviet states and other regions as varied as parts of China and the US.

[14] Of course, undernourishment is often caused by a lack of access to food rather than a lack of food *per se.* Other causes of undernourishment therefore include the prevalence of war, the authoritarian nature of government, an inequitable distribution of power/income and rapid population growth. These variables were not used as instruments since they are unlikely to be exogenous with regard to TFP.

[15] Again, we lose a year of data when lagging our malaria variable.

Appendix A. Data Information

Variable	Definition	Source
y	Per capita income in 1995 US $	World Bank (2004)
K	Physical capital stock per worker	World Bank (2004)
L	Labour force	World Bank (2004)
Undernourished	The proportion of the population that is undernourished	FAO (2000)
Malaria	The incidence of *falciparum* malaria	Gallup *et al*. (1999)
Hk	Human capital, measured as the average years of secondary schooling in the total population	Barro and Lee (2000)
TRAD	Trade openness defined as the ratio of imports plus exports to GNP	World Bank (2004)
INFL	Rate of inflation	World Bank (2004)
AGR	The share of agricultural value added in GNP	World Bank (2004)
Climate	The proportion of a country's population and land area in Koppen-Geiger climate zone B (classified as 'dry')	Harvard University Centre for International Development http://www2.cid.harvard.edu/ciddata/geographydata.htm
Rur. pop. dens.	Rural population density	World Bank (2004)
Tropical	Percentage of a country's land area classified as tropical	Gallup *et al*. (1999) http://www.cid.harvard.edu/ciddata/ciddata.html
Subtropical	Percentage of a country's land area classified as sub-tropical	As above
Malaria Ecology	An ecologically-based spatial index of malaria transmission	http://www.earth.columbia.edu/about/director/malaria/index.html
Lack of Safe water	Percentage of population without access to safe water	World Bank (2004)
Urban pop. density	Urban population density	World Bank (2004)

Appendix B. Countries in our Sample Ranked by Average TFP 1990-95

Country	Rank	TFP	Country	Rank	TFP
Luxembourg	1	1.46	Brazil	27	0.073
Belgium	2	1.28	Hungary	28	0.045
Switzerland	3	1.22	South Africa	29	0.0050
Japan	4	1.09	Malaysia	30	-0.092
France	5	1.067	Mexico	31	-0.14
Denmark	6	1.045	Colombia	32	-0.22
Netherlands	7	1.029	Peru	33	-0.24
Sweden	8	0.95	Tunisia	34	-0.29
United States	9	0.94	Paraguay	35	-0.32
Israel	10	0.93	Thailand	36	-0.46
Ireland	11	0.93	Ecuador	37	-0.47
Norway	12	0.92	China	38	-0.52
Italy	13	0.90	Morocco	39	-0.54
Finland	14	0.89	Philippines	40	-0.80
United Kingdom	15	0.89	Senegal	41	-0.82
Spain	16	0.79	Indonesia	42	-0.89
Australia	17	0.77	Cameroon	43	-0.94
New Zealand	18	0.75	Pakistan	44	-1.00
Canada	19	0.73	Zambia	45	-1.01
Grenada	20	0.67	Zimbabwe	46	-1.01
Portugal	21	0.55	Nigeria	47	-1.16
Argentina	22	0.51	Sri Lanka	48	-1.22
Uruguay	23	0.37	Kenya	49	-1.39
S. Korea	24	0.21	India	50	-1.45
Chile	25	0.10	Ghana	51	-1.46
Venezuela	26	0.093	Bangladesh	52	-1.49

Note: TFP is expressed as a natural logarithm and stems from model (1) in Table 2.

