Does Modernization Improve Performance: Evidence from Indian Police

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Abstract
This paper aims to measure the role of police modernization scheme in its performance in crime repression. We use output distance function as an analytical tool and estimate it using stochastic frontier analysis (SFA) framework in a 'single stage'. We find that the police modernization scheme is helping the state police departments in enhancing their performance, i.e., the police departments which have more modern communication equipments and which are spending more money on the training of their police personnel are doing better relative to the others. The police density is found to be one of the major determinants of its efficiency along with the factors that create more social cohesion. The total factor productivity (TFP) is governed by the catch-up effect which is worsening over time though the technological progress has been observed in most of the states.

JEL Classification: H83, K42, D61
Key Words: Police, Performance Measurement, Modernization, Stochastic Frontier Analysis, India

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1. Introduction

Police in India, like in other countries, perform many diverse tasks such as crime prevention, order maintenance and law enforcement which are difficult to enumerate and assess. To this long list of traditional policing jobs have been added newer forms of crime typical of the 20th century such as terrorism, insurgency, organized crime, etc. No wonder then that in spite of expenses on policing increasing at a rate higher than the incidence of reported crime (Figure 1), the country has witnessed a secular upward trend in the acts of crime committed during. In view of limited resource availability as well as new forms of challenges (such as terrorism, insurgency, organized crime, etc.) facing the police force, the government is left with no other option but to improve efficiency of the police force by utilizing available resources in an optimal manner.

Policing in India is a state subject. As such, any major initiative to improve the functioning and efficiency of the police department has to take place within the domain of the concerned state government. The police departments are poorly funded, even though the police expenditures usually comprise a third of the total budget of state governments (Verma and Gavirneni, 2006). The majority of funds are used to pay the salaries of the police personnel and limited amount is available for general maintenance of vehicles, buildings, communication equipment and uniform. Purchase of materials, generally are done by seeking need based specific grants from the government.

To improve the availability of police hardware (i.e., vehicles, computers, communication equipments, security gadgets, etc.) in the states, the federal Ministry of Home Affairs is operating a police modernization scheme under which the financial resources are transferred to the state police departments through the respective state governments for the procurement of such equipments/gadgets. This financial assistance to the fund–starved state police departments is supposed to play a crucial role in improving police efficiency in the country.

The police modernization is a continuous process. The modernization assistance, which started way back in 1969-70 with a five million Indian rupees (Rs.) provided a total assistance of Rs. 4650 million till 1998-99. During 1999-2000, the modernization assistance was enhanced by Rs. 2000 million per annum. However, the year 2000 with an annual allocation of Rs. 10000 million was a watershed year in the modernization of the state police forces. In addition to this allocation from the Ministry of Home Affairs, the State Governments have also contributed their share to modernize their police forces.[1] This modernization has taken place in the areas of police housing, weaponry, computerization, transport, communications; and scientific aids to investigation, traffic and training. Understanding the role of modernization/provision of better communication infrastructure on the efficiency and productivity of the police is one of the objectives of present study, among others.

Similarly, in order to improve the professional skills of the police personnel, a number of professional training programs are being organized at the various state police training schools/colleges/academies in India. In addition to this, several national level

[1] As law and order is a state subject in India, so it is the responsibilities of state governments to incur expenditure on the maintenance and development of police departments from their own funds. However, the state governments in India receives various kind of central/federal assistance in the form tied and untied grants. Police modernization scheme is a form of tied grant; the state governments get funds from the central government in which state governments also have to contribute a certain proportion of the central grant for the purpose in hand.

institutes[2] also are imparting specialized training to the police personnel in the various fields of police operations with a view to enhancing their professional competence. The paper intends to measure the role of training expenditures incurred by various state governments on the police performance in detecting crime.

A major problem inherent in measuring the efficiency of the police service is to define and quantify the role of the police in the society, that is, given the wide range of outputs, from investigating murders to breath–analyzing motorists, which ones should be chosen in an efficiency and productivity measurement (Drake and Simper, 2003). We employ a 'pure' production methodology to measure the performance of state police departments in clearing up/detecting (charge-sheeting) various acts of body and property crimes and thus to deter future criminal activity.[3]

We use output distance function to measure the performance of the police in India. Output distance function is reciprocal of Farrell measure of technical efficiency. This approach can take care for the multiplicity of the functions performed by the police force. It requires data only on the quantities of various inputs and outputs. In the literature two approaches, data envelopment analysis (DEA) and stochastic frontier analysis (SFA) are used to estimate the output distance function. Each of the approach has its own pros and cons, and provides a spread of efficiency estimates. We use stochastic frontier approach to estimate the distance function. The obtained estimates of the efficiency are required to be reviewed and analyzed to understand the differing performance of each of the police department in the country. That is, the estimates of the performance should be further regressed on a set of environmental variables. Wang and Schmidt (2002) show that the estimates obtained using 'two stages' are severely biased, therefore we use 'one stage' stochastic frontier analysis to get the robust estimates of efficiency and its determinants.

We find that the average level of technical efficiency of the Indian police departments is 0.73 implying that with the existing resources they can do better. It is found that the efficiency estimates are linked to various factors some of them are not under the control of police departments such as level of literacy, industrialization, per capita income in a state. Providing modern communication infrastructure and training to the police departments improve their performance, i.e. the modernization of Indian police improves its performance in clearing the crime cases. Similarly, larger availability of the police in an area improves its performance, i.e., higher police density is positively associated with its effectiveness.

The Paper is organized as follows: Section 2 provides a background note on the Indian police system. Section 3 describes the related literature which puts the study in a perspective. The required input-output variables are defined in Section 4. This Section also describes the methodology followed for the measurement of efficiency and productivity in the study. Results of the study are discussed in Section 5. Section 6 summarizes main findings of the study and puts forward policy recommendations.

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[2] The National Police Academy (NPA), Jai Prakash Narayan National Institute of Criminology and Forensic Science (JPNNICFS), the Central Detective Training Schools (CDTS), the National Crime Records Bureau (NCRB), the Bureau of Police Research and Development (BPR&D), the National Industrial Security Academy (NISA), the Internal Security Academy (ISA), to name a few.

[3] The words clearing-up, detecting, and investigated and charge sheeted are used interchangeably throughout the paper.

