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Review Article

Health Impact of Water Borne Diseases and Regional Disparities in India

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ABSTRACT

In order to meet Millennium Development Goals it is imperative that improved sanitation facilities along with availability of potable water, the two basic facilities for human development could be met effectively by the state intervention. However, despite significant investments over the last 20 years, India still faces the most daunting sanitation challenge and its sanitation is rated as the second worst in the world after China. At present only 28 per cent of people in rural areas have access to toilets leading to severe burden on community, health services and considerable losses to productivity to the nation. With a view to assessing health impact of water borne diseases this study provides first an assessment of direct impact of water and sanitation facilities on incidence of selected diseases in major Indian states. This is followed by an estimation of indirect impact through a case study of Karnataka which brings out sub-state level disparities within the state. Our estimation through regressions and stochastic frontier analysis indicate that quantitative significance of sanitation status is revealed both directly in incidence of selected diseases and indirectly on health system efficiency at sub-state (district) level coefficients. These results indicate that for more equitable health outcomes and an improved efficiency of health system, adequate infrastructure facilities like safe drinking water supply, toilets and electricity are necessary. These inputs may help to reduce disparities and improve the outcomes in deficient districts of Bagalkot, Kolar, Kodagu and Uttar Kannada. Thus in the final section based on our estimates, policy measures are suggested which emphasize that more efficient health outcomes could be achieved by overcoming investment needs through different innovative measures adopted to regions and locations comprising of higher subsidy to sanitation, better management of existing programmes and community participation.

Key words: Health, water borne diseases, regional disparities, efficiency, Karnataka

INTRODUCTION

It is now universally recognized that there is a vital link of water and sanitation with the health status of the people. In the absence of these basic necessities for healthy living, there is scientifically and socially a concern for possible incidence and spread of certain preventable diseases. Some of the common pathogens capable of sickening humans and animals caused by contamination of water through sewage and which survive in bodies of water for days or weeks can cause a number of diseases. [(1)] In general, a classification of water related diseases could be provided in terms of Water-borne, Water-washed, Water-based and Water-related vectors. The diseases cited under these common categories may include Diarrhea, Dysenteries, Typhoid fever, Scabies, Trachoma (Water-borne and Water-washed), Schistosomiasis, Guinea worm (Water-based) and Dengue, Malaria and Trypanosomiasis (Water-related insect vectors). The incidences of these cases vary considerably across Indian states with differing range (Table 1).

Objective of this paper is to attempt an assessment of the direct and indirect impact of water and sanitation facilities on water borne diseases in India within the prevalent regional diversity and disparity. The former relates to incidence of diseases owing to existing water and sanitation facilities and the latter refers to additional burden on the health system caused by such diseases. We integrate impact of water and sanitation and the efficacy of health systems for Karnataka state as a case study. The latter is chosen as it being a middle income Indian state representing the importance of a public health system in minimizing the incidence and impact of water borne diseases for a state that has an average level of income. Based on our analysis we thus emphasize that even in the presence of a public health system, the district level variations within a state do play an important role in influencing health outcomes.

Impact of Water Borne Diseases in Major States in India

In India, the cases of the water borne diseases reported in sixteen major Indian states indicate regional variations caused possibly by geographical locations and other climatic factors. This could be observed, for instance from Table 1, which provides the latest published figures for the year 2008. Some states like Orissa had maximum cases reported for Malaria (36%). The other states like Andhra Pradesh, Karnataka, Kerala and Maharashtra seemed to have Hepatitis cases reported in the range of 8-11 percent. Even ARI cases were also relatively in a similar range for Andhra Pradesh (10.7%) and Tamil Nadu (9.9%) with Kerala having a much higher percentage (27.8%). Likewise, some coastal states like Andhra Pradesh and West Bengal and other state, namely, Maharashtra seemed to have more incidences of Typhoid and Acute Diarrhoea.

The measurement of health benefits from the availability of water supply and sanitation facilities (WSS) has been done in different ways by individual researchers. However, in most of the studies, either the incidence of diseases or infant mortality rate has been considered as dependent variable. The basic difference remained in terms of measuring the magnitude of impact on health status. There have been a number of exhaustive reviews which covered a large no. of studies to analyse the impact of WSS facilities or policies. For instance, an earliest review of 144 studies analysed the impact of improved water supply and sanitation facilities on ascariasis, diarrhoea, drancunculiasis, hookworm infection, scistosomiasis and trachoma.[(2)] This review indicated that WSS led to reduction in morbidity; that median reduction for diarrhoea, trachoma and ascariasis was around 26, 27 and 29 percent respectively. This was in contrast to a similar reduction in scistosomiasis and drancunculiasis put around 77 and 78 percent. The reduction in hookworm infection was observed around 4 percent only. [(2)] Other study opined that improved WSS facilities are not efficacious in improving health status and not particularly cost-effective.[(3)] Yet another review of 67 studies from 28 countries found that WSS investments can reduce diarrhoea morbidity and mortality rates by a median of 22% and 21%, respectively. [(2)] It is worth mentioning that most of the studies reviewed were also influenced by the methodologies adopted, inadequate health indicators and lack of control for confounding variables including selective primary health care and other health facilities.[(4)]

