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Women’s political leadership and efficiency in reducing COVID-19 death rate: An application of technical inefficiency effects model across Indian states

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ABSTRACT

Evidence from earlier studies on COVID-19 suggests that the countries led by female leaders were more successful in handling the COVID-19. India being a patrilocal society evident that women’s political autonomy in the Gram Panchayat does miracles concerning development. With this backdrop, the present paper aims to explore the role of women’s political participation and leadership on the efficiency in reducing the COVID-19 death rate for Indian states. This predominantly empirical paper is entirely based on secondary data compiled from different sources. The empirical analysis of the paper is facilitated by the utilization of the Technical Inefficiency Effects model within the framework of Stochastic Production Frontier. The empirical results accredit us to conclude that the efficiency of the Indian states in reducing the COVID-19 death rate is highly influenced by female political participation and leadership, digitalization, urbanization, and literacy rate. The study ends with suitable policy prescriptions.

1. Introduction

The novel coronavirus that causes the disease phrased by scientists as ‘severe acute respiratory syndrome coronavirus 2’ (SARS-CoV-2) or popularly known as COVID-19 created social and economic havoc globally. The virus spread at a rapid speed through human contacts and the modern transport system helps in the spread of such a contagious disease [1]. Therefore, containing the spread of the disease and improving the infected scenario is a real challenge for every government. Realising the adversity of the virus the World Health Organization on January 30, 2020 declared the COVID-19 as a global emergency [2]. In India the disease has created a massacre as more than ten million people were infected by this disease; starting the first number on January 30, 2020. On March 23, 2020, the Indian government declared a nationwide lockdown to contain the spread of COVID-19 [3]. Taking any decision is a tough challenge for any political personality as the decisions would directly impact the country’s/state socio-economic condition. Under such circumstances, it is recognised by substantial studies that the countries led by female leaders are more successful in handling the COVID-19 [4,5]; Luoto, and Varella, 2020). India is a male dominant society [6], where women are always placed in a subordinate position to men. In such a country where females are considered inferior to men, it will be interesting to scrutinize the legitimate entity of women’s political participation and leadership for the betterment of the nation.

Women leadership in many cases is observed to furnish many desirable outcomes. In a pandemic circumstance, we find nations with women leadership are also performing well in controlling the COVID-19 death per capita [4]. Indian is a patrilocal society [6]; where a male is the indispensible leader of the family and society. In such a society the crime against women is suppressed because of social stigma. Even in such a society, we find when women get political autonomy in the Gram Panchayat they do miracles concerning development [7]. This backdrop motivates us to explore a single research question: does women’s political leadership in the case of Indian states help in controlling COVID-19 more efficiently? This research question when unfolds results in two objectives. Therefore, initially, the objective of the study is to compare the efficiency across Indian states in controlling COVID-19 more efficiently? This research question when unfolds results in two objectives. Therefore, initially, the objective of the study is to compare the efficiency across Indian states in controlling COVID-19 measured by death rate from COVID-19 considering the corresponding statistics up to January 22, 2021 across Indian states. Then the paper ties to unfold the role of women’s political participation and leadership in the efficiency in reducing the COVID-19 death rate. The novelty of the

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study is that it is the first attempt of this kind in the Indian context. Women leadership is rare in India and thus such attempts are also rare. This conceptual approach makes this study a novel one.

The study follows the aforementioned sequence: Section 2 discusses the materials and methods which includes the secondary data sources and the concerned variables, conceptual framework of methodology of this empirical study. The followed section 3 presents the empirical results and section 4 discusses the same. The conclusion and policy prescriptions are presented in Section 5.

2. Materials and methods

The data sources of the corresponding variables and theoretical foundation for the stochastic frontier analysis application in health economics are discussed in this section. This step is necessary for exploring the said objective in the stochastic production frontier (SFP) framework.

2.1. Conceptual framework

There are two well-accepted alternative methods available for the measurement of efficiency, viz., parametric- Stochastic Frontier Analysis (SFA) and non-parametric- Data Envelopment Analysis (DEA). Both approaches have their strengths and weaknesses. The DEA approach is widely used for measuring health system efficiency [8,9] as it is very difficult to specify the output-input relationship concerning a production function. The SFA approach to measuring health efficiency was first successfully conceptualized by Evans et al., [10]; and Murray, and Frenk, [11]. Later on, their pioneering work was extended by Sankar, [12] and Kathuria and Sankar, [13]. Consequently, the application of SFA for measuring health efficiency by considering well-defined production function itself makes the attempt unique.

Moreover, it is noteworthy that there are several problems associated with the DEA approach, viz.,

- The range of state’s inefficiency levels cannot be identified properly,
- The approach utilizes less information than the parametric approach,
- The approach assumes that “statistical noise” is absent when it is present in the form of inefficiency in the form of both uncontrollable (acts of God) and controllable (state’s discretions).

These drawbacks of the DEA approach to measure efficiency prompt us to apply the SFA approach for exploring the said objectives.

The conceptualization of health efficiency in the current paper is developed following Evans et al., [10]; and Murray, and Frenk, [11]. The reciprocal of the COVID-19 death rate is considered as the desired outcome in the model and the output is measured on the vertical axis. On the contrary, the set of inputs are measured on the horizontal axis in figure-1.

The upper line in the figure presents the maximum possible output that can be achieved from the given set of inputs and technology. In literature, this is termed as “frontier” after Farrell, (1957). Conversely, the health outcome that is achievable in the absence of any health system is presented by the lower line in the figure. The principal difference between a firm output and health outcome is that in the absence of input firm output will be zero while there will be some health outcomes even in the absence of health expenditures, simply because all the citizens are not going to die at the same time. According to the figure-1, the maximum possible health outcome is \((a + b + c)\) and we assume that the state has achieved the health outcome equal to \((a + b)\). The system performance is defined as the ratio of the achieved to a potential health outcome. Thus the system performance is defined as:

\[
\frac{b}{b + c}
\]  

Where, \((b + c)\) is the potential outcome and \(b\) is the level of health outcome achieved.

Thus, equation (1) can be interpreted as the “system achieves compared to its potential” [11]. We need a systematic tool to measure the health system efficiency so that we can allow inter as well as intra country and/or state comparison over time. This is exactly perused in the present paper in terms of combating COVID-19. This measure is known as the “Farrell’s (1957), output-based measure of technical efficiency” [14]. It is nothing but the ratio of the observed to maximum achievable outputs. We have framed our empirical model based on this conceptual framework.

