Appendix

Degree of efficiency and free disposable hull analysis

This analysis [namely free disposable hull (FDH)] establishes the degree of efficiency in the following way. The first step is to identify the relatively efficient production results in the sample. In Appendix Figure A, the relatively efficient production results are A, C, and D. Given that producer A's production result is feasible and there is free disposal, all production results where at least as much input is used to generate the same level of output, or less, are also feasible. These relatively inefficient production possibilities are identified by the rectangular area to right and below producer A, which contains producer B. Similarly, the rectangular areas to the right and below producers C and D identify relatively inefficient production possibilities. If there is no observation in the rectangular area to the left and above an observed production result, the latter production result is among the relatively efficient production results in the sample of observations. The border of the set of production possibilities-that is, all the production results to the right of and below the relatively efficient observations-is given by the bold line connecting A, C, and D in Appendix Figure A. This is the production possibility frontier, or FDH. A free disposal is required to obtain a continuous production possibility frontier. In the absence of that assumption, it could not be inferred that all output combinations on the line connecting A, C, and D are feasible.

In fact a producer can be relatively efficient, even though no producer is inefficient in relation to it (*i.e.*, there is no producer in the rectangular area to the right of and below the relatively efficient producer). Such producers are assumed to be on the production possibility frontier. Producers that are efficient by default will here be called independently efficient. Examples of independently efficient production results are producers C and D in Appendix Figure A. Producer A is not independently efficient, as producer B is inefficient in relation to A. Using the criterion described above, a distinction can be made between relatively efficient production results (production results on the production possibility frontier) and relatively inefficient production results (production results in the interior of the production possibility set). We also use the measure of efficiency score that enables a ranking of production results. The calculation of a producer's efficiency score can be illustrated using the example in Appendix Figure A. Producer B is the only relatively inefficient producer in the figure. FDH analysis suggests two alternative ways of measuring the distance of producer B's production result from the production possibility frontier: from either the input side or from the output side. In input terms, the distance is given by the line bB, that is, the quotient of inputs used by producer A over inputs used by producer B, x(A)/x(B). This measure of efficiency is referred to as the input efficiency score. For all observations in the interior of the production possibility set, the input efficiency score is smaller than 1. For all observations on the production possibility frontier (producers A, C, and D) the efficiency score is 1. The input efficiency score indicates the excess use of inputs by the inefficient producer, and therefore the extent to which this producer allocates its resources in an inefficient manner. On the output side, the efficiency score of producer B is given by the line b'B, that, is the output quotient y(B)/y(A). This score indicates the loss of output relative to the most efficient producer with an equal or lower level of inputs. As in the case of the input efficiency score, the output efficiency score is smaller than 1 for observations in the interior of the production possibility set (producer B) and equal to 1 for observations on the production possibility frontier (producers A, C, and D). In the one-input one-output case depicted in Appendix Figure A, formulation of an efficiency score is relatively straightforward. In case of multiple inputs and outputs, derivation of an efficiency score is more complicated.[1] Non-FDH techniques typically assume a convex PPF [for instance, Data Envelopment Analysis (DEA) technique[2] assumes that the production possibility set is convex With DEA, the area under the straight line connecting producer A and D would become part of the production possibility set (Appendix Figure B)]. Consequently, the status of producer C would change; rather than being a relatively efficient unit on the production possibility frontier as under FDH, producer C would now be viewed as relatively inefficient, with a production result in the interior of the production possibility set (If the production technology is also assumed to feature constant returns to scale (*i.e.*, if the technology can be described by a Cobb-Douglas production function), the production possibility frontier would be a straight line through the origin. In this case, producer A would be the only producer on the production possibility frontier as it would have the highest observed output-input ratio, that is, the highest average productivity). The example in Appendix Figure B illustrates that FDH singles out more observations as relatively efficient than DEA, thereby reducing the informational value of FDH analysis.