Table 1: Cases of Water Borne Diseases in Major States (as % to all India*)(2008)

State\ Diseases	Malaria	Hepatitis	ARI	Typhoid	Acute Diarrhoea
Andhra Pradesh	1.9	9.1	10.7	14.5	15.6
Assam	5.3	2.4	0.4	0.2	0.8
Bihar	0.1	0.0	0.0	Na	Na
Goa	0.6	0.1	0.2	0.1	0.1
Gujarat	1.4	3.3	2.2	0.5	3.0
Haryana	0.7	2.1	4.0	1.2	2.0
Karnataka	2.9	10.3	7.5	6.0	6.4
Kerala	0.1	11.1	27.8	0.6	3.2
Madhya Pradesh	3.4	9.2	3.1	6.8	4.9
Maharashtra	2.2	8.0	3.4	8.9	8.8
Orissa	36.0	2.0	3.0	3.7	4.1
Punjab	0.0	7.6	2.1	2.3	1.6
Rajasthan	1.2	2.2	4.8	1.6	3.2
Tamil Nadu	1.7	2.1	9.9	9.4	3.8
Uttar Pradesh	2.4	1.3	3.1	5.3	3.6
West Bengal	4.3	4.7	2.5	14.9	23.9
India (no. of cases)	271037	90440	25541645	916161	11231039

Source: indiastat.com: * as a percentage to no. of cases for India given in the last row of this table.

To capture the benefits of WSS which extend beyond its role in improving health status, [(5)] some attempts have been also made to measure the health benefits resulting from investment in WSS through case-control studies. Such types of studies have been carried out in Lesotho, [(6)] Malawi, [(7)] and Philippines. [(8)] Estimates of these studies have put a reduction owing to WSS investments between 20- 24% in the incidence of diarrhoea. Focusing on the link between the water quality and child health in different parts of the developing world, a study, for instance using a longitudinal data from metropolitan Cebu-Philippines from 1983 to 1986 for child mortality up to 2 years indicated that child mortality varies significantly between birth weight and nutritional status. [(9)] Another study for Bangladesh and Philippines analysing the impact of water quality, sanitation and socioeconomic factors on child health [(10)] pointed out no significant effect between water supply and source of drinking water, sanitation and child health. In the Malaysian context using stratified partial likelihood estimation, similar conclusions were drawn. [(11)] Whereas WHO based on primary survey using a logit regression model indeed indicated a negative relationship between arsenicosis and household income. [(12)] In a survey in Argentina during the period of

1990-1999, it was found that the privatization of water services is associated with 33% reduction in the mortality rate, which amounts to a 5.3% reduction of the baseline rate. [13] The privatization of water systems does not affect mortality in those municipalities with low levels of poverty. The effect on the remaining treated municipalities was found to be increasing with the level of poverty, with child mortality declining by approximately 8% in the areas where water systems were privatized.

Studies in the Indian context indicate a significant impact of water borne diseases on child mortality. An estimated 105 million children under 5 years die each year due to water borne diseases resulting in a loss of 200 million man-hours a day every year(or Rs.36, 000-366 billion crores). [14] Impact of water contamination in increasing water related diseases was also established by a survey of three villages Gudimallur, Devathanam, Vannivedu of Tamilnadu. [15] Another study in rural Andhra Pradesh indicated that up to 15 million people are using water obtained from unsafe source which may have identifiable health effects. [16] A primary survey for the period 1993-94 found that the overall prevalence of diarrhoea is 10.1 with an average of .33 days of illness and mean expenditure of 0.74 rupees per episode of diarrhea. [17] Disease prevalence and length of illness varied inversely with higher income and education. Access to piped water also led to a significant reduction (21%) in diarrhoea prevalence and duration. Using factoral analysis another study also found significant impact of water and sanitation facilities in rural and urban sectors on Infant Mortality Rate (IMR), Crude Death Rate (CDR) and incidence of different diseases. [18] In rural Uttarakhand with a primary survey of 1530 households in 2004-05, sanitation and health link was established focusing on factors affecting diarrhoea episodes and latrine availability indicating that latrine availability affected episodes of diarrhea negatively, and the availability of water, education, poverty and the Swajalprogramme had a positive effect on latrine availability and use. [19] In Dahod District of Gujarat it was found that the toilets significantly reduced not only the cost of medical treatments but also the loss of wages induced by sanitation-related diseases. [20] Money saved from sanitation illnesses for one person for a period of two years could cover the cost of a toilet. A study in Chromepet and Pallavaram township of Tamil Nadu using primary data indicated that drinking water quality, sanitation, fuel type and precautionary measures taken by the household significantly affect the health. [21] By contrast, in the districts of Murshidabad and Bankura in West Bengal, focusing on "Nirmal Grams" (or villages with 100% Sanitation) another study indicated that by providing only toilets in the individual houses, the disease burden may not reduce substantially. It should also be accompanied with improvements in drainage condition, general sanitation, personal hygiene and food sanitation to minimize the disease burden among the villagers. [22]