2. Indian Police System

Article 246 of the Indian Constitution distributes legislative powers between the Union Parliament and State Legislative Assemblies. The police, public order, courts, prisons, reformatories, and other allied institutions figure in the State List. This implies that all matters relating to the organization, structure and regulation of the police force fall within the realm of the states. However, criminal laws and criminal procedures are listed in the Concurrent List over which both Union Parliament and State Legislative Assemblies have legislative powers. Thus, the basic criminal laws, the Indian Penal Code (IPC), the Criminal Procedure Code and the Indian Evidence Act that defines criminal behavior, prescribe police procedures and guide evidence presentation in the courts are enacted by the Union Parliament and apply throughout the country.[4] Note that it is the Indian Police Act of 1861 that govern the constitution and organization of police forces in all the Indian states. Therefore, the laws governing the structure of the police organization, and even the administrative forms and rules are virtually uniform across the country. Moreover, note that the Indian Police Service (IPS) is a federally recruited body which forms the apex of the hierarchy in the police system. Its officers are selected, trained and treated alike and then allotted to different states, again implying that the policing system is almost unitary in the country (Verma and Gavirneni, 2006).

In India, the police are organized at the state level and each of the twenty eight states[5] has its own police organization which works under one command under the power of state government (Verma and Gavirneni, 2006). We choose states as the unit of analysis since the organization are similar everywhere. Each of the state is further divided into ranges, districts and police station jurisdictions. Each of the districts is headed by the district superintendent of police who is an IPS officer. District superintendent of police is responsible for the prevention and detection of crime and the maintenance of law and order. An officer of the rank of inspector or sub-inspector works as station officer in charge of other investigators and constables for patrolling and general duties. The basic duty of the police forces is to register cases, investigate them as per the procedure lay down in the Criminal Procedure Code and ~~to~~ send them up for trial. It is the duty of the courts to convict the offenders after the completion of trials.

The process of criminal justice starts with the registration of the First Information Report (FIR) at a police station. The police write an FIR as they receive information about the commission of a cognizable offence and proceeds to the scene of crime and investigate the facts of the case. After completion of the investigation, the police send a report in the form of charge-sheet to the local court to prosecute the accused, if there are sufficient evidences. The course takes cognizance and initiates the trial of the case on receiving the charge-sheet. The responsibility of the prosecutor is to prove the charges against the accused beyond a shadow of doubt and to ensure that the accused gets full opportunity to defend him/her-self. The courts can award punishments to the offender if the trial ends in conviction. Thus, In India, the main duties of the police are to prevent the commission of crimes, ensure that laws and regulations are enforced, and investigating crimes and offences so that the offenders can be get convicted by the courts and future

[4] The states have also enacted laws on several local and special subjects and some states have also their own police acts.

[5] Before 2001, there were 25 states in India. Three new states namely, Jharkhand, Uttarakhand and Chhattisgarh are curved out from the states of Bihar, Uttar Pradesh and Madhya Pradesh respectively in 2001.

crimes can be deterred. In the present study we focus only on the crime detection and investigation activities of the police because of the difficulties involved in assessing the results of preventive and deterrent activities. Note that most of the efforts and resources of police are devoted to investigation activities that help in detecting the culprits of specific offences and crimes (Thanassoulis 1995)**.**

3. Literature Survey

The estimation of productivity and performance of the police institutions and individual police officers is a debatable issue (Kelling, 1992). The role of police in any given society in not defined clearly and the police is supposed to provide a variety of services (Walker and Katz, 2000).

Usually, the police departments use a vector of inputs such as manpower, vehicles, gadgets, weapons, buildings, etc. and produce a vector of outputs and/or outcomes such as prevention and detection of crime, maintenance of law and order, regulation and control of traffic, security of the VIPs, etc. Outputs are under the control of police departments whereas the outcomes are socially desirable targets which may be influenced by the factors that are not under police control. Generally there is an overlap between the outputs and outcomes of police services (Davis, 2012). Given this complex set of input and output/outcome vectors, how to define the efficiency of police is a big challenge.

A recent study by García-Sánchez et al. (2013) measuring Spain's police performance provides a comprehensive survey of the relevant literature in a tabular form describing the inputs and outputs used, techniques employed and inferences of these studies. DEA has been used for measuring the efficiency and productivity of police in a number of studies (Thanassoulis 1995; Carrington et al. 1997; Nyhan and Martin 1999; Sun 2002; Diez-Ticio and Mancebon 2002; Drake and Simper 2000, 2001, 2002, 2003a,b, 2004, 2005a,b; Verma and Gavirneni 2006; Goltz 2008; Gorman and Ruggiero 2008; García-Sánchez 2007, 2009; Wu et al. 2010, García-Sánchez et al. 2011a; García-Sánchez et al., 2011, 2013). Most of these studies have the single objective of measuring technical efficiency using an input oriented efficiency measure and are limited by the consideration of a single time period. Some studies such as Wu et al (2010) and García-Sánchez et al. (2013) measure dynamic efficiency of police forces by estimating the Malmquist index and its components. The literature survey by García-Sánchez et al. also shows that there is hardly any study which uses the stochastic frontier analysis for measuring efficiency and productivity of the police.[6]

Thanassoulis (1995), perhaps the first study measuring police performance using DEA, focuses solely on the clear up rates for violent crime, burglary and other crimes, while also including the total numbers of each crime as inputs in the analysis alongside the number of officers in measuring the performance of England and Welsh police force. Drake & Simper (2000) measured the size efficiency of English and Welsh police forces using DEA and multiple discriminant analysis and infer about the optimal size and structure of the English and Welsh police. Drake & Simper (2003) estimate distance function models using four different estimation techniques, i.e. DEA, free disposal hull

[6] Drake and Simper (2003a) uses various approaches for measuring the performance of police force including stochastic frontier analysis.

(FDH), super-efficiency DEA and stochastic frontier analysis in order to assess police force efficiency of English and Welsh police force.

Verma and Gavirneni (2006) is the only available study that measures the efficiency of police force in India.[7] It employs DEA technique for measuring the efficiency using 1997 crime data. This study uses total expenditure, number of investigating and non-investigation officers as inputs, and number of persons arrested, number of persons charge-sheeted, number of persons convicted and number of trials completed as outputs. Note that the total expenditure on police includes the wages paid to investigating and non-investigating officers. Thus Verma and Gavirneni suffers from the problem of double counting of inputs. Similarly, number of persons convicted and number of trial completed are the functions which are not under police control in India but depend on the efficiency of other agencies like judiciary and prosecution. Number of persons arrested, a variable used in a number of studies, may reflect activities against human rights since at times police arrests innocent people or culprits with insufficient evidence (Millspaugh, 1937). In sum, Verma and Gevirneni study suffers from the production function misspecification problems.