Therefore the present study measures the technical efficiency only by using the ‘stochastic frontier approach (SFA)’ by considering availability and access to health care infrastructures as inputs and health sector performance as a single output. The empirical results are obtained by utilizing the inefficiency effects model developed by Battese, and Coelli, [15]. Thus, the estimation followed a two-step procedure. Initially, the

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Fig. 1. Health System Performance
Source
Adapted from Murray and Frenk, (1999) and Evans et al. [10],

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efficiency scores of the different states of India are measured, and then, the components responsible for the differences in the performances of different Indian states in reducing the COVID-19 death rate are identified. We next present the econometric model in detail.

2.2. Data

This pre-dominantly empirical study is entirely based on secondary data compiled from various sources. It covers twenty-one major states and one Union Territory, Delhi. As the study is based on the secondary data the selection of the sample states, the sample period and the variables are dictated by data availability. The table-1 provides a comprehensive compendium of the variables and their sources.

It is noteworthy that the output variable death rate of COVID-19 is up to January 22, 2021 and the relevant statistics are compiled from the Ministry of Health and Family Welfare, Government of India. The table divulges that the present empirical analysis includes seven input variables, viz., the doctor-population ratio per 1000; nurses-population ratio per 1000, etc.

Besides that, the study ponders thirteen exogenous variables to precisely identify the components responsible for the differences in the performances of the state in efficiently reducing the death rate of COVID-19. It should be mentioned that these thirteen variables have a strong dominance on the efficiency of combatting COVID-19 for the concerned state. These variables though cannot be considered as input variables but we cannot ignore their effect on the state’s controllable inefficiency. Therefore these variables are considered for the inefficiency analysis and recognised as “exogenous” variables. The detailed discussions of output-input-exogenous variables are executed in the next section. It is noteworthy that following the objective of the study we have considered the percentage of female members in Parliament and Legislative Assemblies of the respective states (Women MP and MLA) as a proxy of women’s political participation and leadership to apprehend the consequence of women’s political autonomy and leadership on the efficiency of the state in handling any crisis, suchlike, pandemic.

2.3. Variables

The application of the “stochastic production frontier model” to measure health system efficiency requires three categories of variables (Evans et al., 2001; [12]). Firstly, we need to recognise an output variable to represent the health sector’s performance. Secondly, input variables formulate the production function describing the input-output relationship. Finally, to identify the factors responsible for the discrepancies in the efficiency of the state in combating COVID-19 we can include some non-health variables. The influence of these non-health variables on the health system performance cannot be ignored yet they cannot be recognised as input variables. In this paper, we termed them as exogenous variables.

2.3.1. Output variable

As the present study is related to the COVID-19 scenario of Indian states we can consider different variables, as outcome variables suchlike, “the reciprocal of the total number of positive cases” or “reciprocal of the death rate” or “recovery rate”. India is a highly populated country with high employment in the informal sector. Thus, the rate of spread of the disease as expected is high and simultaneously, the recovery rate at the current stage of COVID-19 does not show much variation across states. Under such circumstances, it is appropriate to consider the “death rate from COVID-19” as the outcome variable. Since we are dealing with the efficiency of the Indian state in combating COVID-19 thus it again is appropriate to consider the “reciprocal of the COVID-19 death rate” as the outcome variable, because the lower the death rate, the greater the efficiency of the state in combating COVID-19.

| Table-1 Descriptions of the variables. |
|----------------------------------------|
| Variables                              | Definition                                                      | Category | Data Source                  |
| Death Rate (DR)                        | Shows the ratio of the total number of persons who died from Covid-19 to the total number of confirmed cases. | Output   | Ministry of Health and Family Welfare, Government of India |
| Reciprocal of the Death Rate \(\frac{1}{y}\) | Reciprocal of the death rate of COVID-19. The reciprocal was taken to capture the efficiency level of the states to lower the death rate higher will be the efficiency. | Output   | Ministry of Health and Family Welfare, Government of India |
| Doctor-population ratio per 1000 (DOCTOR) \(x_1\) | Shows the ratio of number of government allopathic doctors and population served in India per 1000 population. | Input    | Directorate of State Health Services & National Health Profile |
| Nurses-population ratio per 1000 population (NURSE) \(x_2\) | Shows the total number nurses served per 1000 population. | Input    | Indian Nursing Council |
| Total Police per lakh of population (Police) \(x_3\) | Shows number of police person served per lakh population. | Input    | Ministry of Home Affairs |
| Num Isolation Beds (Isolation beds) \(x_4\) | Total number of isolation beds available for COVID-19 patient. | Input    | COVID-19 modelling estimates for India by a team of researchers affiliated with CDDEP and Princeton University |
| Number of ICU beds (ICU beds) \(x_5\) | The total number of intensive care unit beds available for the care of Covid-19 affected patients | Input    | COVID-19 modelling estimates for India by a team of researchers affiliated with CDDEP and Princeton University |
| Number of ventilators (Ventilators) \(x_6\) | The total number of ventilators available for the aiding artificial respiration during severe respiratory distress of Covid-19 affected patients | Input    | Indian Council of Medical Research (ICMR) report, 2020 |
| Number of COVID testing labs (Labs) \(x_7\) | Total number of laboratories for testing patient bio-fluid for Covid-19 | Input    | Census of India, 2011 |
| Percentage of 60 plus (Older adult) \(x_8\) | Refers the percentage share of 60 and above population in the total population. | Exogenous| Census of India, 2011 |
| Sex Ratio (SR) \(x_9\) | Shows the number of female population per 1000 male population. | Exogenous| Census of India, 2011 |
| Literacy Rate (LR) \(x_{10}\) | Defined as total number of literate persons in a given age group, expressed as a percentage of the total population in the age group | Exogenous| Census of India, 2011 |
| Urbanization (%) (Urban) \(x_{11}\) | Shows the percentage share of population live in urban areas. | Exogenous| Census of India, 2011 |

(continued on next page)
etary expenditures on health will be more appropriate if we have panel
dicators and the health personnel. Based on this idea we have considered
to pinpoint a set of well-defined inputs. As the health sector efficiency is-
-
- measured here the set of inputs must include health infrastructure in
are echoed in contemporary health achievements. Moreover, the mon
Besides that, the stock of expenditures of the past will be a better
availability of the data compelled us to consider the physical inputs.