From the above review of studies we hypothesize that there is a link between health status and water supply and sanitation (WSS) which works directly through its impact via transmission or incidence of water borne diseases. There also exists an indirect impact of WSS which impinges on efficiency of health facilities and has its impact in the presence of differentials in socio-economic variables. In line with some of the studies reviewed above, we have also chosen incidence of diseases (as indicated by number of cases of a particular disease reported) as a dependent variable to estimate direct impact of water and sanitation facilities. However, unlike above reviewed studies we have additionally analysed the impact of the incidence of diseases on health system efficiency

This study is based on secondary data. To estimate direct impact of WSS, information is collected from Ministry of Rural Development and Water supply, indiastat.com, Ministry of Finance, health information in India, and websites of the states and published documents from other agencies including Sulabh International Service organization and individual researchers. Main variables used to study direct impact are number of cases of different diseases and variables relating to availability of water and sanitation in different states, health facility variables and per capita incomes. The information relates to 28 Indian States. The indirect impact of WSS is estimated using district level data for Karnataka state which also makes use of information available from Human Development Report of Karnataka. [23]

In order to estimate the direct impact of WSS, we utilized regression analysis which gave the impact coefficients to indicate the importance of *aprioi* causal factors on the incidence of a particular disease which is denoted by no. of cases of the disease taken as the dependent variable. The 28 Indian states for which data for this analysis have been used include: Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Jharkhand, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Karnataka, Kerala, Madhya Pradesh, Chhattisgarh, Maharashtra, Meghalaya, Mizoram, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand, West Bengal and Pondicherry. It is observed that many of the WSS borne disease like cholera, guinea worm, fileria, plaque and dengue are now nearly non-existent or prevalent in some states only. Thus we used this analysis for five major diseases which are associated with WSS and continue to prevail in most of the states. These include acute diarrhoea, hepatitis, typhoid, malaria and acute respiratory infections (ARI). Among the explanatory variables we included four sets of variables representing drinking water facilities, sanitation amenities, health care facilities and socio-economic factors. Thus in our regressions main explanatory variables were, namely, total habitats covered partly or fully (partial, full)(where the norms of at least 40 litres of safe drinking water per day were fulfilled), percentage of total habitats not as per all India accelerated rural water supply norms (not ARWSP %), total habitats covered by safe water supply (safwat), total habitats covered by safe water supply in rural and urban areas respectively (safrural and safurban), percentage of total habitats affected by Physical & Biological contamination (contamination%), percentage of total places where water being at a far off place (watfaraway %), no drainage facilities (nodrain), no sanitary toilet facilities (notoilet), percentage of improvement in sanitary facilities as envisaged in the investment plan by the department of rural water supply and sanitation (achievement sanitation%). Among the health facilities we covered variables representing government hospitals or hospital beds(Ghosp or Gbeds), hospitals or beds provided by local bodies (LHosp or Lbeds), private hospitals or beds (pvthosp or pvtbeds), total hospitals or beds including government and private(tothosp or totbeds), total no. of hospital beds including allopathic and other systems of medicines (bedsalltype), population covered per bed, all hospitals or all types of beds (popperbed, popallhosp or popallbeds). Per capita income at constant prices is taken to represent the influence of socio-economic status (PCIC). The results of our analysis are presented in the following Tables 2-2(b).

Table 2: Regression Results for Impact of Water and sanitation facilities

Dependent Variable→ / Explanatory Variable\Statistic↓	1. Acute Diarrhoea			2. Hepatitis		
	Total Cases	Male Cases	Female Cases	Total Cases	Male Cases	Female Cases
Intercept	301542.219 (-1.030)	-108612.262 (-.650)	-98162.110 (-.605)	1055.585 (.519)	774.268 (.670)	281.317 (.313)
Contamination%	2.639 (2.639*)	.404 (2.203*)	.406 (2.256*)	-.390 (-2.189*)	-.369 (-2.071**)	-.412 (-2.294)
tothosp	2.059 (2.059**)	-	-	-	-	-
notoilet	1.574 (1.574)	.450 (2. 086*)	.483 (2.283*)	-	-	-
popperbed	-	-.262 (-1.212)	-.333 (-1.570)	-	-	-
PCIC	-	-	-	-.078 (-.452)	-.080 (-.463)	-.074 (-.428)
bedsalltype	-	-	-	.648 (3.803†)	.657 (3.850†)	.628 (3.660†)
safwat	-	-	-	.142 (.780)	.117 (.641)	173 (.941)
R^{-2}	.337	.196	225	.339	.338	.329
F Statistic and DF	5.24†, 25	2.945**, 24	3.328*, 24	4.203*, 25	4.186*, 25	4.069*, 25

Note: Figures in the parentheses denote "t" ratios. Level of significance: †=1% , *=5%, **=10%

