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Does Better Health Influence Economic Performance in India? An Exploratory Analysis at the District Level

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Abstract

The effect of health on both micro and macroeconomic performance is now well established. However, in the few studies carried out at the macro level for India, the link between the two has been shown to be somewhat tenuous. In this short study, we consider the impact of health on economic performance by studying district level data for agricultural productivity. Using two sets of cross-sectional data (from 1980-81 and 1990-91), and after addressing issues of endogeneity, we find that improved health has a positive and significant impact on agricultural productivity. Given its intrinsic and instrumental values, the obvious policy recommendation is for increased investment in health.

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Introduction

The health of an individual or region is of tremendous socioeconomic value. Good health is intrinsically important both in terms of the utility received from it (the intrinsic quality), as well as how it can be used to improve socioeconomic status (the instrumental quality)[1]. This paper is concerned with the latter point, but it should be noted at the outset that health and socioeconomic status share a two-way relationship, mutually enforcing each other in positive and, unfortunately, negative ways[2].

That health is intrinsically linked to the economic well-being of an individual and society is an obvious point. Persons with better health are likely to be more productive in their work tasks and likely to receive higher wages. Their increased longevity would allow for greater opportunities and incentives to educate themselves, and the rate of return gleaned from schooling would be higher as well than for a person in poor health. Additionally, individuals who live longer can be expected to save more, which is thus another avenue for the growth of the economy[3]. The available empirical evidence at the micro and macro levels strongly support these notions. For example, Deolalikar (1988) finds a strong association between weight-for-height, a measure of medium-term health and nutritional status, and individual wages and total farm production in rural south India[4]. At the macro level, according to final report from the 2001 Commission on Macroeconomics and Health, "a typical statistical estimate suggests that each 10 percent improvement in life expectancy at birth is associated with a rise in economic growth of at least 0.3 to 0.4 percentage points per year, holding other growth factors constant[5]."

This short study attempts to estimate the effect of health on district level agricultural production. We will begin with a review of previous studies conducted at the macro level for India which consider health to be an input towards economic performance. This will be followed by a discussion of the model being estimated. The issue of endogeneity will be considered here in depth. Two sets of cross-sectional models will be estimated, one for 1980-81 and one for 1990-91. This is done mainly for comparative purposes. Following this will be a few concluding remarks.

Literature Review: Health and Macroeconomic Performance in India

It is hard to make any strong conclusions from state level studies for India regarding the impact of health on economic growth. While there seems to be some tenuous evidence that health is a strong engine for development, these studies either do not consider health explicitly, or find that health is not a statistically significant input on its own. Most of these studies use a convergence model framework, where growth in gross state domestic product (GSDP) is the dependant variable and initial GSDP, along with other conditioning factors, serve as the independent variables[6]. We have provided a select list of some such studies and their salient attributes with respect to health in *Table 1*. It should be noted that despite differences in sample size, time period considered, and method of regression, health as an input is typically statistically insignificant when studied explicitly.

Table 1: Salient Attributes of Previous Studies

Study	Sample and Time Period	Method	Sample Type	Key Explanatory Variables (significant predictors)	Effects of Health and Human Capital
Govinda Rao, Shand, and Kalirajan (1999)	14 States, 1960-1995	Barro-type regression	Pooled cross sections on 5 year basis	Private investment	Literacy is found to be a significant engine for growth. Health is not explicitly studied.
Nagaraj, Varoudakis, Veganzones (2000)	17 States, 1970-1994	Barro-type regression	pooled cross sections on an annual basis	Industrial share, infrastructure (most specifically, electricity, roads).	Health is not significant by itself in regression, but is noted as a potent engine of growth.
Bajpai, Sachs, and Ramiah (2001)	14 Major States, 1980-1999	Barro-type regression	cross-sectional data	Urbanization drives economic growth. Port access, FDI all centered on this fact. Geographic considerations also come into play.	Not a significant predictor.
Gupta and Mitra (2001)	15 States, 1973-1994	Barro-type regression; simultaneous equations	pooled cross sections on 5 year basis	Varies with model used. Urbanization, industrialization, infrastructure, and literacy seem to be most significant, but not robust.	The association shows the correct sign, but statistically significant. Health has a significant impact in poverty reduction.
Mitra, Varoudakis, and Veganzones-Varoudakis (2002)	15 States, 1976-1994	regression w/ dependent variables of value added and TFP	pooled cross section on an annual basis	Capital stock, labor stock, and infra-structure, which is constructed from principle components from disaggregated data	Health not regressed separately, but has been decomposed to show a positive effect (large in magnitude)