### Table 1 (continued)

| Variables                                      | Definition                                                                 | Category    | Data Source                      |
|------------------------------------------------|---------------------------------------------------------------------------|-------------|---------------------------------|
| Number of persons per room used for sleeping (Sleep) $x_3$ | Average number of persons using a single room for sleeping                | Exogenous   | National Family Health Survey-4, 2015-16 |
| Percentage of self-reported diabetes between age 15–49 (Diabetes) $x_6$ | The percentage of people between 15 and 49 yrs of age in a population who have reported that they are suffering from diabetes | Exogenous   | National Family Health Survey-4, 2015-16 |
| Population density/ km2 (Population density) $x_4$ | Number of people living per square kilometre area                          | Exogenous   | Census of India, 2011            |
| Per capita NSDP (PCNSDP) $x_7$ | Net State Domestic Product (NSDP) is defined as a measure, in monetary terms, of the volume of all goods and services produced within the boundaries of the State during a given period of time after deducting depreciation, divided by total number of population. | Exogenous   | RBI                             |
| Regular wage/ Salaried Employee (%) (Employment) $x_8$ | Shows the percentage share of workers engaged in regular salaried employment. | Exogenous   | NSS, 68th Round, 2011-12         |
| Internet subscriptions (Millions) (Digitalization) $x_9$ | Shows the number of people subscribed for internet.                       | Exogenous   | TRAI                            |
| Women MP $x_{10}$ | Shows the percentage of women MPs out of the total MP seat allotted for each state | Exogenous   | https://gramener.com/enumerator/woomen-india-mla-mp/ |
| Women MLA $x_{11}$ | Shows the percentage of women MLAs out of the total MLA seat allotted for each state | Exogenous   | https://gramener.com/enumerator/woomen-india-mla-mp/ |

Source: Authors’ own specification

### 2.3.3. Exogenous variables

It is a well-established fact that improved health is not an exclusive outcome of the health service providers [11]. This is also patently true for fighting against COVID-19. Some pioneering studies accentuate the influence of non-health determinants, viz., income, educational level measured differently [16]. In the present study, we have considered several variables that have a strong influence on the efficient control of the COVID-19 death rate across Indian states. However, these variables cannot be categorised as the input variables. We recognise them as exogenous variables. These variables are exclusively considered for inefficiency effects analysis. The list of the exogenous variable with definitions is presented in the table-1. It is noteworthy that the exploration of the objective of the implication of women’s political leadership on pandemic control is executed by considering two exogenous variables, viz., percentage of female members in Parliament and Legislative Assemblies of the respective states (Women MP and MLA).

### 2.4. Econometric model

In the beginning, we consider a stochastic frontier production function for the cross-sectional data,

$$y_i = f(x_i, \beta) \exp(V_i)TE_i$$  \hspace{1cm} (2)

Where, $y$ is the health outcome, $x$ and $\beta$ stand for the vector of arguments of the production function, via., access and availability of the health infrastructure inputs, that have a direct impact on health outcome and the vector of the parameters to be estimated respectively; all the variables being expressed in logarithm. The random error component is expressed by $\exp(V_i)$, where the particular cross-section is presented by $i$. It is noteworthy that the most commonly used forms of production functions are Trans-log and Cobb-Douglas models. Implementation of the above model requires the assumption of the form of the production function. We have implemented both the flexible trans-log form and relatively simple Cobb-Douglas form using the cross-sectional data. A study of the possible superiority of the Trans-log over the Cobb-Douglas model can be made using the log-likelihood functions. The value of the generalized likelihood-ratio (L.R.) statistic for testing the null hypothesis that the coefficients of the second-order terms of the Trans-log model are jointly insignificant (i.e., $\beta = 0$) is:

$$L.R. = -2(\ln(L_{C.D.}) - \ln(L_{C.D.}^2))$$  \hspace{1cm} (3)

L.R. is here assumed to be asymptotically distributed as $\chi^2$ with $k$ degrees of freedom (Coelli et al., 1998, pp.218), where $k$ is the number of restrictions and $L_{C.D.}$ is the maximum likelihood function for Cobb-Douglas (restricted) and Trans-log production function (unrestricted) respectively.

We are now returning back to equation-2. The firm-specific technical efficiency [17] which is assumed to be a random variable may be written as: $TE_i = \exp(-U_i)$. Since $TE_i \leq 1$, hence $U_i \geq 0$, i.e., this error is one-sided. So, we can write (2) as:

$$y_i = f(x_i, \beta) \exp(V_i)\exp(-U_i)$$  \hspace{1cm} (4)

Here the assumptions are that $V_i \sim IIDN(0, \sigma^2_V)$ and $U_i \sim IIDN(0, \delta^2)$.

Where $\pi_i$ a $(1 \times m)$ vector of explanatory variables is associated with the technical inefficiency of production of firms over time and $\delta$ is an
A \textbf{mx1} vector of unknown coefficients.

Further \( U_i \) and \( V_i \) are independent of each other and also independent of \( \alpha \). So, the underlying model is Normal-Truncated Normal as introduced by Stevenson, [18].

Following Battese, and Coelli, [15]; the technical efficiency of the health sector for the \( i \)-th state, \( \text{TE}_i \), in the stochastic frontier model (4) could be specified in equation (5).

\[
\text{ln} \left( \frac{1}{\text{DR}} \right) = \alpha_0 + \alpha_{\text{DOCTOR}} \text{ln(DOCTOR)} + \alpha_{\text{NURSE}} \text{ln(NURSE)} + \alpha_{\text{Police}} \text{ln(Police)} + \alpha_{\text{Isolation beds}} \text{ln(Isolation beds)} \\
+ \alpha_{\text{ICU beds}} \text{ln(ICU beds)} + \alpha_{\text{Ventilators}} \text{ln(Ventilators)} + \alpha_{\text{Labs}} \text{ln(Labs)} + (V_i - U_i) \tag{6}
\]

Where, \( \text{ln} \) is the natural logarithm (i.e., to the base \( e \)).