Table 2(a): Regression Results for Impact of Water and sanitation facilities

Dependent Variable→ / Explanatory Variable\Statistic↓	3. Typhoid			4. Malaria
	Total Cases	Male Cases	Female Cases	Total Cases
Intercept	-21250.614 (-.793)	-10410.91 ((-.770)	-10839.70 (-.813)	2.575 (1.203)
Contamination%	.347 (2.125*)	.348 (2.167*)	.346 (2.077**)	-
Tothosp	.306 (1.810**)	.305 (1.84**)	.306 (1.774**)	.417 (2.538† †)
Notoilet	.472 (2.854†)	.485 (2.989†)	.457 (2.709††)	-
Popperbed		-	-	-
PCIC	-.092 (-.544)	-.108 (-.651)	-.075 (-.434)	-
Nodrain		-	-	.355 (2.161*)
R^{-2}	.402	.424	.378	.281
F Statistic and DF	4.866†, 23	5.226†, 23	4.49†, 23	6.276†, 27

Note: Figures in the parentheses denote "t" ratios. Level of significance: †=1% , † †=2%, *=5%, **=10%

Table 2(b): Regression Results for Impact of Water and sanitation facilities

Dependent Variable→	5. ARI		
	Total Cases	Male Cases	Female Cases
Explanatory Variable\Statistic↓			
Intercept	-504482.21 (-1.39)	-187707.98 (-1.132)	-316774.22 (-1.616)
Bedallty	.391 (2.624† †)	.405 (2.658† †)	.378 (2.58† †)
Achievement sanitation%	.249 ((1.688)	.258 (1.713)	.240 (1.658)
Partial	.500 (3.516†)	.460 ((3.161†)	.531 (3.797†)
R^{-2}	.513	.490	.529
F Statistic and DF	9.774† , 25	9.007†, 25	10.337†, 25

Note: Figures in the parentheses denote "t" ratios. Level of significance: †=1% , † †=2%, *=5%, **=10%

The results of regressions actually indicate that water and sanitation facilities have influenced the incidence of all the five diseases. It should be noted that results presented here depict only those variables which were significant although others which are not shown were tried in separate regressions for the same dependent variable.

The regression coefficients indicate that due to physical and biological contamination the total no. of cases for acute diarrohea and typhoid has increased. The respective coefficient of this variable representing contamination for these diseases has been 2.639 and .347 (columns 2, Tables 2 and 2(a) respectively. However, in terms of male and female cases, this impact has been different than total no. of cases (columns 3 and 4, same Tables). In regard to hepatitis, the results indicate that an increase in coverage of habitation under safe water supply and thus overall reduced contamination has been significant with a negative sign for cases of this disease (columns5-7, Table 2).For Malaria cases (Table 2(a), last column) as expected the lack of drainage facilities had a positive influence for the incidence of the disease. In case of ARI (Table2 (b)), the inadequate achievement of targets to cover areas through sanitation facilities (achievement sanitation%= .249) might have led to more no. of total cases but statiscally it is not confirmed through significance in the results presented here. Also, partial coverage of habitations through safe water supply (partial=.500) had added influence to increase the incidence of ARI. Further the positive impact of non-availability of toilet facilities is also seen for typhoid case (notoilet=.472, Table 2(a)).In both diseases, namely, typhoid and ARI, the impact has been higher on male no. of case relative to females possibly due to differences in reporting for them. In all the regressions the impact of income variable (PCIC) has not been statistically significant thus indicating that increase in income has not been able to compensate for the WSS facilities. An important role of hospital facilities or health system (depicted either as totalhospitals; totalhosp for typhoid and malaria and total beds of all types; bedsallty for hepatitis and ARI), as seen through these regressions is an increased reporting through health system thus a positive coefficient of this variable.

Impact of Health Systems, Regional Disparities and Sanitation Factors; State and District Level Analysis

The results of the direct impact of WSS on incidence of selected diseases in major Indian states indicate that health facilities have played a considerable role in reporting of the incidence of WSS related diseases.

To attempt an assessment of the indirect impact of sanitation on health in India, we integrate impact of water and sanitation and the efficacy of health systems for Karnataka state. In this section we thus emphasize that even in the presence of a public health system; these factors do play an important role in influencing health outcomes. Using district level (or sub-state level) information, we focus on a case study of middle income state, namely Karnataka. First we use stochastic frontier analysis for the state to assess the efficiency of the health system (Annexure 1). From sub-state level data for the state, we derive the efficiency estimates and use these estimates to explain that the differential impact of health systems in terms of health outcomes could be explained by intra-state regional disparities and sanitation factors both at the state and district level. We presume that differences in technical efficiency pertaining to health system could be discerned at district level health facility planning by non-health related parameters. Thus, we explain the dispersion in technical efficiency (or health system efficiency) by a set of variables which includes income (per capita income or male and female income), literacy (total or rural and urban separately), urbanization, water supply and sanitation facilities, gender development index (GDI) and persons below poverty line (BPL). Having estimated the efficiency of health system in our first stage of estimation, our model in the second stage is thus:

Dispersion in Technical efficiency = f (PCI, male and female income respectively, literacy, rural and urban literacy separately, urbanization, water supply and sanitation facilities, infrastructure variable such as road per square km., BPL, GDI) + error term

Results of our panel data estimation using frontier model for Karnataka are presented in Annexure 1, Table 1. Using the results of frontier model, actual and estimated life expectancy (LEXP) are presented which depict Dakshina Kannada as the most efficient district (MED) with its actual LEXP moving highest towards its estimated LEXP in the year 2004. However, in terms of highest percentage increase in actual life expectancy we find Hassan as the best performer in the duration 1991-2004 (last column, Table 3).