Appendix C. Additional Results on TFP Determinants

Table C1. The Determinants of TFP, (X = Undernourishment, RANDOM Effects)

Variable	(1)	(2)	(3)	(4)	(5)	(6)
		Dummy X	Africa	Non-Africa	Lagged X	2SLS IV
X	-0.22***	-0.83***	-0.03	-0.23***	-0.25***	-0.33***
	(0.028)	(0.12)	(0.050)	(0.034)	(0.031)	(0.093)
TRAD	0.0096	0.11**	-0.035	0.071	-0.0048	-0.0012
	(0.051)	(0.051)	(0.12)	(0.054)	(0.049)	(0.0012)
INFL	0.0029	-0.0080	0.084***	-0.014	0.016	0.0055
	(0.015)	(0.014)	(0.029)	(0.015)	(0.023)	(0.016)
AGR	-0.43***	-0.39***	-0.40***	-0.39***	-0.49***	-0.34***
	(0.045)	(0.047)	(0.10)	(0.053)	(0.045)	(0.081)
R^2	0.89	0.82	0.53	0.86	0.83	0.88
n	152	152	23	123	100	152
Hausman	37.0	40.8	45.1	25.5	59.7	88.8
FE v. RE	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Standard errors in parentheses.

*** and ** denote significance at 99%, and 95% confidence levels, respectively.

Table C2. The Determinants of TFP, (X = Malaria, RANDOM Effects)

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
		Dummy X	*Africa*	*Non-Africa*	*Lagged X*	*2SLS IV*
X	*-0.75***	*-0.54***	*-0.99***	*-0.84**	-	*-1.06**
	(0.23)	*(0.12)*	*(0.27)*	*(0.44)*		*(0.27)*
TRAD	*0.45***	*0.47***	*-1.82**	*0.48***	-	*-0.035*
	(0.13)	*(0.12)*	*(0.80)*	*(0.15)*		*(0.12)*
INFL	*0.057**	*0.061**	*-0.052*	*0.061**	-	*0.037*
	(0.028)	*(0.027)*	*(0.062)*	*(0.033)*		*(0.030)*
AGR	*-0.52***	*-0.46***	*-0.15*	*-0.49***	-	*-0.40***
	(0.073)	*(0.073)*	*(0.16)*	*(0.091)*		*(0.066)*
R^2	*0.80*	*0.81*	*0.85*	*0.74*	-	*0.81*
n	*97*	*97*	*19*	*81*	-	*97*
Hausman	*36.8*	*39.8*	*5.0*	*34.2*	-	*14.3*
FE v. RE	*(0.00)*	*(0.00)*	*(0.42)*	*(0.00)*		*(0.03)*

Standard errors in parentheses.

***, ** and * denote significance at 99%, 95% and 90% confidence levels, respectively.

Random effects estimation of specification (5) is not possible as the lagging of malaria leaves only one year of data in the sample.

Table C3. The Determinants of TFP, (X =Access to Safe Water, RANDOM Effects)

Variable	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*
		Dummy X	*Africa*	*Non-Africa*	*Lagged X*	*2SLS IV*
X	*-0.13****	*-0.10**	*0.018*	*-0.13****	*-0.15****	*-0.63****
	(0.043)	*(0.056)*	*(0.056)*	*(0.049)*	*(0.044)*	*(0.17)*
TRAD	*-0.043*	*-0.021*	*-0.14**	*-0.042*	*-0.034*	*-0.056*
	(0.033)	*(0.035)*	*(0.087)*	*(0.034)*	*(0.037)*	*(0.045)*
INFL	*-0.019*	*-0.019*	*0.50****	*-0.0099*	*-0.015*	*0.053*
	(0.052)	*(0.056)*	*(0.16)*	*(0.052)*	*(0.052)*	*(0.067)*
AGR	*-0.52****	*-0.60****	*-0.61****	*-0.48****	*-0.50****	*-0.33****
	(0.038)	*(0.037)*	*(0.13)*	*(0.042)*	*(0.042)*	*(0.075)*
R^2	*0.82*	*0.80*	*0.58*	*0.79*	*0.82*	*0.70*
n	*238*	*238*	*43*	*195*	*190*	*233*
Hausman	*259.5*	*281.69*	*14.2*	*133.3*	*110.8*	*2.4*
FE v. RE	*(0.00)*	*(0.00)*	*(0.08*	*(0.00)*	*(0.00)*	*(0.13)*

Standard errors in parentheses.

***, ** and * denote significance at 99%, 95% and 90% confidence levels, respectively.

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