Here equation-(7) presents the technical inefficiency effects.

The estimation of the equation-(6) and (7) are facilitated by the utilization of the \text{FRONTIER}-4.1 programme [20].

3. Results

The empirical results of this pre-dominantly empirical study are presented in this section.

3.1. State-wise COVID-19 death rate and women’s political leadership

The pandemic COVID-19 has a very high contagion rate coupled with changeable nature. Although India has a very dense population, it is the Indian government’s spontaneous plans-of-actions that successfully hinder the death rate by around 1% update. Considering the huge

\[
U_i = \delta_0 + \delta_{\text{Elderly}} \text{ln(Elderly)} + \delta_{\text{SR}} \text{ln(SR)} + \delta_{\text{LR}} \text{ln(LR)} + \delta_{\text{Urban}} \text{ln(Urban)} + \delta_{\text{Sleep}} \text{ln(Sleep)} + \delta_{\text{Diabetes}} \text{ln(Diabetes)} + \delta_{\text{Heart}} \text{ln(Heart)} + \delta_{\text{Population density}} \text{ln(Population density)} + \delta_{\text{PCNSDP}} \text{ln(PCNSDP)} + \delta_{\text{WomenMLA}} \text{ln(WomenMLA)} + W_i \tag{7}
\]
population of India the death rate could be considered under control but a single death is equally undesirable. Speaking of the governance, it was observed that the countries that are governed by female leaders faced lower COVID-19 death per capita and quickly controlled the spur [4]. Therefore it can be commented that women’s political leadership affects the efficient management of this pandemic. We tried to find the fact in the Indian context considering the state’s gender-based Chief Ministers. But out of the twenty-two sampled states, only West Bengal has female Chief Ministers. The rest of the states is governed by male leaders. Hence, we have considered the percentage of female members in Parliament and Legislative Assemblies of the respective states (Women MP and MLA). The figure-2 gives the conglomerate interplay between the percentage of female Members of Parliament along with Members of the Legislative Assembly and the death rate of COVID-19 across Indian states.

A sharp observation of the figure discloses that the state’s death rate fluctuates from 0.13% (Karnataka) to 3.24% (Punjab). The highest death rate of COVID-19 is obtained for Punjab followed by Maharashtra and West Bengal. On the contrary, the lowest death rate is observed for Karnataka proceeds by Arunachal Pradesh (0.33) and Kerala (0.40). The female-led state West Bengal is in the twentieth position with a death rate of 1.79%. From the figure-2 it can be opined that there is not much impact on women’s political leadership indirectly reducing the death rate of COVID-19. Such a complicated relationship cannot be identified through a simple graphical presentation. We need in-depth analysis to understand the influence of women’s political leadership on panoptimic and this is exactly performed in the next section.

3.1.1. Cobb-Douglas versus trans-log production function

The possible choice between the production function is facilitated by the log-likelihood ratio test (Coelli et al., 1998, pp. 218). The test result is presented in table-2.

Table-2 discloses that the test yields statistically insignificant $\chi^2$. Consequently, we cannot prefer Trans-log over its simpler form Cobb-Douglas production function. In the present case, the Trans-log regression yields a smaller value of Log-likelihood Functions, compared to Cobb-Douglas regression; accordingly, we reject the trans-log form and continue with the Cobb-Douglas form in the subsequent estimation.

3.1.2. Efficiency analysis of different states in India

In this section, we have explored the main objective of the study the variation in efficiency in reducing the COVID-19 death rate across Indian states. The apriori assumption of the heterogeneity of data is checked by considering the summary statistics of the relevant variables (see table-A.1 in appendices). Table-A.1 in the appendices confirms the heterogeneity of the data. It is noteworthy that the efficiency scores are a relative performance indicator and it is stating that how efficiently one state is performing in reducing the COVID-19 death rate relative to the most efficient state. The identification of the state as efficient or inefficient is facilitated by considering the overall mean efficiency score, 0.680 as the benchmark [21]. Accordingly, a state will be recognised as technically efficient iff its efficiency score exceeds the mean efficiency score and vice-versa. For instance, the technical efficiency score for West Bengal is 0.933, higher than the overall mean efficiency score and thus the state is recognised as technically efficient in combating COVID-19 relative to the other state in the list [21]. Based on this benchmark

Table-2

| States            | Efficiency Score | Ranking |
|-------------------|------------------|---------|
| Andhra Pradesh    | 0.636            | 14      |
| Arunachal Pradesh | 0.531            | 17      |
| Assam             | 0.199            | 21      |
| Bihar             | 0.838            | 6       |
| Chhattisgarh      | 0.357            | 20      |
| Delhi             | 0.622            | 16      |
| Gujarat           | 0.819            | 9       |
| Haryana           | 0.899            | 5       |
| Jharkhand         | 0.907            | 4       |
| Karnataka         | 0.960            | 1       |
| Kerala            | 0.725            | 12      |
| Madhya Pradesh    | 0.925            | 3       |
| Maharashtra       | 0.835            | 7       |
| Manipur           | 0.044            | 22      |
| Meghalaya         | 0.502            | 19      |
| Odisha            | 0.525            | 18      |
| Punjab            | 0.624            | 15      |
| Rajasthan         | 0.809            | 10      |
| Tamil Nadu        | 0.833            | 8       |
| Uttar Pradesh     | 0.751            | 11      |
| Uttarakhand       | 0.694            | 13      |
| West Bengal       | 0.933            | 2       |

Mean Efficiency 0.680

Source: Authors’ own calculation based on secondary data

Table-3

| States            | Efficiency Score | Ranking |
|-------------------|------------------|---------|
| Andhra Pradesh    | 0.636            | 14      |
| Arunachal Pradesh | 0.531            | 17      |
| Assam             | 0.199            | 21      |
| Bihar             | 0.838            | 6       |
| Chhattisgarh      | 0.357            | 20      |
| Delhi             | 0.622            | 16      |
| Gujarat           | 0.819            | 9       |
| Haryana           | 0.899            | 5       |
| Jharkhand         | 0.907            | 4       |
| Karnataka         | 0.960            | 1       |
| Kerala            | 0.725            | 12      |
| Madhya Pradesh    | 0.925            | 3       |
| Maharashtra       | 0.835            | 7       |
| Manipur           | 0.044            | 22      |
| Meghalaya         | 0.502            | 19      |
| Odisha            | 0.525            | 18      |
| Punjab            | 0.624            | 15      |
| Rajasthan         | 0.809            | 10      |
| Tamil Nadu        | 0.833            | 8       |
| Uttar Pradesh     | 0.751            | 11      |
| Uttarakhand       | 0.694            | 13      |
| West Bengal       | 0.933            | 2       |