Table 3: Ranks of Districts and Increase in LEXP in Karnataka

	District/ Year	Ranks of Districts according to realization of potential Life Expectancy		% increase in actual LEXP in 1991-2004
		1991	2004	
1	Bagalkot	19	25	3.05
2	Bangalore Rural	9	12	3.26
3	Bangalore Urban	24	22	3.86
4	Belgaum	21	20	5.12
5	Bellary	13	9	5.25
6	Bidar	8	10	3.77
7	Bijapur	16	18	5.74
8	Chamarajnagar	5	6	1.60
9	Chikmaglur	17	13	5.16
10	Chitradurga	14	19	2.87
11	Dakshina Kannada	2	1	2.12
12	Davangere	12	14	4.44
13	Dharwad	10	5	4.74
14	Gadag	7	7	4.50
15	Gulbarga	27	27	5.71
16	Hassan	26	15	9.58
17	Haveri	18	17	4.36
18	Kodagu	3	3	3.77
19	Kolar	25	26	3.55
20	Koppal	6	8	5.83
21	Mandya	23	24	3.28
22	Mysore	20	23	3.02
23	Raichur	11	11	5.79
24	Shimoga	4	4	2.43
25	Tumkur	22	21	3.65
26	Udupi	1	2	2.57
27	Uttara Kannada	15	16	3.28

Source: Estimated; GoK, 2006 (23); LEXP= Life Expectancy in years

Reasons for these inter-district disparities could be seen from Table 4 which depicts major inputs for health sector in the state. Notably, the distribution of per capita hospitals, primary health centers (PHCs), beds and Auxiliary Nurse & Midwife(ANMs) in the state is highly inequitable. In fact, there is a considerable difference between maximum and minimum values for each of the variables (columns 2-4, Table 4). In terms of population served per sub-centre, the corresponding maximum and minimum is for Raichur (6.25 thousand) and Dakshina Kannada (2.66 thousand). These values do not indicate that it is the low work load at sub-center in Dakshina Kannada which is helping it to achieve a better life expectancy. By contrast, Kodagu district with the lowest population served per medical institution (10.17 thousand) and the maximum number of hospital beds (234) and staff per lakh (83.67) has 3rd rank both in 2004 and 1991 in terms of its distance of potential and unlike Hassan where the highest actual increase in life expectancy took place (9.58%) between 1991-2004, Kodagu has depicted only 3.77% increase in life expectancy in the duration. Thus the input availability and utilization situation in most of the districts indicate that it is neither the adequate availability of healthcare sector inputs nor does merely efficient utilization of these inputs that may explain the differentials in achievements in life expectancy.

To some extent, among other inputs, however, this differential pattern in efficiency is explained by lack of facilities of safe drinking water, toilets and electricity in rural and urban areas separately (Table 5). In fact, the best achiever district, namely Hassan, has a much lower non-availability in rural areas (17.06%) relative to either Kodagu (30.35%), Bidar (28.96%) Koppal (33.24%), Udupi((29.69%), Raichur(39.32%) or Dakshina Kannada (32.18%). This actually depicts that the availability of basic infrastructure facilities of safe drinking water, toilets and electricity for the rural population has played a strong supportive role in enhancing overall efficiency of health system, besides the adequate utilization of basic health inputs of hospitals, PHCs, Sub-centres(SCs) and medical and paramedical staff. It implies that improvement in the LEXP in the less efficient districts may be feasible expeditiously if these facilities (WSS and electricity) are made available to reduce rural-urban disparities in the state.