It is instructive to take a deeper look into a few of these studies. Nagaraj, et al, (2000) and Mitra, et al, (2002), employ similar techniques in their treatment of health. Because of the high degree of collinearity between various forms of infrastructure and human capital inputs, principle component analysis was used to create an aggregate index of infrastructure from inputs such as health, proxied for by the infant mortality rate (IMR), education (literacy and enrollment), irrigation, power, railways, and banking.

Nagaraj, et al, regress this aggregate index against growth in GSDP. Aggregate infrastructure turns out to be a statistically significant determinant of economic growth. The impact of health is measured in two ways. The first is from a (vector) decomposition of the principle component, where individual elasticities of the inputs comprising the index are calculated. IMR is found to have a fairly large elasticity with respect to the steady state GSDP (-0.37). However, regressions that are run on disaggregated infrastructure data, specifically including IMR, and literacy for that matter, on their own, fail to find a statistically significant effect from these variables.

Mitra, et al, who study the effect of infrastructure in TFP and technical efficiencies across a wide set of industries, also use the vector decomposition approach in computing the impact of health. While the effect of IMR on steady state TFP varies across industries, it is found to be quite large in general: in fact, it is among the largest for any type of infrastructure. Unfortunately, IMR was not regressed by itself in any of these regressions.

Gupta and Mitra (2001), consider several possible set of simultaneous equations which model the interrelationship between health (IMR), economic growth, and poverty. The two relevant specifications find IMR to impact growth in the expected direction. However, these estimates are statistically significant only at the 20% confidence level. Their study does illustrate, however, the strong poverty reducing role of health. This particular point is also made by Ravillion and Datt (2002).

Given that so many cross-country studies have illustrated the significant impact of health on economic growth, the natural question to ask is why studies at the regional level have not been so emphatic in their results. There are three possible explanations.

First, health may not be an important factor towards economic performance in India. This can be safely rejected given the strong body of micro level evidence cited earlier and the large gains in health status accrued since Independence. Secondly, large contributions by other inputs (such as urbanization and other types of infrastructure) might "cloud over" the effects of other variables, such as health. Alternatively, the relative lack of other complementary developmental inputs or a supportive environment for growth in certain regions might work to check the statistically measured impact of better health on economic performance[7]. Third, small-sample sizes and multicollinearity create statistical difficulties in estimation. The use of district level data in this study will certainly allow us to avoid some of these pitfalls in analysis: the large sample size allows for greater degrees-of-freedom in specifying our model and issues of multicollinearity seem to be less severe at this disaggregated level.

Data and Estimation

A First Pass: Variables and Model Formulation

This study will consider the impact of health on economic performance at the macro level by considering district level data for the agricultural sector. While this breaks from the type of analysis considered above, to our knowledge collated sets of income data at the district level are unavailable[8]. The model to be estimated is the following:

$$VAg = f\,(Land, Animal, Machine, Irr, Fert, Lit, IMR, Roads, Labor, Geo)$$

where *VAg* represents the total value of agricultural output (in current rupees), *Land* is the total gross sown area (in hectares), *Animal* represents the total cattle population (male and female), *Machine* the total number of tractors, *Irr* is the percentage of the gross cropped area that is irrigated, *Fert* represents the amount of fertilizer used (in kg.), *Lit* represents the rural literacy rate, *IMR* is the rural infant mortality rate, *Roads* represents the percentage of villages with (pucca) access roads, *Labor* is the number of workers per hectare, and *Geo* represents a set of agro-climatic control variables[9]. *IMR* is used as a proxy for health status, and *Lit* is used as a proxy for education and know-how. Besides what it actually represents, we take *Roads* to also proxy for accessibility to rural markets and, more importantly, general infrastructure. Sample districts were chosen based on availability of data across all these indicators. Animal and tractor data turned out to be the limiting factor but, in both sets of years, we still have over 220 districts for analysis. Agro-climatic zone-wise sample means are given in *Tables 2* and *3*.