Another drawback of FDH analysis (as well as DEA) compared with parametric techniques is that correction for random factors unrelated to efficiency is not possible and therefore statistical noise is included in the measure of inefficiency. On the other hand, both DEA and parametric techniques impose more restrictions on the production technology than FDH analysis. As noted above, DEA assumes convexity whereas parametric techniques impose a functional form for the production possibility frontier. Where these assumptions inaccurately capture the production processes underlying the observed production results, the efficiency results will be affected.[3] The above discussion suggests that the choice between different techniques of estimating efficiency is a trade-off between imposing fewer restrictions on the production technology and obtaining relatively unambiguous results.[4] In the case of government spending on education and health, there is little a priori justification for making certain assumptions regarding convexity and economies of scale. This argues against the use of parametric techniques, and favors the use of the relatively parsimonious FDH analysis. Tulkens and colleagues[5] provides a more comprehensive overview of the differences between FDH analysis and these alternative techniques.

Results of dispersion as dependent variable

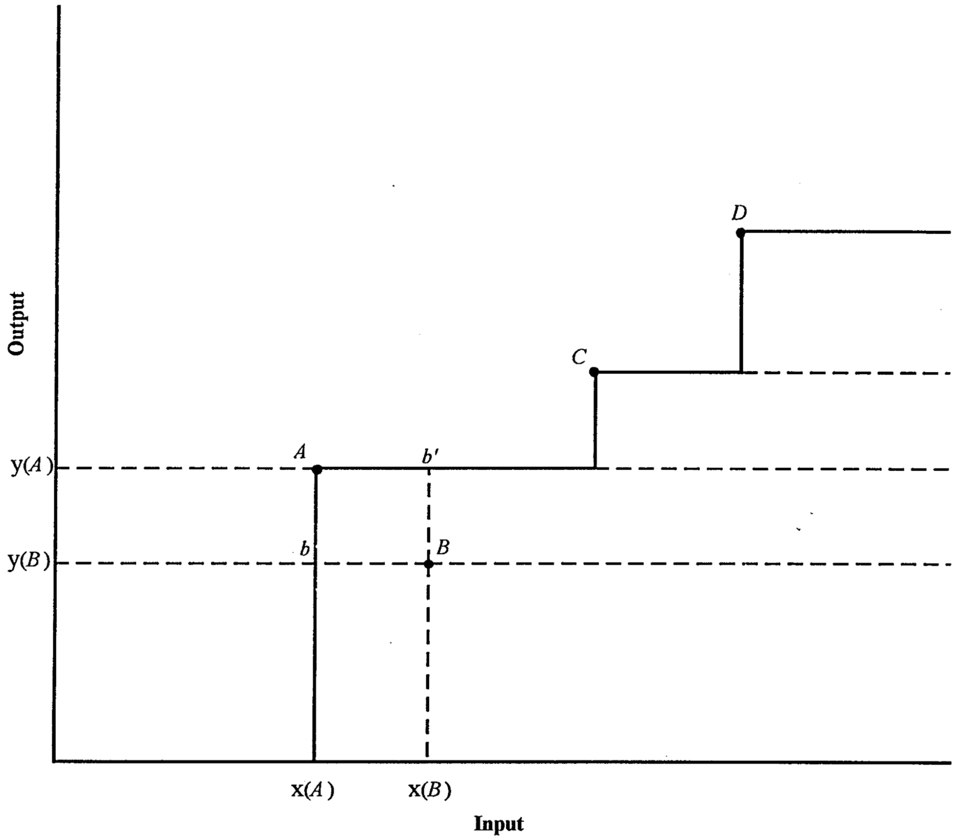
Among the set of explanatory variables, we included per capita income, male and female enrolment, budgetary expenditure on health (in per capita as well as percent to total state budget separately), and total rural habitats covered fully by water supply schemes The results using panel data for the states between 2005-11 indicated two of these variables namely, per capita income (Pcincome) and Gross primary enrolment (boys and girls separately) as statistically significant in the males and females dispersion results (Appendix Table A).

Appendix Table A. Results for dispersion as dependent variable.

