Chapter – V

SUMMARY AND CONCLUSIONS
5.0 SUMMARY

Efficiency measurement dates back to Farrell who introduce the notions of technical, allocative and cost efficiencies. The 'bench mark' to carry efficiency measurement was chosen to be unit output isoquant. Farrell's input efficiency is bounded by 0 and 1.

Through axiomatic approach, Shephard introduced input and output distance functions, invented to measure input and output oriented technical efficiencies. Shephard's input technical efficiency measure is reciprocal of Farrell's input technical efficiency measure.

Farrell's equivalently Shephard's approach is radial as such they enquire for radial reduction of inputs to achieve, input technical efficiency. Following Farell, a voluminous literature exists in the name of data envelopment analysis.

The input and output oriented DEA models of Charnes, Cooper and Rhode's (1978) popularly known as CCR model; the multiplicative DEA model of Charnes et al (1983); the additive DEA model of Caharness et al. (1985), the DEA model that discriminates the returns to scale of Banker et al. (1984), popularly known as BCC model were fundamental contributions to Data Envelopment Analysis. Radial distance functions were prominently employed in these studies.
Fare et al. (1985) introduced graph approach towards measuring technical efficiency, the efficiency measure was named as Russell’s measure of efficiency. It simultaneously reduces inputs and augments outputs to transform an inefficient unit into efficient unit. If an input is reduced by a rate $\lambda$, an output is augmented at the rate of $\lambda^{-1}$.

The present study distinguishes DEA outputs, as good and bad outputs. In the process of good output production it is inevitable that bad outputs are also produced. To reduce bad outputs to zero, the good outputs should also be reduced to the same level, the hypothesis of which is called “null Joint”. A good programming problem is initiated to measure output oriented technical efficiency in two steps.

In the primal problem, the additional augmentation of good outputs is enquired assuming that inputs freely disposed (without any cost) but bad outputs are weakly disposed (with cost). Both the mathematical programming problems involved in goal programming are linear programming problems. In the former Goal programming problem additional good output augmentation is maximized. In the later Goal Programming Problem bad outputs are contracted.

In the presence of good and bad outputs, one may desire to look for augmentation of good outputs and reduction of bad outputs simultaneously. The ‘directional distance function’ is one such efficiency measure which has the Shephard’s efficiency measure as a special case. The linear
programming problem that represents direct distance function optimize
good and bad outputs in the direction of directional vector.

To the policy maker evaluation of a project is very much essential.
For a cost target it is desirable to know the potential output. Against a cost
target, under certain conditions the potential revenue or output can always
be predicted. If the value of potential revenue or the value of the potential
output is smaller than the target cost the project may be dropped. The
complete exercise can be done solving appropriately formulated linear
programming problems.

5.1 CONCLUSIONS

The present study deals with estimating and assessing the efficiency
of the police across 28 states of India. The empirical analysis identifies
three inputs of police, viz.

- Number of police personnel
- Number of motor vehicles
- Number of walkie and talkie and other communication
equipment.

Four good and one bad outputs are considered. These are percentages
of number of crimes for which charge sheets are filed to the total number of
crimes for the crime categories.

- Crime against women and children
- Violent Crimes
- Property Crimes
- Other IPC crimes
- Custodial crimes

For 28 states assuming that returns to scale are constant linear programming problems of the following type are constructed and solved:

Max. \( \theta \)

Subject to \( \sum_{i=1}^{n} \lambda_i x_i \leq x_0 \)

\( \sum_{i=1}^{n} \lambda_i y_i \geq \theta y_0 \)

\( \sum_{i=1}^{n} \lambda_i u_i = u_0 \)

where \( x, x_0 \in \mathbb{R}^n \)

\( y, y_0 \in \mathbb{R}^m \)

\( u, u_0 \in \mathbb{R} \)

\( \lambda \geq 0 \)

The police organizations of 13 states are found technically efficient. Among the rest of 15 police organizations it is observed that there is a significant variation in output technical efficiency. Efficient states are those that are relatively smaller in area and density of population. In some of these states bad output viz., custodial crimes are not registered.

To rank the 13 efficient decision making units performed peer analysis. If an efficient DMU appears in the peer list of inefficient DMUs
than another DMU then the former DMU is considered to be more efficient than the later. If peer analysis fails to resolve a tie among efficient units, one may resort to cross efficiency analysis that requires to solve appropriate dual linear programming problems one time for one DMU.