Table 4: Health Facilities and Related Parameters in Karnataka

District	Population served Per Medical Institution(in'000)	Number Of Hospital Beds Per Lakh* Population	Staff Per Lakh*	Population served Per PHC(in'000)	Population served Per SC(in'000)	Children Of One Year Age Received Complete Immunization (%)
Bagalkot	26.32	47	26.58	26.81	7.66	64.4
Bangalore Rural	15.46	51	36.73	20.74	5.29	92.7
Bangalore Urban	37.19	123	14.23	27.46	6.08	72.1
Belgaum	23.14	50	24.04	24.54	5.58	74.3
Bellary	20.36	91	25.31	25.32	5.28	77.3
Bidar	23.39	67	34.35	28.76	5.23	89
Bijapur	22.15	67	28.11	22.63	4.99	77.6
Chamarajnagar	14.63	86	40.08	15.96	4.11	84.8
Chikmaglur	10.94	113	57.67	18.29	2.84	95.9
Chitradurga	14.45	88	51.19	22.41	6.23	80.8
Dakshina Kannada	20.97	96	37.62	18.68	2.66	93.3
Davangere	15.34	99	31.71	18.33	5.07	93.4
Dharwad	34.12	112	24.75	25.95	4.33	86.3
Gadag	19.69	57	29.94	22.45	5.17	86.9
Gulbarga	19.06	66	26.16	22.66	4.69	81
Hassan	11.02	110	45.13	17.58	3.11	84.4
Haveri	16.39	54	33.01	23.37	3.95	81.2
Kodagu	10.17	234	83.67	16.63	2.96	109.7
Kolar	17.41	99	35.57	23.68	5.24	79.3
Koppal	21.18	51	22.16	24.08	6.16	72.8
Mandya	13.58	91	40.09	20.46	3.97	81.5
Mysore	14.90	137	44.15	17.36	3.49	90.2
Raichur	25.38	58	19.76	26.82	6.25	88.8
Shimoga	13.88	110	44.63	19.38	2.91	109.5
Tumkur	17.40	61	34.01	21.69	5.09	78.4
Udupi	13.10	89	38.75	14.55	3.64	93.8
Uttara Kannada	12.51	105	53.04	15.72	3.14	80
Karnataka	18.56	88	26.58	21.42	4.46	81.94

Source: GoK, 2006 (23); Lakh= 100,000

Table 5. Population Having None of the Three Facilities of Safe Drinking Water, Toilets and Electricity in Karnataka(%)(2001)

District	Total	Rural	Urban
Bagalkot	29.03	33.42	18.24
Bangalore Rural	12.04	13.99	4.72
Bangalore Urban	3.07	9.18	2.28
Belgaum	21.52	25.66	8.5
Bellary	24.61	30.95	13.17
Bidar	24.73	28.96	8.6
Bijapur	33.36	38.84	13.61
Chamarajnagar	32.93	36.14	14.29
Chikmaglur	19.82	22.65	8.26
Chitradurga	20.28	22.67	9.65
Dakshina Kannada	21.67	32.18	5.51
Davangere	16.73	20.38	8.44
Dharwad	14.97	18.97	11.74
Gadag	19.97	20.84	18.32
Gulbarga	30.78	38.18	9.6
Hassan	14.94	17.06	5.1
Haveri	22.29	24.58	13.09
Kodagu	27.03	30.35	5.8
Kolar	12.32	14.88	4.49
Koppal	31.24	33.24	21.51
Mandya	19.2	20.77	10.87
Mysore	18.7	27.67	3.78
Raichur	34.06	39.32	18.68
Shimoga	18.63	24.79	7.42
Tumkur	18.32	21.15	6.61
Udupi	25.25	29.69	6.13
Uttara Kannada	18.34	22.53	8.14
Karnataka (State Average)	19.13	25.66	6.88

Source: GoK, 2006(23).

As noted by us in the beginning of this section, there are influences external to the system that may also lead to differential in efficiency at the district level. To explore such external factors, we used dispersion in efficiency as a dependent variable in the second stage of our regression exercise using data for the district level. Among the set of variables used by us as explanatory variables we included per capita income (PCI), gross domestic product per worker, total literacy, male and female literacy separately, total enrolment, proportion of out of school children, population density and gender development index.

The results of best fit are presented in Table 6. In the regression results using Dispersion in health system efficiency (DISPERSION), endogeneity was doubted for gender development. To identify this possible endogeneity, we used female literacy (FEMLIT) (or other variables like, gender enrolment and proportion of out of school children) as instrument. The results using IVM and 2SLS indicated that female literacy could be used as an instrument for gender development and this is retained in the final regression. [24]

Table 6: Instrumental variables (2SLS) Regression results for Dispersion as Dependent Variable in Karnataka

Number of observations = 27;		
F(2, 24) = 11.84* R-squared = 0.4754, Adj. R-squared = 0.4317 Root MSE = .03242		
DISPERSION	Coefficient.	Standard Error
FEMLITR	-.003*	.000731
TOTA3	-.004*	.001
CONSTANT	1.390*	.059

Instrumented: FEMLITR; Instruments: TOTA3, GDI
Source: Estimated; Note: * denotes significance at 1% level
** denotes significance at 5% level

DISPERSION= dispersion in health system efficiency as estimated from the results presented in Table 3. This is the difference between what could have been achieved based on frontier model and what is actually realized ; FEMLITR =female literacy; TOTA3=Population Having None of the Three Facilities of Safe Drinking Water, Toilets and Electricity (%); GDI= gender development index

Only two of the variables, namely, female literacy (FEMLITR) and percentage of total Population Having None of the Three Facilities of Safe Drinking Water, Toilets and Electricity (%)(TOTA3) have emerged statistically significant. The negative sign of these variables indicates that over the decade, planned efforts to impart female literacy and to reduce lack of three basic facilities have partly helped to reduce regional disparity in efficiency of health system across districts (Table 6). However, the low coefficients of these variables depicts that this has not been able to compensate for deficiency in public investment and health sector investment policies in the state which has overlooked changing population densities in different regions and districts of the state (Table 7, column 3).