Table 2: Agro-Climatic Zone-wise Sample Means (1981)

Variable	Arid (23)	Semiarid (114)	Subhumid (74)	Coastal (13)
VAg	479164.8	676170.1	391758.2	1059597.8
Land	772.7	512.44	461.5	373.7
Labor	446056.1	623123.5	518087.8	828771.7
Animal	210680.9	186577.1	186595.8	133866.7
Machine	110183.2	38964.3	17763.5	6632.9
Irrig	18.0	25.1	16.76	19.83
Fert	7836.9	14029.3	6227.9	14868.5
IMR	95.1	111.35	130.7	89.0
Lit	21.1	59.7	23.0	36.5
Roads	24.2	28.5	21.8	37.5

- Of 15 major states, those not included are Assam, Bihar, Kerala, and West Bengal. As perhumid districts are all in West Bengal, we do not have any observations for this agro-climatic group here.
- Figures in parentheses are sample sizes.

Table 3: Agro-Climatic Zone-wise Sample Means (1991)

Variable	Arid (24)	Semiarid (110)	Subhumid (68)	Perhumid (8)	Coastal (12)
VAg	1523011.2	2141249.3	1377939.7	3781003.5	2594748.1
Land	797.8	515.9	405.9	445.6	337.9
Labor	50544.0	159931.4	117383.3	551501.6	194891.8
Animal	183138.87	179961.8	156294.9	249296.9	108803.6
Machine	254307.6	99568.4	77505.2	8388.4	15191.6
Irrig	15.4	29.4	20.7	9.0	15.3
Fert	15231.2	30764.0	14898.3	38673.1	30868.8
IMR	73.3	75.6	94.1	70.1	47.3
Lit	35.0	41.2	38.2	45.5	53.2
Roads	46.7	46.1	27.4	35.3	65.1

- Of 15 major states, those not included are Assam, Bihar, Kerala, Orissa, and Punjab.
- Figures in parentheses are sample sizes.

Some brief comments need to be made regarding a few of the indicators listed above. Values for *VAg* and *Fertilizer* were given in either per hectare or per capita terms. We converted them into totals by multiplying by agricultural land area, which was calculated using percentage of gross sown area and total land area. *Labor* was calculated using the percentage of agricultural workers and cultivators among all workers, the percentage of workers to the population, and the total population of the district. There is a good chance that this may leave other kinds of unmeasured work, such as child labor.

The agro-climatic controls were defined using the designations provided by NBSS and LUP (1992). The districts here are divided amongst 20 “agro-ecoregions” based on soil type, water resources, topography, and climate. These are further grouped into five bioclimatic types (perhumid, subhumid, coastal, semiarid, and arid). We use dummy variables to delineate each district as a member of one of these zones, with the arid zone serving as the base.

Our use of *IMR* as a proxy for health status will likely raise some concerns. Admittedly, as is pointed out in many studies, a better measure of health would be the prevailing morbidity rate. Additionally, life expectancy and adult death rates are probably better proxies of adult health, which would be a more relevant measure given the scope of our study. However, these indicators are simply not available at the district level. For that reason, *IMR* seems to be the only good proxy for health that is available. This should not be too much of a problem since all of the studies reviewed above for India employ IMR as a proxy for health.

The model will be estimated using a Cobb-Douglas production function in a cross-sectional format for 1980-81 and 1990-91, which are the only years for which district-level health data is available. This sort of modeling, while restrictive in its assumptions, provides the best fit. An additional problem is the manner in which we have specified health and education. As our earlier discussion suggested, health is essentially a *productivity enhancing agent* and ideally should be considered as such[10]. We will readdress this point in the discussion, but, for our purposes here, specifying health as an *input to production* allows for a direct measurement of the impact of health on agricultural production.