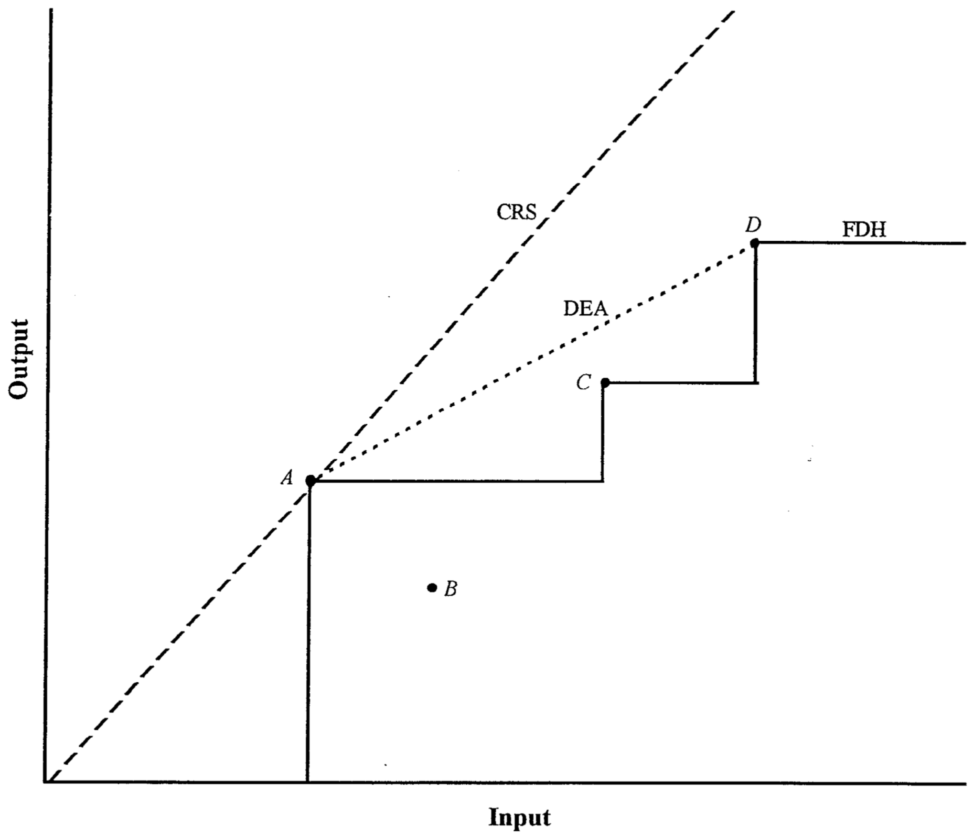
Dispersion	Coefficient		t	
	M	F	M	F
Pcincome	0.0000**	0.0000	-1.9200	-1.45
Fullycover rural habitat by water supply	-0.0004	0.0004	-0.1200	0.11
Grossprimary enrolment boys	-0.0272***	-.0264*	-3.3600	-2.10
Constant	0.2371***	0.2496***	4.1500	3.28
Sigma_U	0.0503	0.0579		
Sigma_E	0.0095	0.0102		
Rho	0.9657	0.9698		

Males: F test that all u_i=0: F(14, 72)=67.59; prob>F=0.0000; fixed-effects (within) regression; number of obs.=90; number of groups =15; R-sq: within=0.2249; obs per group: min=6, between=0.0000, overall=0.0026; F(3,72)=6.96; corr(u_i, Xb)=-0.1194; prob>F=0.0004. Females: fixed-effects (within) regression; number of obs=90; number of groups=15; R-sq: within=0.1147; obs per group: min=6, between=0.0920, overall=0.0854; F(3,72)=3.11; corr(u_i, Xb)=0.1750; prob>F=0.0316; F test that all u_i=0: F(14, 72)= 60.47 prob>F=0.0000. *5% level of significance; **10% level of significance; ***1% level of significance. We also tried the alternative model using random effects. However, the results of Hausman test indicated fixed effect model.

Appendix Figure A. Free disposable hull production possibility frontier.



Appendix Figure B. Alternative production possibility frontiers: free disposable hull, data envelopment analysis, and constant returns to scale.



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