Table 7: Gender Development Index (GDI), Population Densities, Poverty And Income In Karnataka

District/Sectors	Improvement in GDI (1991-2001)	Increase in Population Density (1991-2001)	No. Of Rural Families Below Poverty Line (2001)	Growth rate of NDDP (1991-02) (at constant prices)			
				Primary sector	Secondary sector	Tertiary sector	All Sectors
Bagalkot	18.22	18.96	23.5	6.8	4.3	7.6	6.4
Bangalore Rural	22.14	12.15	35.75	8.9	7.6	11.9	9.7
Bangalore Urban	23.48	34.80	15.67	2	6.2	11.3	9.1
Belgaum	20.95	17.60	23.7	4.2	4.5	7.2	5.4
Bellary	21.44	22.45	44.57	4	6.2	7.5	5.8
Bidar	19.92	19.48	39.6	2.5	5.5	6.9	4.9
Bijapur	17.90	17.01	42	1.6	5.9	6.7	4.3
Chamarajnagar	18.01	9.25	36	4.4	2.6	6.7	4.8
Chikmaglur	15.64	12.06	27	2.6	4.2	5.5	3.8
Chitradurga	20.23	14.74	41.5	3.9	4.7	6.8	5.1
Dakshina Kannada	10.70	14.60	15.4	4.2	-1	9.7	5.1
Davangere	17.17	14.83	20	4	3.1	6.8	4.8
Dharwad	17.89	12.91	39	3.9	5.2	5.9	5.3
Gadag	24.70	13.59	46.4	5.1	3.6	9.8	6.7
Gulbarga	25.69	21.38	33.7	2.6	6.6	7.4	5.3
Hassan	24.26	10.00	27.13	3.6	6.2	6.9	5.2
Haveri	24.17	13.31	32	5.3	5.4	8.2	6.4
Kodagu	11.83	11.76	19	1.3	5.1	4.9	2.8
Kolar	21.39	13.70	40.27	5.4	3	6.3	5.3
Koppal	31.07	24.81	42.5	3.2	10	9.7	7.1
Mandya	20.77	7.25	29.86	3.5	4.8	6.6	4.9
Mysore	21.98	15.02	28.14	5.4	5.9	8.3	6.9
Raichur	25.59	21.72	43.2	1.5	6.7	4.9	3.5
Shimoga	15.56	12.87	36	3.8	3.9	7.6	5.4
Tumkur	17.05	11.47	31.4	3.9	4.1	7.1	5.1
Udupi	9.32	6.72	24.67	4.2	0.4	7	4.6
Uttara Kannada	16.61	10.92	30.45	1.5	7.7	6.3	5.1

Source: GoK, 2006 (23); GDI= gender development index; NDDP= net district domestic product

Owing to increase in population density some of these districts are constrained in their achievements. Besides Bangalore Urban, for instance, examples of these districts also include Bellary, Koppal, Gulbarga and Raichur (Table 7, column 3). Moreover, high level of rural poverty (ranging above 40%) in some of the districts like Gulbarga, Kolar, Bellary, Chitradurga and Raichur also played constraining role in overcoming district level disparities in life expectancy. Though a number of these districts (like Bellary, Chitradurga, Kolar and Koppal) with high rural poverty depicted a high increase in NDDP in 1991-2002 (last column, Table 7);a further breakup of this income growth across sectors, however, suggests this growth largely owing to secondary and tertiary sectoral incomes (columns 6-7, Table 7). Consequently, as such rural poverty and disparities in income had adversely influenced their health outcomes which the direct health sector inputs could not compensate. However, a positive aspect of the development is also observed in a positive impact of Gender Development Index in these results. In fact, better performing districts like, Hassan, Koppal, and Raichur in terms of achievements in their life expectancy have depicted higher improvement in GDI in 1991-2001 (Table 7, column 2).

Overall, thus we find that besides differentials in availability and efficient utilization of health system inputs, inequitable distribution of income across rural and urban sectors, changing population densities in respective districts as well as lack of gender specific focus of public sector intervention in terms of education and other opportunities has lead to disparities in health outcomes (or life expectancy). Results also emphasize a need for appropriate links and coordination between economic and social sector policies particularly at district level which might avoid sub-optimal health outcomes for the poorer districts in the middle income state in the country.

The results of our analysis of efficiency variation at sub-state level using a case study of a health care system in Karnataka, thus, indicate that the efficiency of public health delivery system is low and considerable disparities across districts in terms of per capita availability of hospitals, beds and manpower inputs had adverse impact on improving the life expectancy in the state. For future planning, these factoral disparities within the health system should be overcome and combine with adequate infrastructure facilities like safe drinking water supply, toilets and electricity to improve the outcomes in deficient districts of Bagalkot, Kolar, Kodagu and Uttar Kannada. It may require a considerable increase in medical and public health expenditure in rural areas in the state. This could be attempted partly through funds from National Rural Health Mission (NRHM) and also by improving rural sanitation in poorer districts. [25] Besides the significance of factors like rural poverty and disparities in income, overall skewed distribution of income across rural and urban sectors, changing population densities in respective districts as well as lack of gender specific focus of public sector intervention in terms of education and other opportunities should not overlooked. These factors have indeed influenced the health outcomes which the direct health sector inputs have not been able to compensate.