García-Sánchez et al. (2013) report that most of the studies using DEA use only the single stage analysis of efficiency estimates. These studies either don't consider the factors that influence police performance or consider these variables in the second stage by regressing the efficiency estimates on the environmental variables using Tobit regression analysis (e.g., Drake and Simper 2005). Simar and Wilson (1999) show that the efficiency scores are correlated with the explanatory variables and the estimates obtained using Tobit model will be inconsistent and biased. Simar and Wilson (2007) propose bootstrapped DEA scores with a truncated regression. Johnson and Kuosmanen (2011) show that the finite sample bias of DEA efficiency estimates in the first stage carries over to the second stage regression, causing bias in the estimated coefficients of the environmental variables. The correlation between the inputs and environmental variables further accentuate the bias. That is, though these 'two stages' studies are able to recognise the factors that influence efficiency but fail to consider them in comparative or benchmarking process.

Single stage DEA approach which can incorporate environmental variables along with usual inputs and outputs was proposed by Banker and Morey (1986). This approach restricts the comparison set to other decision making units in the same or higher (lower) categories and requires that the categories be nested. As a result, the comparison set for most decision making units gets reduced and the discriminatory power of the model declines. This is the reason that in Wu et al (2010) and García-Sánchez et al. (2013) a large number of observations were found operating at the frontier. For example, in García-Sánchez et al. (2013) about 55 percent observations are found to be fully efficient. Similarly, Gorman and Ruggiero (2008) using multi-stage DEA model, observe that most of the US states are technically efficient in providing the police service. Moreover, this single stage DEA approach requires that the direction of the effect of each of the included environmental variable be known in advance (Fried et al 2002). Therefore, Smith and Street (2005) conclude that "*there is no generally accepted methodology for how to*

[7] Though there are various governments commissioned and academic studies that employ various indicators such as crime cases reported from an area to measure the police performance in India. Such kind of measures can be interpreted in either way; the higher number of registration of cases may indicate the increase in crime or higher confidence in the police. But none of these studies employs production function methodology to measure the police performance in India.

account for environmental variables in DEA models ..." (p. 412). Note also that these models are deterministic and fail to take account for the effects of statistical noise.

We use 'single stage' SFA to overcome the shortcomings of 'single stage' or 'two stage' DEA approaches. SFA, being stochastic in approach, is able to take care of statistical noise and omitted variables. In the SFA, it is not necessary to know the effect of environmental variables in advance and even the direction of the effect of each of the included variables can be verified, and the obtained efficiency estimates are robust. Wang and Schmidt (2002) show that how neglected environmental variables affects the efficiency estimates in 'two stage' analysis. They show that these environmental variables scale both mean and variance of inefficiency distribution, and make a case for including all the environmental variables in the first stage itself as the determinants of inefficiency.

4. Data and Methodology

A comprehensive measure of police performance that captures the multifaceted, and even sometime even conflicting functions performed by the police forces drives the organization to higher level of performance (Moore and Braga, 2003). In the design of a performance measure for the police forces one needs to differentiate between outputs and outcomes. Outputs are measures of internal performance and outcomes imply societal benefits that the police produce, and both are highly correlated to each other (Davis, 2012). Davis argues for using outputs in the performance measure as police can directly influence them, whereas outcomes are noisy as they are influenced by the factors outside the control of police and the police officers have fewer incentives to try to influence the outcomes, therefore, we focus only on the outputs. Section 4.1 describes the variables chosen for the present study as outputs, inputs and environmental variables that influence the performance.

The other concern is about the choice of a performance indicator. At present the single output based measure such as number of crime cases registered by the police is taken as a measure of performance in India. The higher number of registered cases can be interpreted as either a measure of underperformance or higher confidence in the police force. Therefore, rather than using the single indicator, a measure which can capture a set of indicators with the given resources should be used for measuring the performance. In the present study we employs output distance function and estimate it using SFA to obtain the performance estimates. The methodology is discussed in Section 4.2.

4.1 Data

We take information of 25 states and the union territory of Delhi for measuring technical efficiency and productivity of police. The newly-crafted states of Chhattisgarh, Jharkhand and Uttarakhand have not been selected, since the data for these states were available from 2001 onwards only. Similarly, the union territories of A&N Islands, Chandigarh, D&N Haveli, Daman & Diu, Lakshadweep and Pondicherry have also not been considered, since these union territories are very small in size, and insignificant in terms of police strength, crime, police vehicles and communication gadgets as compared to the states and union territory of Delhi which has been considered. The selected 25 states and the union territory of Delhi account for 94 percent of the police strength in the country as on December 2006, and are, therefore, representative of the police force of the country.

For the purpose of this study, a period of 7 years (1999 to 2005) has been taken to measure the technical efficiency and productivity of the Indian police. The selection of the period of study is based on two factors (i) the year 2000 is considered a watershed in the history of police modernization as the central assistance in this year increased substantially, as a result, the benchmark year is taken just before that; and (ii) the availability of all the required data for the selected states and union territory.

In India the police organizations employs a vector of inputs such as manpower, vehicles, weapons, communication gadgets, buildings, etc and produces a vector of outputs such as maintenance of public order, detection of crime, regulation and control of traffic, security of the VIPs[8], response to natural and man-made disasters, etc. Choice of inputs and outputs is a crucial factor in defining the production function of police and an excellent discussion on the evaluation of the inputs and outputs in tabular form can be found in (García-Sánchez et al., 2013). Choice of variables for the production function in the present study, though based on literature survey, is restricted by two factors (i) availability of data; and (ii) personal experience.[9] We define the police production function in terms of the following outputs and inputs:

Outputs:

i) Number of property offences detected (investigated and charge-sheeted)
ii) Number of body offences detected (investigated and charge-sheeted)
iii) Value of Property recovered (Rs millions)

Inputs:

i) Number of non-investigation officers
ii) Number of investigating officers
iii) Number of police vehicles
iv) Number of property offences registered/occurred
v) Number of body offences registered/occurred
vi) Value of property lost (Rs millions)

The police output has been defined in terms of its ability to detect the various types of body and property related offences, and in terms of its ability to recover the stolen property. As far as the property related offences are concerned, we consider four major offences, i.e. robbery, dacoity[10], burglary and theft. The other property offences such as cheating, criminal breach of trust, preparation and assembly for dacoity, etc. have not been considered, since the essence of property offences is adequately captured by these four property offences selected. In so far as the body offences are concerned, we consider the major body offences such as murder, attempt to murder, culpable homicide not amounting to murder, rape, kidnapping and abduction, hurt/grievous hurt, dowry death, molestation, sexual harassment, and cruelty by husband or relatives. An important index of police efficiency in detecting property offences is the recovery of property stolen in such offences; since the recovery of stolen property involves an extra effort on the part of the police to link the criminal with the crime. Therefore, the property recovered has been taken as an output of the police. Note that some of the studies (e.g., García-Sánchez

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[8] According to a news report in India about 50000 police personnel are deployed for the security of VIPs. (The Times of India, January 08, 2013).