Mean Efficiency 0.680

Source: Authors’ own calculation based on secondary data

Table-4

Maximum likelihood estimates of the stochastic production frontier function of performances in reducing COVID-19 death rate for different Indian states.

| Variables | Coefficients | S.E | t-ratio |
|-----------|--------------|-----|---------|
| Constant  | $b_0$        | 0.010 | 0.247 | 0.041 |
| In (DOCTOR) ($x_1$) | $b_1$ | 5.463*** | 0.760 | 7.184 |
| In (NURSE) ($x_2$)   | $b_2$ | 0.247*** | 0.122 | 2.026 |
| In (Police) ($x_3$)  | $b_3$ | 0.222*   | 0.124 | 1.796 |
| In (Isolation beds) ($x_4$) | $b_4$ | -0.132*** | 0.064 | -2.076 |
| In (ICU beds) ($x_5$) | $b_5$ | -0.176*  | 0.489 | -0.360 |
| In (Ventilators) ($x_6$) | $b_6$ | 0.071   | 0.524 | 0.136 |
| In (Labs) ($x_7$)    | $b_7$ | -0.100   | 0.163 | -0.612 |
| In (Elderly) ($x_8$) | $b_8$ | 0.957*** | 0.362 | 2.640 |
| In (LR) ($x_9$)      | $b_9$ | 0.752    | 0.793 | 0.943 |
| In (Urban) ($x_{10}$)| $b_{10}$ | -0.883*  | 0.471 | -1.874 |
| In (Sleep) ($x_{11}$) | $b_{11}$ | 0.061   | 0.975 | 0.063 |
| In(Diabetes) ($x_{12}$) | $b_{12}$ | 0.801*** | 0.078 | 10.270 |
| In(Heart) ($x_{13}$) | $b_{13}$ | 0.802*   | 0.422 | 1.902 |
| In(Population density) ($x_{14}$) | $b_{14}$ | 0.645*   | 0.366 | 1.763 |
| In (PCNSDP) ($x_{15}$) | $b_{15}$ | -0.193   | 0.611 | -0.315 |
| In (Employment) ($x_{16}$) | $b_{16}$ | -0.984   | 0.872 | -1.129 |
| In(Digitalization) ($x_{17}$) | $b_{17}$ | -0.881*** | 0.403 | -2.189 |
| In(WomenMP) ($x_{18}$) | $b_{18}$ | -0.564*** | 0.083 | -6.777 |
| In(WomenMLA) ($x_{19}$) | $b_{19}$ | -1.034*** | 0.523 | -1.979 |
| $\gamma$ | 0.472*** | 0.175 | 2.699 |
| $\mu$ | 0.009*** | 0.085 | 11.685 |
| Log(likelihood) | -35.669 |        |        |
| LR test of the one-sided error | 23.937*** | Prob > $x^2$ | 0.004 |
| Wald chi2(7) | 12.40* | Prob > $x^2$ | 0.0881 |

Source: Authors’ own calculation based on secondary data

Note: *$*$significant at 1% level, **$*$significant at 5% level and *$*$significant at 10% level.

Frontier application fails for Translog production function.
thirteen out of twenty-two states are turned out technically efficient. Thus in our case, 59% of states are performing efficiently (Table 3).

Based on the efficiency score the ranking of the states is also presented in the same table. The table discloses that the top three efficient states are Karnataka (0.960), West Bengal (0.933), and Madhya Pradesh (0.925). It is noteworthy that among these three states West Bengal is governed by a woman leader. In fact, the Chief-minister is also the health and family welfare minister. On the contrary, the least efficient states are Manipur, Assam, and Chhattisgarh. The two most inefficient states are from the north-eastern region of Indian, which reflects the backwardness of the health services of this region.

3.1.3. Analysis of stochastic frontier: factors affecting efficiency

This section explores the role of women’s leadership in improving health system performance, particularly in pandemic circumstances. The Table 4 presents the estimated coefficients, along with the t-ratio, up to three significant digits.

The first part of the table explains the input-output relationship. The output in the present model is the reciprocal of the death rate of COVID-19. The SPF relation discloses that the significant influences on output are corroborated by a list of inputs, viz., DOCTOR, NURSE, Police, and Isolation beds. All these inputs except the Isolation bed significantly help in reducing the COVID-19 death rate. The impacts of the rest of the listed inputs are statistically insignificant.

The empirical results of the estimated coefficients of the inefficiency effects are particularly interesting. Altogether we have considered 13 inefficiency effects variables, termed exogenous variables. The inefficiency on the part of the state in reducing the COVID-19 death rate is significantly influenced by the factors- Elderly, Literacy rate, Urbanization, Diabetics, Heart, Population density, Digitalization, Women MP, and Women MLA. It is noteworthy that these are the factors that are controllable and helps in reducing inefficiency on the part of the states in combatting COVID-19. Here the negative sign of the estimated coefficient indicates by emphasizing these factors the controllable inefficiency on the part of the state in combating COVID-19 can be reduced. Accordingly, these factors help in escalating the state’s efficiency in combating COVID-19. The table-3 discloses that the inefficiency variables which are in negative relation with the state’s inefficiency in reducing the COVID-19 death rate are- Literacy rate, Urbanization, Digitalization, Women MP, and Women MLA. On the contrary, the variables which are responsible for enhancing the state’s inefficiency in reducing the COVID-19 death rate are- Elderly, Diabetics, Heart, and Population density [29]. Most interestingly, the variables, viz., Women MP and MLA, which are used as the proxy to epitomize women’s political participation and leadership, become statistically significant with a negative sign. All these variables are statistically significant at different levels.

The possible reasons for such empirical results are discussed in the discussion section.