The reader is likely to note that the two cross-sectional sets employed here could potentially be merged into a panel data set, which offers the possible advantages of controlling for unobserved fixed effects over time and a providing a larger set of data to work with. However, because data for some of the same variables were gleaned from different sources for the different time periods, and since the estimates for *VAg* are likely to be expressed in current prices, pooling our cross-sectional data would be problematic. Additionally, availability of cattle and tractor data across states is somewhat different across our two cross-sections, thus reducing our effective sample size when pooled. Cross-sectional analysis would allow us to keep all the information and, for our purposes, time series analysis is really not necessary anyway.

A Second Pass: Issues of Endogeneity

There is every possibility that some of our input variables may share an endogenous or simultaneous relationship with the dependant variable. In the case of health, higher agricultural productivity might work to decrease *IMR* through greater provision of disposable income, which can be used towards building obtaining medical care or purchasing more (nutritious) food[11] . Additionally, it may be that unobserved variables that have a positive effect on *VAg* are significantly correlated with better health. For example, there could exist other types of infrastructure, which are not proxied for well by *Roads*, which have a large influence on agricultural production and are also positively correlated with *IMR*. Through similar reasoning general infrastructure, and possibly literacy, might also share an endogenous relationship with agricultural productivity. In all of these cases, the presence of endogeneity would thus render ordinary least squares (OLS) to be biased and inconsistent in its parameter estimates.

Regarding the endogeneity of health, Behrman and Deolalikar (1988) develop a theoretical framework for the household, where health, nutrition intake, farm productivity, and demand for medical services, are modeled by a set of simultaneous equations. The realized values for these factors are determined by maximizing the underlying household utility function. The results of the analysis provide a list of possible exogenous variables that can be used as valid instrumental variables (IVs). However, aggregation to the district-level poses some problems. The first is that the household utility maximizing framework may not hold in the same manner at the macro level. Secondly, the data available at the district-level is sparse with respect to possible instruments, and thus makes it difficult to follow any rigorous theoretical specification.

Despite the possible endogeneity of some of the other variables, we will limit our discussion to specifying *IMR* as the sole endogenous variable[12]. An ideal instrumental variable is highly correlated with the endogenous variable in question but not with the error term in the estimated equation; i.e., it must be exogenous with respect to our production function. The IVs used in this analysis are motivated mainly by common sense and literature review. We use the percentage of villages with tap water access, which represents the quality of living standards and level of sanitation, and population density, which represents the effective spatial access to public goods and medical facilities, as IVs[13]. An additional set of IVs that we employ are state-level geographic dummies (South, East, and West)[14] which Murthi, et al, 1995, find to be significant determinants of child mortality. Their rationale for the inclusion of these regional dummies is that they represent differences in social outlook, kinship patterns, attitudes, and other unobserved qualities, which have strong effects on health status.

We estimate our endogeneity-corrected models using two-stage least squares (2SLS). We begin by first using Hausman's suggested test to ascertain that *IMR* is indeed endogenous with respect to the IVs chosen[15]. In essence, this allows us to make sure that differences in OLS and 2SLS results are not due to sample error alone. To make sure that the IVs themselves are not endogenous, we use overidentification tests[16]. For both sets of years, we find that *IMR* is indeed an endogenous variable, and that the 2SLS results are not biased because of endogeneity in the instruments.

Results and Discussion

The estimated production functions for 1980-81 and 1990-91 are presented in *Table 4*. In the 1980-81 OLS model, *IMR* and *Lit* have the largest elasticities, followed by that of *Land* - the elasticities on *Fert* and *Labor* are also statistically and practically significant. The returns to health are quite large here: a 10 percent decrease in IMR results in over a 4 percent increase in output value, *ceteris paribus*. The 1990-91 OLS models show similar results, but with *Roads* and *Irr* coming into statistical significance. Here, the coefficient on *Land* is the largest, followed by that on *IMR*.

Interestingly, in both sets of years, the coefficient on *Machine* is negative, and is in fact significant in the latter period. This could be a result of the aggregate nature of the dependant variable: it may be that crops which are less machine-intensive may fetch a higher value added[17].