[9] One of the authors has been working in Indian police for the last 25 years.

[10] Verma and Gavirneni (2006) define dacoity as armed robbery by 5 or more people.

et al., 2013) have used percentage of offences cleared by the police as outputs, but percentage fails to capture the scale effect of the outputs.

In the production function there are two essential inputs, labor and capital. We use the number of police officers and police vehicles as proxies for the workforce for the capital variables. As the police outputs have been defined in terms of detection of various types of crime, in the input vector only the number of investigating officers in each state should be taken; leaving out the number of non-investigating officers (non-investigating staff in the civil police, the entire district armed police, and the entire state armed police personnel). Investigating officers handle all work from the registration of the criminal complaint to the collection of evidence, recording witness statements, preparing the case for court trial and maintaining related paperwork. They are also responsible for the upkeep of police station records, collection of intelligence and maintaining cordial relations with the citizens. It is their work which determines the performance of police department to a large extent (Verma and Gavirneni, 2006). Non-investigating employees do patrolling and general duties such as filing records, answering telephones and other administrative tasks. Following Drake and Simpler's (2003a) observation that, '*the demarcation between the police function and civilian involvement in policing has become more blurred over time*' (p. 171), we include both investigating and non-investigating officers in the production function as inputs.

Since mobility is the *sine quo non* for any effective police action (be it responding to emergency calls for help, visiting the scene of crime, providing security to the VIPs, etc.), the number of police vehicles available with each state police departments during the relevant period has been taken as an input. Moreover, the various categories of 'reported crimes' are treated as inputs on the assumption that these numbers form the basis for subsequent work of investigation and prosecution. The police no doubt work to prevent crimes but it is impossible to measure the number of crimes that were prevented. If the number of crimes reported is high then it signals a higher input in the analysis. Clearly, for the police organization to become efficient a lower value of the denominator will be a welcome factor. Hence, the use of reported crimes as inputs do take into account the preventive work performed by the particular police department.

Environmental Variables

By Environmental variables we mean those factors that are external to the police force and may influence the efficiency and productivity of police force in either direction. The effects of these variables on the efficiency estimates have important policy implications.

We have taken the states as unit of analysis and these vary considerably amongst them not only in terms of size, population and economic development, but also in terms of nature and extent of reported crime attributable to differing level of socio-economic conditions prevailing in these states generally captured by such variables as literacy, industrialization, urbanization, sex ratio etc and availability of public infrastructure. Moreover, as the objective of the study is to estimate the impact of modernization scheme, the states get differing level of central assistance in the form of tied grant for this purpose. We try to get an understanding about the effect of modern communication infrastructure and expenditure on various training programs by including these variables in the estimation of SFA as environmental variables.

As the communication equipments (telephones, wireless, computers etc) play a very important role in determining the police response to the various crimes and calls for help in the modern high-tech world, the numbers of communication equipments available with each state police are supposed to increase the police performance.

Similarly, the initial training and periodical skill up-gradation of the police officers is an important factor in determining their ability to detect crime, therefore the expenditure on police training for each state police is hypothesized that it leads to higher performance of the police in clearing the reported cases of crime and offences.

We included police density defined as police personnel per square kilometer, level of industrialization in a state defined as the proportion of industrial sector in the state gross domestic product, literacy rate, sex ratio defined as number of women per thousand men, and per capita state gross domestic product as other environmental determinants of police performance.

The data on crime and police strength have been taken from the '*Crime in India'* (various volumes), National Crime Records Bureau, Ministry of Home Affairs, New Delhi. The data on police expenditure and police expenditure on training, police vehicles, and police communication equipments have been sourced from the Bureau of Police Research & Development (BPR&D), Ministry of Home Affairs. Data on all other socio-economic variables is taken from the website: www.indiastat.com. Note that all the monetary figures are used at 1999 prices.

4.2 Estimation Methods

The review of the relevant literature reveals that there are two widely used frontier methods available for estimation of technical efficiency of the decision making units: DEA and SFA. The parametric models require prior specification of a functional form, such as Cobb-Douglas, Translog, CES, etc.

As we employ a production function approach; we assume that a police department employs a vector of inputs $x \in \Re^K_+$ (e.g., number of police personnel) to produce a vector of outputs $y \in \Re^M_+$ (e.g., body crime detected). Let $P(x)$ be the feasible output set for a given input vector x. The technology set is defined as:

$$T = \{(x, y) : x \text{ can produce } y\} \tag{1}$$

Formally, the output distance function is defined as:

$$D(x, y) = \min_{\theta}\{\theta > 0 : (y/\theta) \in P(x)\} \tag{2}$$

Equation (2) characterizes the output possibility set by the maximum equi-proportional expansion of all outputs consistent with the technology set (1). The output distance function can be used to measure the Debreu–Farrell technical efficiency.[11] The DF measure is the reciprocal of the value of the distance function and it gives the factor by which all output could be expanded proportionately if the production units were operating on the frontier. These properties include monotonicity and homogeneity conditions. The advantage of homogeneity property is that it allows one to consider proportional changes in outputs.

[11] For properties of output distance function, see Murty and Kumar (2002).