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Annexure 1

Model Specification

We consider a general stochastic frontier model that is presented as:

$\ln q_j = f(\ln x) + v_j - u_j$ …………………(1)

Where $\ln q_j$ is the health output (life expectancy or inverse of IMR) produced by a health system "j"

X is a vector of factor inputs represented by per capita health facilities (including per capita availability of hospital beds, per capita primary health centers (or sub centers), per capita doctors, per capita paramedical staff, per capita skilled attention for birth.

v_j is the stochastic (white noise) error term

u_j is one sided error term representing the technical inefficiency of health system "j"

Both v_j and u_j are assumed to be independently and identically distributed (iid) with variance σ_v^2 and σ_u^2 respectively

From the estimated relationship $\ln \hat{q}_j = f(\ln x) - u_j$

The efficient level of health outcome (with zero technical inefficiency) is defined as:

$\ln q^* = f(\ln x)$

This implies $\ln TE_j = \ln \hat{q}_j - \ln q^* = -u_j$

Hence $TE_j = e^{-u_j}$, $0 <= e^{-u_j} <= 1$

If $u_j = 0$ it implies $e^{-u_j} = 1$

Health system is technically efficient.

This implies that technical efficiency of j^{th} health system is a relative measure of its output as a proportion of the corresponding frontier output.

A health system is technically efficient if its output level is on the frontier which in turn means that q/q^* equals one in value. At the district level only cross sectional data are available and the distribution of the inefficiency term is assumed to be a standard truncated normal distribution.

Results of our estimation using frontier model for Karnataka are presented in below in Table 1. It could be observed that all the independent variables to explain life expectancy (LEXP) have emerged with appropriate signs and are statistically significant. Notably the variables representing total number of medical institutions in the area (MEDINST) and rural population served per sub-centre (PERSC) have emerged with positive signs. This indicates the positive impact of governmental intervention in expansion of hospital facilities and the desirable impact of institutional delivery coverage in enhancing life expectancy. These variables are partly also indicative of adequacy of the various inputs provided through medical institutions and rural health sub-centers.

Table 1: Stochastic Frontier Panel Data Model for Karnataka
(Time-invariant inefficiency model)

Number of observations = 54	Number of groups = 27	
Wald chi2(3) = 90.52, Log likelihood = 120.64605,	Prob> chi2 = 0.0000	
Dependent Variable→ LEXP	Coefficient	Std. Err.
→Explanatory Variables		
MEDINST	0.094*	0.011
PERSC	0.057**	0.026
CONSTANT	3.342*	0.199
→Stochastic Parameters		
MU	0.095*	0.024
LNSIGMA2	-6.323*	0.342
ILGTGAMMA	1.406**	0.560
SIGMA2	0.001	0.000
GAMMA	0.922	0.040
SIGMA_U2	0.001	0.000
SIGMA_V2	0.000	0.000

Source: Estimated; Note: * denotes significance at 1% level ** denotes significance at 5% level
MEDINST= total number of medical institutions in the area
PERSC= rural population served per sub-centre

In explaining these results it is worth mentioning that some of our variables used as explanatory variables might have been influenced by endogeneity. The latter is said to occur in models in which economically endogenous variables are determined by each other and some additional economically exogenous variables. The simultaneity gives rise to empirical models with variables that do not satisfy the zero conditional mean assumption. [26] To derive consistent estimates we generally use an instrument variable method (IVM). This method consists in finding an instrument variable (IV) that satisfies two properties: the IV must be uncorrelated with error term and must be highly correlated with the variable which is influenced by endogeneity. Keeping in view this problem, we identified the endogenous variable by using instrument variable method (24). Thus, in the specification for measuring efficiency of health system, we found that three variables were significant, which included number of medical institutions in an area (MEDINST), rural population served per sub-centre (PERSC) and deliveries attended in medical institutions (TOTDELINST). The last of these variables, namely deliveries attended in medical institutions, could have been possibly endogenous within a given health system comprising of infrastructure facilities of hospitals, sub centres (SCs) and primary health centres (PHCs). Thus in the Instrument Variable Method (IVM), we used PERSC separately as instruments for TOTDELINST and total government beds per lakh population (GOVTBEDSLAKH) in an area. Using Instrument variable method and applying 2SLS, our estimates indicated an endogeneity between PERSC and TOTDELINST as well as separately between PERSC and availability of government beds (GOVTBEDSLAKH)(24). Thus using this diagnostic check, the final specification for frontier efficiency measurement using panel data comprised of two variables, namely, number of medical institutions in an area (MEDINST) and rural population served per sub-centre (PERSC), in which the latter variable indeed captures the influence of deliveries attended in medical institutions (TOTDELINST) and availability of government beds. Further, the suitability of fixed effect model with panel data in frontier estimation for the preferred specification was verified by us by using Hausman specification test which confirmed that fixed effect model is more consistent relative to random effect model.

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