Table 4: Production Function Estimates

Year	1980	1980	1990	1990
Method	OLS	2SLS	OLS	2SLS
Constant	4.19** (1.19)	11.84** (2.34)	6.69** (0.88)	9.51** (1.37)
Lit	0.38** (0.102)	0.146 (0132)	0.212* (0.105)	0.54 (0.124)
Land	0.39* (0.163)	0.379* (0.19)	0.701** (0.112)	0.726** (0.116)
IMR	-0.461** (0.143)	-1.718** (0.352)	-0.315** (0.105)	-0.754** (0.193)
Roads	0.116 (0.09)	0.087 (0.111)	0.209** (0.08)	0.141 (0.088)
Irrig	0.052 (0.05)	0.122* (0.060)	0.17** (0.039)	0.184** (0.041)
Fert	0.284** (0.048)	0.202** (0.06)	0.195** (0.041)	0.184** (0.043)
Labour	0.244* (0.096)	0.096 (0.118)	0.08 (0.044)	0.058 (0.047)
Animal	0.137 (0.083)	0.209* (0.099)	0.007 (0.057)	0.012 (0.059)
Machine	-0.03 (0.0238)	-0.014 (0.033)	-0.05* (0.023)	-0.048* (0.024)
Coastal	0.395* (0.193)	0.694** (0.238)	0.453** (0.175)	0.411* (0.183)
Semiarid	0.168 (0.127)	0.547** (0.175)	0.236* (0.113)	0.308* (0.120)
Subhumid	0.09 (0.138)	0.579** (0.201)	0.372** (0.134)	0.487** (0.146)
Perhumid	-	-	0.85** (0.221)	0.937** (0.232)
adjusted R^2	0.737	0.679	0.771	0.758
number of observations	224	224	222	222

- Figures in parenthesis are standard errors.
- * - significant at 5% level, ** - significant at 1% level

Interestingly, the computed elasticities for *IMR* in the 2SLS models are much larger than that of the OLS models[18] . *A priori*, one would expect OLS to *overestimate* the impact of *IMR* if the two variables indeed shared a simultaneous relationship. There are two possible explanations for the results gleaned here. First, the elasticities specified by the 2SLS estimation are the correct ones, which means that OLS must somehow *underestimate* the impact of health on economic performance. This could conceivably occur, for example, if a large number of districts with high *VAg* rely very heavily on strenuous human labor relative to physical capital, which thus would have a detrimental impact on health through the nature of the work load. A generalization of this is that *IMR* may be partially positively correlated with an omitted factor that has a positive effect on agricultural production. This is borne out by the results of the Hausman test. For both sets of years, the reduced form residuals take on positive and statistically significant coefficient values, which clearly suggests that the unobservables in the model have a positive impact on the dependant variable. Second, these results may also arise simply because the instruments are of poor quality.

While we can rule out this second option to some extent thanks to the Hausman and overidentification tests carried out earlier, it is hard to make any ground on the first conjecture given the available data. In any case, it is clear that the 2SLS models employed here generally support the results gleaned from the OLS models: health indeed has a statistically and economically significant impact on agricultural performance at the district level.

Additionally, it should be noted forcefully that the 2SLS estimates gleaned here are not at all outlandish when compared to other studies that treat health as an endogenous variable. Interestingly, Deolalikar (1988) finds an elasticity of 1.3-1.8 for weight-for-height on farm production. This elasticity is greater than those of the other inputs by a large margin (second highest elasticity is around 0.4, for labor hours supplied). For their cross-country growth model, Bloom, et al, (2001) find that a 1 year increase in life expectancy raises output by roughly 4 percent.

Another question that arises is why exactly do the coefficients some of the variables change so greatly across the years considered? For example, the coefficient on *Land* jumps almost two-fold across the decade and several other variables jump in and out of statistical significance. Because of the fact that certain variables were gleaned from different sources across the years, and that the sample composition is somewhat different, it is hard to make any non-statistical conjectures on such queries. However, there are important lessons we can take from both sets of regressions. We can see clearly that, while the nature of the production process may have changed across districts, health's role in promoting economic performance in agriculture has been very strong over time[19].

Discussion and Concluding Remarks

The National Health Policy of 1984 set several long range goals towards achieving better health outcomes and health services by the year 2000. While the overall health of the population has improved since then, these achievements have fallen quite short of the intended objectives[20]. As this study indicates, there has been a tremendous loss of economic output, and social welfare, associated with this shortfall.