The output distance function is parameterized using semi translog flexible functional form. In our case, we include three output, six inputs, and time trend as a proxy for technological changes[12], which results in:

$$\ln D(x,y) = \beta_0 + \sum_{m=1}^{M} \beta_m \ln y_m + \sum_{n=1}^{N} \alpha_n \ln x_n + \frac{1}{2}\sum_{m=1}^{M}\sum_{m'=1}^{M} \beta_{mm'} \ln y_m \ln y_{m'} + \frac{1}{2}\sum_{n=1}^{N}\sum_{n'=1}^{N} \alpha_{nn'} \ln x_n \ln x_{n'} + \sum_{n=1}^{N}\sum_{m=1}^{M} \delta_{nm} \ln x_n \ln y_m + \gamma_0 time + \frac{1}{2}\gamma_1 time^2 + \sum_{n=1}^{N} \gamma_{1n} \ln x_n .time + \sum_{m=1}^{M} \gamma_{1m} \ln y_m .time \tag{3}$$

Accounting for homogeneity and symmetry conditions, the following parameter restrictions must be satisfied:

$$\sum_{m=1}^{3} \beta_m = 1; \sum_{m=1}^{3} \beta_{mm'} = 0; \sum_{m=1}^{3} \gamma_{1m} = 0; \sum_{m=1}^{3} \delta_{nm} = 0;$$
$$m = 1,2,3.$$
$$\alpha_{nn'} = \alpha_{n'n}; \beta_{mm'} = \beta_{m'm}$$

where x and y are respectively $N\times1$ and $M\times1$ vectors of inputs and outputs, *time* is a time-trend. Specification (3) allows for neutral and biased technological changes. The effect of a neutral TC is captured by coefficients γ_0 and γ_1. The extent of input-biased TC is estimated by coefficients γ_{1n}. The effects of changes in output due to TC (i.e., output-biased technological change) are estimated by coefficients γ_{1m}. Note that we use square terms and interaction terms in inputs only with respect to first three inputs namely, number of investigating officers, number of non-investigating officers, and number of police vehicles.

Orea (2002) employed the Quadratic Identity Lemma for parametric decomposition of the Malmquist productivity index using an output distance function and its components. The Malmquist productivity indicator (PC) can be decomposed into two component measures: efficiency change (EC) and technological change (TC). EC measures how close an observation is to the technology frontier and TC measures the shift in the technology frontier over a period of time. Technical efficiency reflects how the different police departments are able to use available resources (e.g. number of police members) from the existing production technology, technological progress reflects the increases, for example, in the number of offences charge sheeted, which could be achieved, from one period to another, without altering the amount of police members. The latter could occur by introducing new innovation is detecting the crimes (García-Sánchez et al., 2013).

Based on our panel data for 1999–2005, the analysis of the technical efficiency, and the evolution of efficiency is carried out using the Malmquist Productivity Index. Using the homogeneity property the output distance function can be estimated

[12] Technological progress occurs due to both inducements and advancements in general science and technology. Therefore, a time trend is included to account for the impact of scientific innovation on production technology (Lansink et al., 2000, p. 500, footnote 1).

stochastically which takes a similar form as SFA.[13] SFA estimates the best practice frontier using maximum likelihood estimators (Coelli et al 2005).[14]

5. Empirical Results

Descriptive statistics for all the variables used in the study is given in Table 1. In most instances, the standard deviation is higher than the mean values for most of the variables. This could be attributed to the fact that the states in the sample have widely varying characteristics with respect to structural inputs and outputs, and environmental variables used in the estimation of stochastic frontier analysis.

To obtain the technical efficiency estimates the stochastic output distance function is estimated in a single step using maximum likelihood estimator. The one-sided error term is assumed to be half normally distributed. The model is estimated for a pooled sample of 26 Indian police departments for the period of 1999 to 2005 with time trend and its square and interaction terms to capture the effect of exogenous innovations.

The parameters of estimated output distance function are given in Table 2. Most of these parameters are significant either at the 1% level or at the 5% level. The log likelihood ratio test is also significant at the 1% level with the number of restrictions equal to eleven. The estimated parameters indicate that the first-order coefficients on the output and inputs have the expected values regarding economic behavior. After examining the signs of the second-order parameters, it would appear that they also involve interesting results. These, however, require a more detailed analysis to measure their final influence. Thus, using the estimated coefficients, we are able to verify that the resultant distance functions satisfy the regularity conditions of convexity-concavity on inputs and outputs for the large majority of observations. The parameters associated with the trend and long-term energy price variables are of specific interest. Negative parameters indicate positive changes in technology, and a positive parameter indicates technological regression. We find the absence of a neutral TC because the coefficient of time is not statistically significant. Rather, we observe the presence of biased or embodied TC, since the coefficients of the interaction terms between the time trend and the outputs are statistically significant.

The value of the output distance function computed for each observation gives a measure of technical efficiency at a state level. Figure 2 reports the yearly mean statistics of technical efficiency for the sample states. The mean value of technical efficiency for the states in the sample over the period of 1999 to 2005 is 0.74 meaning that the police department in India is 26% inefficient. It is worth noting that the mean technical efficiency of police force in India is volatile with a mean of 0.79 in 1999 to 0.71 in 2003. In the year of 2005 its level was 0.73 implying that over the period the mean efficiency level of Indian police has declined.

Figure 3 shows the mean level of technical efficiency observed by the different states over the sample period. We observe that Delhi is on the frontier throughout the

[13] For details on parametric decomposition of Malmquist index see Orea (2002), and for 'single stage' stochastic estimation of output distance function see Murty and Kumar (2003).

[14] However, the stochastic estimation of distance functions by SFA has attracted the criticism because the problem of endogeneity arises when both inputs and outputs are included among the regressors. As pointed out by the reviewer, Bayesian econometrics can be used for estimating distance functions to overcome the endogeneity problem (O'Donnell 2011), which can be the task of future research.

study period and the lowest level of efficiency has been observed in the states of Arunachal Pradesh and Mizoram. Both of these states are performing even below the 10 percent level of their potential. The other states that are performing below 50 percent of their potential are Goa, Orissa and Sikkim. On the other hand the states of Bihar, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh are performing above 90 percent of their potential.