All the variance parameters are significant at a different level and the variance parameter (ψ) is found significantly different from zero for a half-normal distribution. This indicates the correctness of the assumption of half-normal distribution related to the error terms. The correctness of the specified assumptions of the distribution of the composite error term is indicated by the statistical significance of the estimates of sigma-squares (σ̂²), 0.472. The ratio of state-specific variability to total variability (γ) is positive and significant, implying that state-specific technical efficiency is important in explaining the total variability of the health system. Also, the (γ) estimate associated with the sigma-squared of the technical inefficiency effects is relatively large, indicating the viability of the model. The estimate for the variance parameter, γ, is significantly different from “0”, indicating that the inefficiency effects are likely to be highly significant for Indian states in reducing the COVID-19 death rate. The statistical significance of the variance parameters validates the model and makes the model reasonable to use.

The robustness of the specification is reflected by the Log(likelihood) value, −2.612, indicating convergence of the results. Moreover, the appropriateness of the specification is also contemplated by the statistical significance of the Wald χ²(7) 12.40 (with a p-value of 0.0881) and by the high Likelihood Ratio Chi-squares 23.937 (with a p-value of 0.004).

Nevertheless, the robustness of the results is also checked by the endogeneity test. The test result is presented in Table 5.

The result divulges that Durbin (score) and Wu-Hausman values are 0.482 and 0.291 respectively with corresponding probabilities 0.4877 and 0.5987. These two tests results strongly recommend the acceptance of the null hypothesis of variables are exogenous.

4. Discussion

COVID-19 becomes a worldwide menace. The disease started spreading worldwide in December 2019. Because of the high contamination rate, the Director-General of the World Health Organization (WHO) recognised this disease as the “Public Health Emergency of International Concern” and announced such a situation as a pandemic on January 30, 2020 [2]. The COVID-19 has strongly influenced the regular life, health performances, and economy of India. Under such circumstances, it will be appropriate to scrutinize the state’s efficiency in reducing the COVID-19 death rate to understand the discrepancies in the level of achievements across Indian states. This study thus will accredit us to identify the factors responsible for the state’s inefficiency in reducing the COVID-19 death rate.

The present study involves twenty-one Indian states and one union territory, Delhi. The selection of the Indian states and territory is strongly dictated by data availability. The first part of this empirical paper involves a discussion of the ranking of the Indian states based on their efficiency scores, obtained by using SFA. Based on the efficiency scores we find the top three most efficient states in reducing the COVID-19 death rate are- Karnataka, West Bengal, and Madhya Pradesh, respectively. It is noteworthy that among the top three states West Bengal is the only state which is governed under women’s leadership. It should be remembered that the efficiency score represents the relative performance and does not give any hierarchical measurement concerning health outcomes. For example, the second minimum death rate is recorded for Arunachal Pradesh, (0.33%). However, the state ranked 17th concerning the technical efficiency score, 0.531 for combating COVID-19. Considering our benchmark the state is recognised as an inefficient state in reducing the COVID-19 death rate. The relative health efficiency score stipulates that given the state’s health infrastructure the state has executed only 53% potential to combat COVID-19. If the health system of the state-operated as efficiently as the most efficient state the state could resist the COVID-19 death rate by 96%. On the contrary, if the state was as inefficient as the most inefficient state, Manipur, the ability of the state to reduce the death rate of COVID-19 could have declined to 4% with the corresponding death rate of 1.28%. These divergences in the health outcomes across Indian states may be due to the differences in the utilization as well as performances of the existing health system of the states [32].

The empirical estimates of the SFA model have two parts-the first part deals with the empirical estimates of the input-output relationship in the SPF structure and the second part discusses the factors responsible for the state’s inefficiency in reducing the COVID-19 death rate in the
inefficiency effects model scenario. The input-output relationship in the present paper is scrutinized by considering a Cobb-Douglas production function in the log-linear form as dictated by the LR test result. The empirical estimates of the SPF divulge that the conventional health infrastructure inputs are in a positive and significant relationship with the output variable. Thus the escalation of the availability of Doctors, Nurses helps in reducing the COVID-19 death rate. In the present scenario, the role of the Police is more than a protector, health assistance. Thus the corresponding estimated coefficient becomes positive and significant contemplating the positive role of the police force in combatting COVID-19. The positive and significant roles of the said inputs are re-establishing the patent facts [22]. The negative and significant estimated coefficient of the Isolation bed discloses that an increase in the Isolation bed increases the COVID-19 death rate. The result is not astonishing. The requirement of the Isolation bed reflects an escalation of the serious COVID-19 cases. This contemplates a serious condition and obviously in these circumstances as expected the COVID-19 death rate will increase. A similar result is also documented in Maity, Ghosh, and Barlaskar, [22]. It is noteworthy that the effect of some of the listed health infrastructure variables, viz., ICU beds, Ventilators, and Labs become insignificant. This may be due to the reason that the current scenario of combatting COVID-19 in India is more favourable and thus the requirement of these specialised health infrastructures is demanded less.

It is recognised by several studies that favourable health outcome is not only the result of the improved health infrastructure but some social, demographic and economic factors also help in achieving the desired goal [22]. These variables although play an important role in improving the present health scenario of any state and/or country but they cannot be recognised as input variables. In the present paper, they are recognised as exogenous variables. These variables are specially used in this paper to recognise the factors responsible for the controllable inefficiency of a state to combat COVID-19. Altogether we have considered thirteen such variables. To explore our second objective we have included two variables, viz., Women MP and Women MLA as exogenous variables. These variables are considered to proxy women’s political leadership. The estimated coefficients of these variables will help us to recognise whether there is at all any role of women’s political leadership in achieving the desire socio-economic goal of any nation and/or state. The positive and significant impacts are documented for the exogenous variables- Elderly, Diabetics, Heart, and Population density indicate an escalation of these variables will enhance the inefficiency of the state in combatting COVID-19. The result is patently true. The co-morbid, viz., Diabetics and Heart patients, as well as the elderly, are at high risk in the COVID-19 scenario [29]. Therefore the state with a higher elderly population and co-morbid patients needs to give special emphasis to provide proper health care even in this adverse scenario. This is the reason for the negative and significant effect of these exogenous variables on the inefficiency of the state. The disease COVID-19 is recognised as a highly contagious disease and spread quickly among the mass. The high population density means a higher likelihood of spreading the disease quickly. Moreover, with high population density, the maintenance of social distancing becomes the toughest job. Thus the population density enhances the inefficiency on the part of the state in combatting COVID-19.