Better health has traditionally been considered as a *result* of the development process. While several of the cross-country and micro-level studies have looked at the instrumental roles of health, the studies that have emerged in the Indian context have generated somewhat tenuous conclusions at best. In this study, we have shown that health does indeed influence economic performance in India and does so in a significant way. For 1981, we calculate elasticities of -0.4 to -1.7 and for 1991, -0.3 to -0.75, for OLS and 2SLS models, respectively. Given this, and the fact that health has a significant role in promoting general well-being and reducing poverty, the obvious policy recommendation that arise from this work is for greater investment in public health – especially the targeting of avoidable diseases and undernutrition.

Several improvements can be made on this study. Since health is essentially a factor that enhances labor productivity it should be modeled as such, and not necessarily as an input to production. While the modeling done here gives us a direct estimate of the returns to health status to production value, treated health as a productivity enhancing agent is more in line with our theoretical understanding of how health works to promote development. Mitra, et al, 2002, as we mentioned earlier, have already specified health in this manner, albeit in the context of an aggregate index of infrastructure. In another study (with K.R. Shanmugam, to be submitted for publication) we have looked at health as a determinant of technical efficiency. However, despite these shortcomings, we are confident that the present study illustrates the significant role of health in promoting economic performance.

Notes

1 The discussion of intrinsic and instrumental values is motivated by Dreze and Sen (1995).

2 According to CMH (2001), poor health contributes to poverty both through its negative effect on wages earned, as well as through the portion of income that is spent on medical care. Increased deprivation from these avenues only works to worsen health status. The individual/society is therefore placed into a self-reinforcing cycle. The cycle also works in the opposite direction.

3 These points are taken from Bloom and Canning (2000). There are other avenues through which health can have a large impact on economic performance, as well. Bloom and Canning cite the fact that East Asian countries gained a great deal from improvements in child health and declines in fertility through a large intergenerational increase in the share of working-age individuals in the population.

4 For reviews of related studies, see Behrman and Deolalikar (1988) and Strauss and Thomas (1998).

5 Recent studies linking health and macroeconomic performance at the macro level include Barro and Xala-i-Martin (1995), Bloom, et al, (2001), and Bhargava, et al, (2001). Barro and Xala-i-Martin and Bhargava, et al, use convergence models (rooted in neoclassical growth theory). Bloom, et al, employ a production function approach, which is manipulated into a growth model.

6 See Barro and Xala-i-Martin (1995). The convergence model analysis is rooted in neoclassical growth theory. Conditioning factors include health, education, rule of law, democracy, infrastructure, etc.

7 See Govinda Rao, et al (1999) and Sachs, et al, (2002) for a discussion on these additional determinants. This is essentially the idea of intersectoral linkages: human capital requires physical capital and supportive institutions in order to have an effect economic performance. Kerala is an example of this. Despite Kerala's superlative record in human development, it ranks just about in the middle of the pack as far as GSDP. This can be attributed to poor industrial performance and a general lack of private investment and ill-developed entrepreneurship.

8 According to Murthi, et al, (1995), the National Sample Survey Organization (NSSO) provides data on per capita expenditure. However, this data is available only for defined regions of an intermediate size between districts and states.

9 Data for value of agricultural production, irrigation, fertilizer usage, gross sown area, electrification, and population size were obtained from CMIE (2000). Tractor and cattle population were provided by the ICRISAT CD-ROM. Rural literacy rates were taken from Government of India (1981) for 1981 and CMIE (1993) for 1991. Rural

IMR data for 1981 was provided by Government of India (1988) and from Irudaya Rajan and Mohanachandran (1998) for 1991. The percentage of villages with pucca roads and tap water for 1981 and 1991 were taken from Government of India (1986) and Government of India (1997), respectively. The percentage of agricultural workers and cultivators were obtained from CMIE (1982) for 1981 and CMIE (1993) for 1991.

10 See Bloom, et al, (2001), who address this concern using an "aggregate Mincer equation," where health, education, and work experience are specified as labor augmenting factors. Estimation of this particular equation is difficult in our case given the paucity of data and the need to draw data from different sources for various years.