The effect of modernization scheme on the technical efficiency of states police is analyzed by estimating a relationship between technical inefficiency and the communication parameters namely the number of telephones, wirelesses and computers, and expenditure on training programs. The model shows that the technical inefficiency is not a linear function of modernization scheme. In Table 2, the coefficients of these modernization variables are statistically significant for wirelesses and computers at the 1% level but the coefficient of the telephones variable is not significant even at the 10% level. The coefficient of the expenditure on training programs is found to be statistically significant at 11 percent level. The sign of the coefficients of these variables in Table 2 are of particular interest given the objective of understanding the role of modernization scheme in the police performance in India. A negative sign for the estimated coefficients shows that the higher the level of these variables in a state the higher is its technical efficiency. The signs of estimated coefficients of wirelesses, computers and expenditure on the training programs are negative, but the coefficient of the variable telephones is positive and it is statistically insignificant. In other words, the more the availability of modern communication facilities and training programs for the police personnel in a state the more efficient they become. This result supports the hypothesis that the modernization scheme is helping in improving the performance of state police departments.

The extent of social cohesion and the citizens' commitment are important determinants of police performance (Mathieson and Passell 1976), and these factors are beyond the control of police departments. We have taken sex ratio, literacy rate, level of industrialization, and per capita income as indicators of social cohesion. We find that all of these variables are significant determinant of police performance in India. Literacy rate and level of industrialization in a state are positively associated with the police performance, but the level of per capita income and sex ratio are found to negatively affect the police performance. The negative association between the per capita income and police performance may be due to the reason that it is not the level of income but its distribution that determine higher social cohesion in a state.

In India, it is often cited that the reason behind low level of police performance is low per capita police availability (about one police personnel for 750 people). Note that, the law and order provided by the police is a conventional public good, in which there is non-rivalry and non-excludability in consumption, though there can be congestion problem in its use. Therefore, we consider police density in determining its performance; a state with low population densities may require more police personnel as it has to maintain a minimum capacity to maintain law and order and public safety. We find the coefficient of police density is negative and statistically significant implying a positive association between police density and police performance. For example Delhi which has the highest police density (3849 per 10 thousand square Km.) in the country is operating at the frontier and Arunachal Pradesh has the lowest police density in the country (6.58 per 10 thousand square Km.) and its technical efficiency level is only 0.07. The per capita police availability is second highest in the state of Mizoram but it has the lowest police efficiency.

We compute cumulative Malmquist productivity (CPC) index and its components to understand the evolution of police efficiency over time using the parametric estimates of output distance function. Figure 4 shows the cumulative values of Malmquist index and its components at the all India level. The total factor productivity (TFP) of police force in India increased by about 4percent in a span of 7 years. The improvement of this magnitude in the productivity of the police force can be attributed to innovations which were strong enough to offset the losses caused by changes in technical efficiency. Here it is worth ~~to~~ noting that the changes in TFP are governed by the catch-up effect i.e., changes in technical efficiency, though we observe positive technological changes (innovations) throughout the period of study. This technological progress reveals that over the period of time the frontier is moving outward implying thereby that fewer resources are required to solve the same percentage of crime cases.

Figure 5 reveals the evolution of technical efficiency at the state level. Fifty percent of the states have observed increased in TFP in 2005 over 1999. Highest TFP growth was observed in the state of Goa which is governed by the improvement in both catch-up effects and innovations. Technological progress is observed in most of the states, i.e., it is only six states where technological changes have worsened. Catch-up effect is found to be positive in about 38 percent of the states and about 58 percent of the states are moving away from the frontier over the period of time. We observe absence of catch-up effect for Delhi, as it has been operating at the frontier in all of the study years. The decreasing trend in the catch-up effect may be attributed to increased terrorists, insurgency and organized crime activities in the states. Most of the North-Eastern (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura) observe far less technical efficiency which is decreasing over the period to time, and these states are prone to insurgency problems for a long time (Bhaumik, 2007).

6. Conclusions

The year 2000 is the turning point in the program of modernizing the police forces in the country started way back in the 1969-70 by The Ministry of Home Affairs with meagre resources. In this year, with an eye on improving the performance of police forces, the central assistance to state police departments was increased substantially so as to enable them to procure modern equipments on large scale.This study makes an humble attempt to evaluate the impact of the modernization schme. To measure performance of Indian police we estimated output distance function using SFA which provides the estimates of technical efficiency and analyse its determinants in a single stage. The SFA framework provides robust unbiased estimates of the techncial performance as compared to the DEA approach in which there is no generally accepted methodology for how to account for environmental variables.

The major findings of the study are the following: on an average, by improving its efficiency, the Indain police could have solved about 26 percent more crime cases with the existing resources. Delhi, a Union Territory, is the best performing and Mizoram is the least performing of the states in terms of police efficiency in clearing the crime cases. The introduction of communication gadgets and increased training expenses appear, in particular, to have gone a long way to help improve the efficiency of the police departments in India. Such types of modernization scheme need to be strengthened overtime. We also find factors such as literacy rate and the extent of industrialization in a state to have important bearing on the social cohesion within a region leading in turn to smaller incidence of crime. The study identifies police density, defined as the availability of police per square kilometer of area as one of the major determinants of police performance in India. The states having higher police density are doing better in terms of higher rate of charge-sheeting, i.e., the crime cases that are sent for trial to the courts.

The results concerning the evolution of technical efficiency reveals that in case of majority of states in the union, over the period of seven years, the TFP of police force has increased by about 4 percent which may be attributed to innovations though the catch-up effect is worsening. It appears that while technological modernization has succeeded in improving efficiency and productivity of the forces, new challenges in the form of increased incidence of terrorism, insurgency and organized crime, as well as political interference tend to slow down the pace of such gains.

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Table 1: Descriptive Statistics of the Variables Used in the study

Variable	Mean	Std. Dev.	Min	Max
Investigating Officers	5320.91	4805.53	213	21050
Non-investing Officers	33113.88	29425.81	1391	118427
Vehicles	3113.39	2528.80	143	12468
Telephone	650.15	707.30	21	2853
Wireless	663.32	713.21	21	2815
Computer	405.54	603.21	4	3891
Property Crime Reported	14159.79	14874.3	118	65518
Body Crime Reported	17439.22	18418.43	100	65554
Property lost (Rs million)	406	529	0.726	2940
Property Crime Detected	5756.709	6219.662	7	23620
Body Crime Detected	15050.08	16549.07	17	56661
Property Recovered (Rs million)	131	156	0.337	789
Police per 10 thousand Kms	210.52	730.76	6.37	3857
Literacy Rate (%)	68.73	10.09	47.53	90.92
Sex-ratio (women per thousand men)	890.76	85.97	728	1252
Per Capita state domestic product (SDP)(RS)	19672.97	8443.39	5786	52201
Industry share in state domestic product (%)	22.36	6.59	9.35	41.33
Police Training Expenditure (Rs Million)	76.55	64.45	01.18	306.55