On the contrary, the negative and significant effects of the exogenous variables are obtained for Literacy rate, Urbanization, Digitalization, Women MP, and Women MLA. These exogenous variables documented negative effects on the efficiency of the state in combatting COVID-19. Thus enhanced literacy rate and proper digitalization help in increasing the efficiency of the state in combatting COVID-19. Simultaneously, more women’s representation in politics will also help in achieving the desired efficiency of the state in combatting COVID-19. Literacy gives awareness and thus higher literacy rate will be helpful in successful lockdown which in turn helps in escalating the efficiency of the state in combatting COVID-19. The exogenous variables urbanization and digitalization documented a positive influence on the efficiency of the state because urban areas are likely to have more facilities concerning both health and social infrastructures. Concurrently, in the current scenario, digitalization plays an important role in maintaining daily life. Online banking, online shopping, e-learning, work-from-home, etc., become an integral part of this new-normal life and all these activities are supported by internet connectivity as well as availability. Thus the state with a higher literacy rate and improved digitalization can be expected to lead a normal life even in a situation of lockdown. This may be the reason for the positive and significant effects of these exogenous variables on the efficiency of the state in combatting COVID-19. Moreover, urban areas are characterised by better living facilities, concerning availabilities of opportunities for maintaining normal life in the new-normal circumstances. Improved health facilities may be expected to be available in the urban localities. Improved internet connectivity and better online order delivery systems, including basic as well as emergencies items, are more common in urban areas. These are the possible reasons for the positive significant influence of the exogenous variable Urbanization on the efficiency of the state in reducing the COVID-19 death rate. Our findings are supported by the earlier study conducted by Maity, Ghosh, and Barlaskar, [22].

The main purpose of the current paper is to explore the role of women’s political leadership in achieving desire socio-economic goals. To portray the political leadership of women we have considered two variables, viz., Women MP and Women MLA. Both of these exogenous variables documented positive and significant effects in escalating the state’s efficiency in combatting COVID-19. This result is also supported by the earlier studies by Ref. [4]; Luoto, and Varella, 2020. In fact, in the case of the Indian Gram panchayat, it was found an improvement in the socio-economic scenario of the villages when the panchayats were governed by women leaders [7]. Unfortunately, in the present paper, we are unable to check the impact of women leaders because in our list of Indian states only West Bengal is governed by the female chief minister. Even after this, we can recognise the better performance of West Bengal in combatting COVID-19 compared to other states. The possible reason is that women are with their cool and understanding attitude can handle the pressure more efficiently than their counterparts [5]. Political leadership is likely to empower women to take all necessary actions needed to combat untoward scenarios, such-like, pandemics [23]. Because of this, the states with larger representations of Women MP and MLA are found to be more efficient in reducing the COVID-19 death rate in our case.

5. Conclusion

The novel coronavirus or COVID-19 is a shock for all the countries around the globe. The pandemic has permanently changed the social, economic, demographical, or attitudinal nature of almost all nations. When some of the countries have faced the worst hit by the virus, some are successful in containing the spread of this virus and are also successful in saving the lives of their nation. The pandemic has taught us many lessons. It has proved that maintaining health and well-being is more important than achieving mere economic success. Fighting against this virus is a collaborative task of every layer of society, where starting from health personals to IT professionals everyone is working hand in hand against this pandemic [24]. Therefore the fight is an inclusive mission. The role of women leaders against the hiking curve of the virus is also important. Research exhibits that the nations with female leadership are better at controlling the COVID-19 death and flattening the curve [4]. The caring, nurturing trait of the female leaders placed them in an advantageous position as during crisis the people always want to listen to the leader whom they trust [5]. Therefore it is an interesting and important fact to connect the female leadership with the efficient performance of the nation during COVID-19, which may give us a further vision for female political leadership. The present paper aims to explore a single research question related to female political
participation and leadership with the efficient controlling of the COVID-19 death rate across Indian states. India being a diversified nation [25], performance efficiency is influenced by many factors. Considering the reciprocal of the COVID-19 death rate as the output variable we have found that Karnataka, West Bengal, and Madhya Pradesh are the top three efficient states out of the twenty-two states. Among the top three states, West Bengal is governed by a female leader. In fact, the performance of West Bengal, answer our research question in some way. The efficiency scores across Indian states motivate us to explore further the contribution of women’s political leadership in the efficiency in reducing the COVID-19 death rate. To achieve this goal beyond the input-output relationship in the SPF framework, the present study has utilized Battese, and Coelli, [13]; technical inefficiency effects model to pinpoint the factors influencing controllable inefficiency in combatting COVID-19 across Indian states. Furthermore, we have considered thirteen exogenous variables for identifying the inefficiency variables. Recognising the role of women leaders in the successful controlling of COVID-19 around the globe (Luoto, and Varella, 2020), we have tried to identify the role of female political leaders in reducing the COVID-19 death rate. However, out of the twenty-two states, only one state, viz., West Bengal has a female Chief Minister. Thus, we considered the share of female members out of the total members in Parliament and Legislative Assemblies of the respective states to the proxy, women’s political participation, and leadership. The share of women MPs and MLAs is observed to be negatively related to the inefficiency of the state’s desirable health outcome. Henceforth, our research question is explored empirically and the corresponding result enables us to recognise that women’s political participation and leadership is also an important determinant of the state’s efficiency in combatting COVID-19. Therefore, from the preceding detailed discussion, we can conclude that the more the percentage of women’s political participation and leadership greater the likelihood of efficient management of current pandemic circumstances. Based on our findings and discussion we have prescribed the following policy implications:

Firstly, as it has been found that the number of health personnel and infrastructural facilities significantly reduce the death rate; more attention should be given to the improvements in the health sector of the nation. The states are also recommended to utilise their existing health facilities more appropriately. Moreover, the state government needs to take pertinent steps to make all necessities available to all classes of people so that there can be successful lockdown as and when required. The protections of the health warriors are also states’ responsibility as we evident some undesirable incidences against doctors, nurses and police during this pandemic circumstance [26]. Accordingly, the states, the nations need to put forward their social and economic resources to cope with this extreme circumstance. Secondly, the present study and also earlier studies have documented that female political participation is a decisive factor for better performance; therefore, policies should be framed to encourage the women of the country and/or state for political autonomy and participation. India has already introduced the “Women Bill” [27] to encourage women for political participation and leadership. However, the successful implementation of the “Women Bill” is subject to the well-mean of the political parties. Reservations of some political seats will not serve the purpose entirely; unless women along with men are voiced for women’s political autonomy this goal will remain partially achieve [28]. In fact, this policy implication is against the social stigma and myth against women’s ability about decision making. This stigma suggests that women empowerment results prosperity of the society and consequently women should be given equal opportunities for building an ideal society [31]. Thirdly, as it has been found that more numbers of heart and diabetic patients hinder the success towards the controlling of the death rate, the co-morbid patients should be taken extra care of. They should be provided with the necessary amenities. Fourthly, it is patentely true that the elderly are at a high risk concerning the COVID-19 death rate. Consequently, special care should be thrust to accommodate their medical and daily life requirements, particularly those who live alone or with their spouse only. In West Bengal police come forward with a programme “Pronam” (Respect) to ensure such services to the elderly (http://www.kolkatapolice.gov.in/HTML/Pr onam.html [30]). We recommend the introduction of such programmes in all states. Fifthly, the positive role of literacy rate and urbanization authorise us to recommend that escalation of literacy rate and extension of urban facilities even in the interior regions can change the COVID-19 death scenario irrespective of Indian states. Accordingly, state and central governments are solicited to put emphasis on the escalation of literacy rate and extension of facilities to overcome such adverse circumstances. Finally, observing the positive role of digitalization and employment (although not statistically insignificant) we recommend more emphasis should be thrust on the advancement of technology in all areas and the creation of formal employment opportunities. These two may be pinpointed as essential for the successful “lockdown” to control the COVID-19 death rate. If the governments, viz., state and central governments can create enough job opportunities within state as well as with countries the citizens will not migrate to other places within or outside the country in search of livelihood. An appropriate and inclusive socio-economic policy formulation can achieve this target. By that way we can also resist brain-drain of any country.

Concerning the limitations of the study, it is noteworthy that the empirical analysis of the study is based on the total statistics, including both rural and urban areas of Indian states. Rural and urban India experiences much diversification concerning the delivery of health services. Consequently, it is essential to have micro-level statistics to perform a comprehensive analysis. However, the non-availability of data compels us to utilise the macro-level statistics for the study. Moreover, the choice of the variables and states for the empirical analysis is dictated by data availability. Thus depending on the availability of data the paper can be extended considering rural and urban India separately and by including some other relevant variables, suchlike women’s political empowerment, physical quality of life, etc., in future. Furthermore, the measurement of efficiency is facilitated by the FRONTIER-4.1 programme which the ranking of the states becomes time-invariant. Nevertheless, as the empirical analysis of the current study is facilitated based on the cross-sectional data, the application of the FRONTIER-4.1 programme does not result in serious problems.

The concept of efficiency is important in every sphere of life including health economics. The analysis of the efficiency across Indian states permits us to identify the most efficient state to combat COVID-19. Moreover, the recognition of the factors contributing to the efficient performance of the state in controlling COVID-19 gives us a layout for controlling the spread of COVID-19. By following the steps of the most efficient state others can also get success. In fact, the policies may be extended beyond boundaries with similar social-demographic-economy to combat COVID-19 across the world. Accordingly, the present empirical model is a generalized one and maybe plied across countries based on the availability of the data.

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Authors’ contributions

S.M., conceived of the study, participated in its design and coordination, performed the statistical analyses, and drafted the manuscript; U.R.B., helped in data compilation and participated in the design and helped to draft and revised the manuscript. All authors read and approved the final manuscript.
Availability of data and material

The study is based on secondary data and all the data sources are mentioned in the text. For further details kindly consult Table 1.

Information on rights and permissions

Not Applicable.

Declaration of competing interest

The authors declare and specify that they have no competing interest and/or conflict of interest.

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Appendix

Table A.1

Summary statistics of output, inputs and exogenous variables

| Variables          | Mean   | Std. Dev. | Maximum | Minimum |
|--------------------|--------|-----------|---------|---------|
| Death rate         | 1.22   | 0.74      | 3.24    | 0.13    |
| (1/Death rate)     | 1.39   | 1.57      | 7.68    | 0.31    |
| In (1/Death rate)  | 0.01   | 0.73      | 2.04    | –1.17   |
| DOCTOR (x2)        | 0.14   | 0.13      | 0.45    | 0.04    |
| NURSE (x2)         | 2.42   | 1.87      | 7.61    | 0.18    |
| Police (x3)        | 256.51 | 239.84    | 962.70  | 74.80   |
| Isolation beds (x4)| 67982.41 | 80673.62 | 350340.00 | 2212.00 |
| ICU beds (x5)      | 3918.86 | 4186.01  | 14070.00| 90.00   |
| Ventilators (x6)   | 1982.09 | 2074.42  | 7035.00 | 45.00   |
| Labs (x7)          | 25.00  | 20.98     | 72.00   | 2.00    |
| Older adult (x1)   | 7.82   | 1.82      | 12.60   | 4.60    |
| SR (x2)            | 951.27 | 47.67     | 1084.00 | 868.00  |
| LR (x3)            | 74.33  | 7.57      | 94.00   | 61.80   |
| Urban (x4)         | 32.75  | 17.85     | 97.50   | 11.29   |
| Sleep (x9)         | 2.73   | 0.40      | 3.40    | 1.80    |
| Diabetes (x10)     | 3.00   | 1.27      | 5.60    | 1.10    |
| Heart disease (x11)| 2.82   | 1.59      | 6.50    | 1.00    |
| Population density (x3) | 920.64 | 2336.40 | 11297.00 | 17.00 |
| PCN DSP (x2)       | 107036.70 | 57660.97 | 279601.00 | 30617.00 |
| Employment (x10)   | 27.04  | 12.56     | 77.25   | 14.85   |
| Digitalization (x11)| 20.37  | 12.86     | 37.00   | 0.85    |
| Women MP (x12)     | 9.37   | 7.52      | 28.60   | 0.00    |
| Women MLA (x13)    | 8.32   | 3.51      | 14.40   | 2.70    |

Source: Authors’ own calculation based on secondary data

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