The peer analysis failed to resolve tie between DMU5 and DMU23; DMU 9 and DMU 18; DMU8, DMU 11 and DMU17; DMU3 and DMU19. Through cross efficiency evaluation the ties are resolved for tied efficient DMUs. These police organizations are ranked as shown below.

- Uttarakhand
- Goa
- Arunachal Pradesh
- Sikkim
- Chhattisgarh
- Mizoram
- Himachal Pradesh
- Meghalaya
- Haryana
- Jarkhand
- Tripura
- Assam
The rest of Police Organizations of 15 states that are inefficient are ranked according to the good output losses they suffer from. The fifteen DMUs are ranked as follows:

- Orissa
- Rajasthan
- Jammu and Kashmir
- Gujarat
- Kerala
- Andhra Pradesh
- Punjab
- Karnataka
- Bihar
- Tamilnadu
- West Bengal
- Maharashtra
- Manipur
- Madhya Pradesh
- Uttar Pradesh

To formulate and solve the secondary goal programming problem for each of these 28 states it is mandatory that bad output should be positive.

Deletion of the police of states whose bad output (number of custodial crimes) is zero leaves 18 police states.
For the police of the 18 states for which bad output is positive both the primary and secondary linear programming problems are solved. The later problem solved is as follows:

\[
\begin{align*}
\text{Min } & \lambda \\
\text{Subject to } & \\
\sum_{i=1}^{n} \lambda_i x_i & \leq x_0 \\
\sum_{i=1}^{n} \lambda_i y_i & \geq y_0 \\
\sum_{i=1}^{n} \lambda_i u_i & = \lambda u_0 \\
\lambda & \geq 0
\end{align*}
\]

Among the 18 decision making units four emerge to be output technical efficient. The peer analysis performed rank the efficient units as follows

- Orissa
- Kerala
- Karnataka
- Gujarat

None of these DMUs were efficient when the reference technology was provide by the police of all the 28 states. Significant bad output reduction possible for the police of Orissa, Kerala, Gujarat and Maharashtra.
Solving directional distance function based linear programming problems. We can measure good output augmentation and bad output reduction simultaneously. In this context we have solved the linear programming problems of the following type:

\[ \text{Max } \theta \]

subject to \( \sum_{i=1}^{n} \lambda_i x_i \leq x_0 \)

\[ \sum_{i=1}^{n} \lambda_i y_i \geq y_0 + \theta g, \]

\[ \sum_{i=1}^{n} \lambda_i u_i = u_0 - \theta g, \]

\( \lambda_i \geq 0 \)

where \((g, g_*)\) is the directional vector for good and bad outputs.

The directional vectors chosen are as follows

\((g, g_*) = (y_0, u_0)\)

\(y_0\) and \(u_0\) are good output vector and bad output of the DMU in focus.

Technically efficient states appear to be smaller in area and/or density of the population. An important reason for this appears to be that in these states the number of policemen per a square kilometer is high in each of these states. Most of the efficient states (police efficiency wise, not crime rate wise) appear to fill in the North-Eastern part of India.
These states are deleted from the 28 states of India as such we are left with the police organization of 13 states of India. To evaluate potential good output augmentation and bad output reduction of police we have used directional distance function potential good outputs. \((1 + \theta^*)y_o\) and bad outputs \((1 - \theta^*)y_o\) are computed for the police of states.

- Karnataka
- Kerala
- Orissa
- Bihar
- Madhya Pradesh
- Punjab
- West Bengal
- Tamilnadu
- Andhra Pradesh
- Uttar Pradesh
- Rajasthan
- Gujarat
- Maharashtra

For the purpose of planning the policy maker or economist requires to know against a target cost of police, the desired number of police and potential output. If \(C\) is the cost target under a set of assumptions. We solve the following linear programming problem:
Max $\lambda$

Subject to $\sum_{i=1}^{n} \lambda_i x_i \leq x$

$\sum_{i=1}^{n} \lambda_i y_i \geq \lambda y_0$

$px \leq c$

$\lambda_i \geq 0$

For each state three cost targets are considered.

These are,

- Current expenditure on police
- 20 percent more of current expenditure on police
- 40 percent more of current expenditure on police

For all the cost target potential police output and strength are computed.

5.2 SUGGESTIONS FOR FUTURE RESEARCH

For police outputs prices are not available using the concept of 'Assurance Region' shadow prices for various outputs may be constructed sensitivity analysis may be performed to assess robustness of efficient police organizations of states.