11 Of course, the effect of higher agricultural production value on health depends on the distribution of the resultant income. In the *National Nutrition Monitoring Bureau: Annual Survey Report (1990-91)*, the four South Indian states (Andhra Pradesh, Karnataka, Tamil Nadu, and Kerala), nutritional status (in terms of KCAL consumed, vitamin intake, etc) is better for higher socioeconomic classes than lower, and the same trend is seen from cultivators to landless laborers. This clearly suggests that production income is unevenly distributed. However, if the caloric intake of all groups increases over time, then the mean level of health would likely increase with higher agricultural production value per hectare.

12 We tried other specifications as well, including treating literacy and roads as endogenous. The results with respect to most variables, including the health variable, were basically the same.

13 Srinivasan (1996) clearly illustrates the effect of population density on access to medical care and other public goods. My own studies on the determinants of district-level health (not shown here) provide the same results in a multivariate formate.

14 South represents Andhra Pradesh, Kerala, Tamil Nadu, and Karnataka. Bihar, West Bengal, and Orissa are included in East. Gujarat and Maharashtra comprise West. The remaining states comprise the base region (North).

15 Here, the reduced form equation of the suspected endogenous variable is computed and the residuals are taken and regressed with all the variables specified in the original production function. If the coefficient on the residuals is statistically significant, the null hypothesis of endogeneity is accepted. This test is important as 2SLS is inconsistent when all of the independent variables are exogenous. See Wooldridge (1999) for more details.

16 The overidentification test involves computing the 2SLS residuals and regressing all of the exogenous variables against this value. The null hypothesis of exogeneity in the IVs is rejected when the value $n*R2$ is significant in a Chi-square distribution for $IV - a$, where n is the number of observations, $R2$ is the goodness-of-fit in the regression against the 2SLS residuals, IV is the number of instrumental variables from outside the model, and a is the number of endogenous variables. Clearly, this test can only be

carried out when there are more instrumental variables than endogenous variables. See Wooldridge (1999) for more details.

17 There are precedents for negative coefficients on input variables at this level of aggregation. See Fan and Hazell (2000), where electrification and market presence show negative signs. Additionally, we did try to find crop-wise data for districts. Such data, however, is severely limited in nature. To our knowledge, it is only available for crop output and cropped area.

18 There are other differences in the 2SLS results as well with respect to the statistical and practical significance of *Lit* and *Roads*. In both cases, these are significant in the OLS models but not so in the 2SLS models. This held true in other specifications we tried, were one or both of these variables were treated as endogenous.

19 Another interesting point to note is that the returns to better health has appeared to *decline* over time. While this could be due simply to the fact that *IMR* data for the different time periods were taken from different sources, there are other compelling ideas as well. For example, it may be that decreases in subsistence farming, and increases in the capital- and knowledge-intensive nature of agriculture, that could render labor quality less important in the scheme of production.

20 See Gumber (2001).

References

1. Barro, R., and Xala-i-Martin, X. *Economic Growth*. New York: McGraw-Hill. 1995.

2. Behrman, J.R. and Deolalikar, A.B. “Health and Nutrition.” In Hollis B. Chenery and T.N. Srinivasan, eds., *Handbook of Development Economics.* Vol 1. Amsterdam: North-Holland, pp. 631-711, 1988

3. Bhargava, A., Jamison, D.T., Lau, L.J., and Murray, C.J.L. “Modeling the Effects of Health on Economic Growth.” *Journal of Health Economics* 20 (2001): 423-440.

4. Bloom, D., and Canning, D. “The Health and Wealth of Nations.” *Science* 287, no. 5456 (2000): 1207-1208.

5. Bloom, D., Canning, D., and Sevilla, J. “The Effect of Health on Economic Growth: Theory and Evidence.” *NBER Working Paper 8587* (2001).

6. Center for Monitoring the Indian Economy (CMIE). *District Level Data for Key Economic Indicators with over 60 Maps*. Mumbai: CMIE, 1982.