Table 2: Estimated Parameters of Stochastic Output Distance Function

Variable	Coef.	Std. Err.	P>z	Variable	Coef.	Std. Err.	P>z
Ln(y1)	2.226			Ln(x1)*ln(x2)	-0.398	0.34	0.245
Ln(y2)	2.317	0.53	0	Ln(x1)*ln(x3)	0.028	0.20	0.891
Ln(y3)	-3.543	0.53	0	Ln(x2)*ln(x3)	-0.892	0.40	0.024
Ln(x1)	1.082	1.09	0.323	time	-0.139	0.15	0.349
Ln(x2)	-7.011	0.99	0	Time^2	-0.006	0.01	0.276
Ln(x3)	4.757	1.29	0	Ln(y1)*time	-0.018		
Ln(x4)	-0.309	0.07	0	Ln(y2)*time	0.048	0.02	0.037
Ln(x5)	-0.648	0.08	0	Ln(y3)*time	-0.030	0.02	0.05
Ln(x6)	-0.136	0.04	0	Ln(x1)*time	0.001	0.03	0.958
(Ln(y1))^2	-0.098			Ln(x2)*time	0.030	0.04	0.5
(Ln(y2))^2	-0.109	0.08	0.179	Ln(x3)*time	0.005	0.03	0.893
(Ln(y3))^2	-0.579	0.08	0	Constant	7.848	2.42	0.001
(Ln(x1))^2	0.216	0.27	0.43	ln σ_v^2			
(Ln(x2))^2	1.959	0.56	0	Constant	-6.095	0.47	0
(Ln(x3))^2	0.304	0.29	0.294	ln σ_u^2			
Ln(y1)*ln(y2)	-0.186			Police per 10 thousand Kms	-0.026	0.00	0
Ln(y1)*ln(y3)	0.284			Literacy Rate	-0.037	0.02	0.089
Ln(y2)*ln(y3)	0.295	0.07	0	Sex ratio	0.005	0.00	0.01
Ln(y1)*ln(x1)	0.174			Industry share in state domestic product	-0.092	0.04	0.012
Ln(y1)*ln(x2)	-0.395			Ln(per capita SDP)	2.378	0.91	0.009
Ln(y1)*ln(x3)	0.167			(Ln(police training expenditure))^2	-0.170	0.11	0.107
Ln(y2)*ln(x1)	0.234	0.14	0.097	Ln(telephone)	0.456	0.63	0.472
Ln(y2)*ln(x2)	0.095	0.25	0.701	Ln(wireless)	-1.032	0.20	0
Ln(y2)*ln(x3)	-0.462	0.20	0.024	Ln(computer)	-0.443	0.16	0.006
Ln(y3)*ln(x1)	-0.408	0.11	0	Constant	-15.267	7.81	0.051
Ln(y3)*ln(x2)	0.300	0.20	0.139	σ_v	0.047	0.01	
Ln(y3)*ln(x3)	0.295	0.14	0.035				
Log likelihood					45.73		
Log likelihood Ratio Test for One-sided Error					161.92		
Observations					182		

Note: y1: value of property recovered; y2: number of property crime detected; y3: number of body crime detected; x1: number of investigation officers; x2: number of non-investigating officers; x3: number of vehicles; x4: value of property lost; x5: number of property crime cases reported; and x6: number of body crime cases reported.