7. Center for Monitoring the Indian Economy (CMIE). *Profiles of Districts*. Mumbai: CMIE, 1993.

8. Center for Monitoring the Indian Economy (CMIE). *Profiles of Districts*. Mumbai: CMIE, 2000.

9. Commission on Macroeconomics and Health (CMH). “Macroeconomics and Health: Investing in Health for Economic Development.” *Report of the Commission on Macroeconomics and Health*. 2001.

10. Deolalikar, A.B. “Nutrition and Labor Productivity in Agriculture: Estimates for Rural South India.” *The Review of Economics and Statistics* 70, no. 3 (1988): 406-413.

11. Dreze, J and Sen, A. *India: Economic Development and Social Opportunity*. Oxford: Clarendon Press, 1995.

12. Fan, S. and Hazell, P. “Should Developing Countries Invest More in Less-Favored Areas? An Empirical Analysis of Rural India.” *Economic and Political Weekly* April 22, 2000.

13. Government of India. “Availability of Infrastructural Facilities in Rural Areas of India: An Analysis of Village Directory Data.” *Census of India 1991*. New Delhi: Office of the Registrar General: 1997.

14. Government of India. “Child Mortality Estimates of India.” *Census of India 1981*, Occasional Paper 1 of 1988. New Delhi: Office of the Registrar General, 1988.

15. Government of India. “Study on Distribution of Infrastructural Facilities in Different Regions and Levels of Urbanization.” *Census of India 1981*, Occasional Paper 1 of 1986. New Delhi: Office of the Registrar General, 1986.

16. Government of India. *Census of India 1981*, Series I, Part II-B(i), Primary Census Abstract, General Population. New Delhi: Office of the Registrar General, 1981.

17. Govinda Rao, M., Shand, R.T., and Kalirajan, K.P. “Convergence of Income across Indian States: A Divergent View.” *Economic and Political Weekly*. March 27, 1999.

18. Gumber, A. “Economic Reforms and the Health Sector: Towards Health Equity in India.” Paper presented at the National Seminar on Economic Reforms and Employment in the Indian Economy, 2001.

19. Gupta, I. and Mitra, A. “Economic Growth, Health and Poverty: An Exploratory Study for India.” *IEG Working Paper No. 39* (2001).

20. Irudaya Rajan, S. and Mohanachandran, P. “Infant and Child Mortality Estimates: Part 1.” *Economic and Political Weekly* May 9, 1998: 1120-1140.

21. Mitra, A., Varoudakis, A., and Véganzonès-Varoudakis, M. “Productivity and Technical Efficiency in Indian States’ Manufacturing: The Role of Infrastructure.” *Economic Development and Cultural Change* 50, no. 2 (2002): 395-426.

22. Murthi, M., Guio, A., and Dreze, J. "Mortality, Fertility, and Gender Bias in India: A District-Level Analysis." *Population and Development Review* 21, no. 4 (1995): 745-782.

23. Nagaraj. R., Varoudakis, A., and Véganzonès, M. "Long-Run Growth Trends and Convergence across Indian States: The Role of Infrastructure." *Journal of International Development* 12, no. 1 (2000): 45-70.

24. National Bureau of Soil Survey and Land Use Planning (NBSS and LUP). *Agro-Ecological Regions of India*., 2nd ed. (NBSS Publication No. 24.) Nagpur: NBSS and LUP, 1992.

25. National Institute of Nutrition (NIN) and Indian Council of Medical Research (ICMR). *National Nutrition Monitoring Bureau: Annual Survey Report (1990-91)*. Hyderabad: NIN and ICMR, 1992.

26. Ravallion, M. and Dutt, G. "Why has Economic Growth been More Pro-Poor in Some States of India than others?" *Journal of Development Economics*. 68 (2002): 381-400.

27. Sachs, J.D., Bajpai, N., and Ramiah, A. "Understanding Regional Economic Growth in India." *CID Working Paper No. 88* (2002).

28. Strauss, J. and Thomas, D. "Health, Nutrition, and Economic Development." *Journal of Economic Literature* 36 (1998): 766-817.

29. Wooldridge, J.M. *Introductory Econometrics: A Modern Approach*. Cincinnati, OH: South-Western, 2000.