Figure 1: Crime Incidence and Expenditure on Police in India

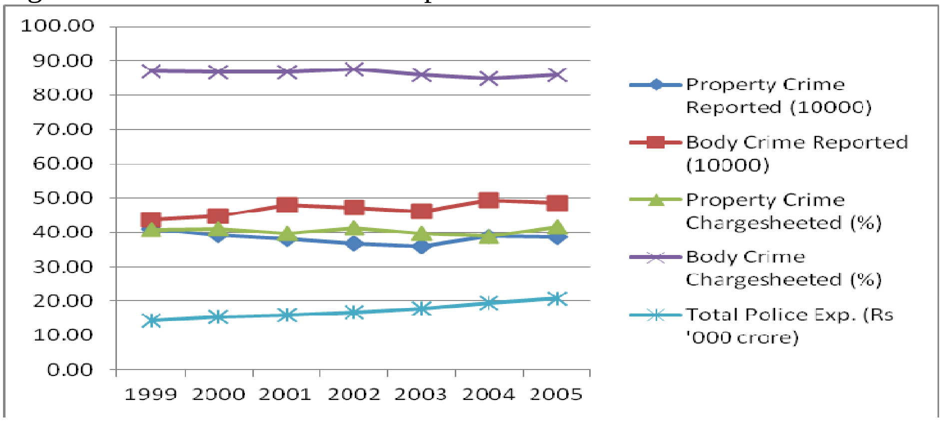


Figure 2: Trend in the Technical Efficeincy of Police in India

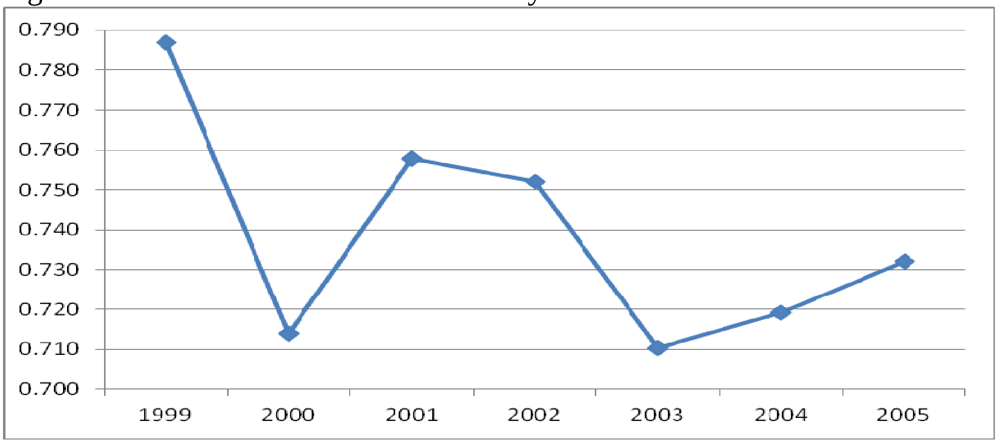


Figure 3: Average Technical Efficiency of the States Police in India

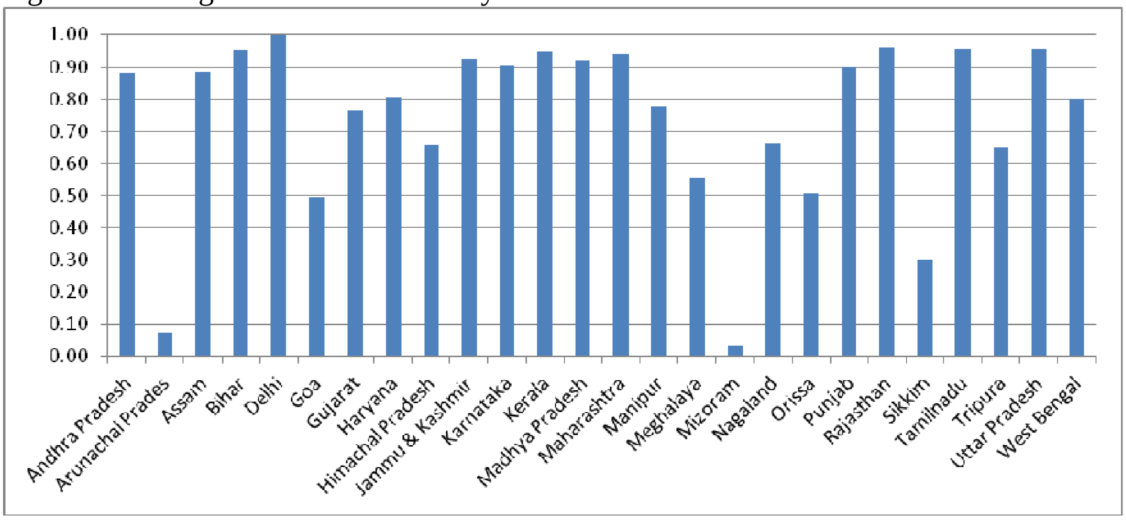
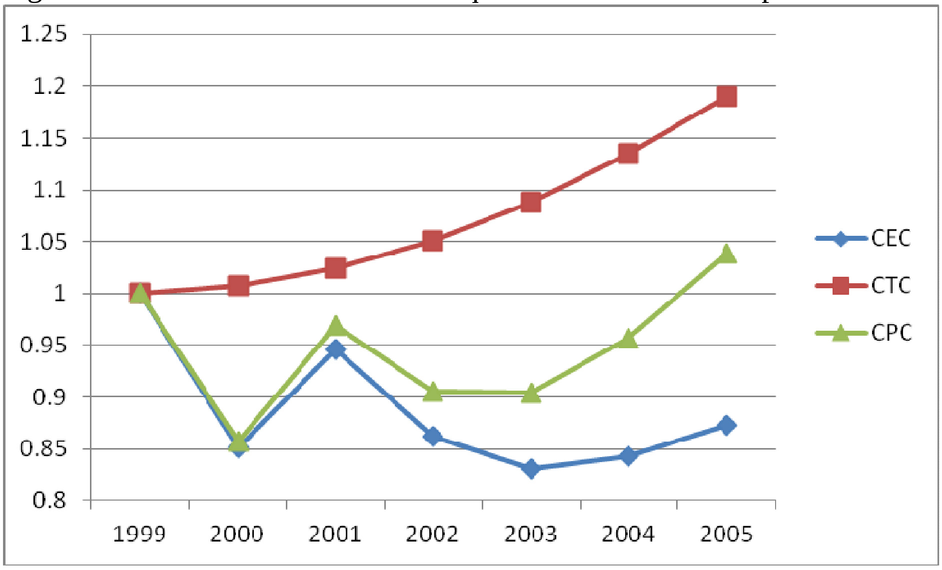
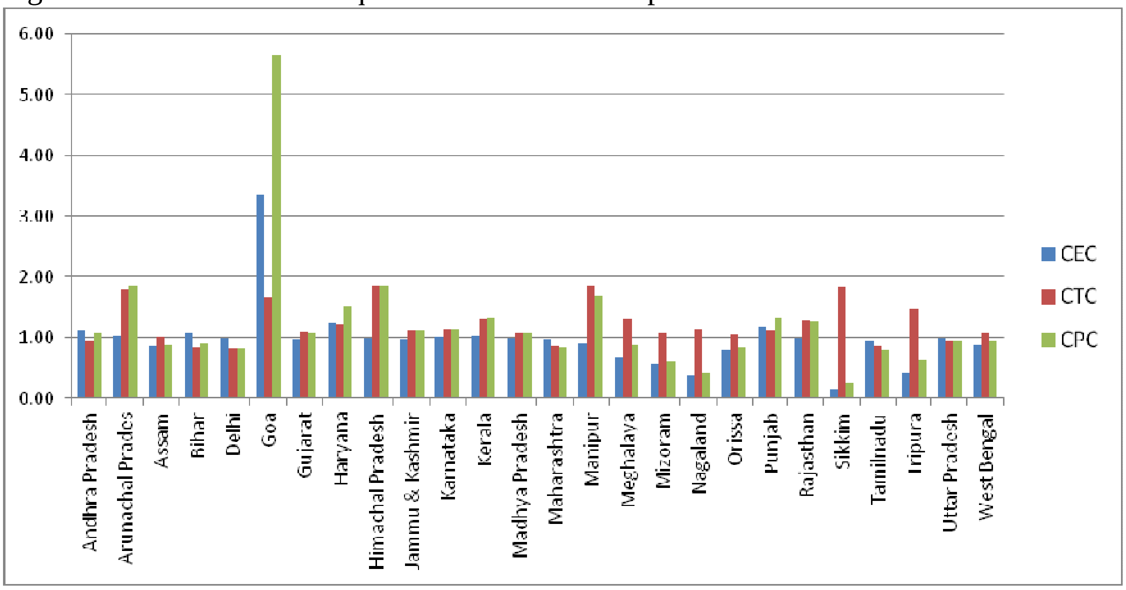


Figure 4: Trend in Cumulative Malmquist Index and its Components in India



Note: CEC: cumulative efficiency change, CTC: cumulative technical change, and CPC: cumulative productivity change

Figure 5: Cumulative Malmquist Index and its Compenents for States Police in India



Note: CEC: cumulative efficiency change, CTC: cumulative technical change, and CPC: cumulative productivity change