Does Firm Ownership Differentiate Environmental Compliance? Evidence from Indian Chromite Mining Industry

Das, Amarendra

Centre for Development Studies, Thiruvananthapuram, Kerala, India

15 August 2009

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Amarendra Das

Abstract

This paper compares the environmental performance of public and private firms in the context of Indian chromite mining industry. It proposes a new methodology to measure firms' environmental performance in a multidimensional framework. Comparison of unidimensional and multidimensional environmental defiance indices reveal no significant difference between the public and private firms.

Key words: Firm ownership, Multi Dimensional Environmental Compliance.

I

1. Introduction

Do private and public firms comply with environmental regulations differently? Both theoretical and empirical economic literature stand highly divided on this. Drawing on the basic tenets of public economics it is argued that private firms solely focus on the profit maximisation and do not heed to the environmental damages and other negative externalities (Baumol and Oates, 1988). Friedman (1970) argues that the sole objective of business is to maximise profit[1]. Consequently, private firms are believed to be the bad performers compared to the public firms whose basic objective is to maximise the social benefits. In contrast, it is asserted that publicly owned plants are quite likely to be older, less efficient and therefore more pollution-intensive than their private counterparts. We might expect lower pollution intensity for public plants operating under soft budget constraints because they do not confront the full cost of abatement. However, bureaucratic control may also shield state-owned facilities from local pressure. Empirical finding of Pargal and Wheeler (1996) reveal that public ownership is strongly associated with dirty production and hence the bureaucratic shielding effect seems to outweigh any leverage from soft budgets. Further they state that after controlling for the age and production efficiency, the residual effect of public ownership is not clear.

A major weakness of the existing studies is the measurement of environmental performance with single indicator and the enquiry of its association with firm ownership or economic performance. For example, Pargal and Wheeler focus only on water pollution and examine its association with age, productivity, ownership and local community characteristics. Such unidimensional measures might not reflect the true performance of a firm. A firm defying in one indicator might have fully complied in other indicators and spent enormous resources for this purpose. Examination of the association between unidimensional environmental performance and other parameters such as ownership, firm size and age of the firm, therefore might be misleading. It is imperative to measure the environmental performance of a firm in a multidimensional framework. Here, I propose a new methodology to measure the environmental performance in a multidimensional framework and demonstrate its application in the context of Indian chromite mining industry. Environmental compliance mining firms have been assessed on four indicators, namely: (i) Quality of mine drainage water, (ii) Overburden management, (iii) Suspended particulate matter (SPM) in ambient air and (iv) Hexavalent chromium [Cr(VI)] in drinking water.

Enquiry into the environmental performance of Indian chromite mining industry is motivated by two reasons: i) Mining industry cause enormous environmental pollution. So much so that the

[1] 'There is one and only one social responsibility of business–to use it resources and engage in activities designed to increase its profits so long as it stays within the rules of the game, which is to say engages in open and free competition without deception or fraud' (Friedman, 1970)

sole region producing chromite in India, Sukinda, remained under much controversy for it was ranked by the Blaksmith Institute of the USA as world's fourth most polluted region in year 2007. In response to the uproar in media and public discourse State Pollution Control Board (SPCB) of Orissa came up with a report refuting the allegation of Blacksmith Institute. SPCB argued that the data source and methodology adopted by the Blacksmith institute are unreliable. The SPCB assessed the performance of chromite mining firms on four indicators namely: Overburden management, quality of mine drainage water, air pollution, and CVI in different water sources. The performance of each firm varied in different indicators. Therefore, it is hard to conclude that a firm fully complying in one indicator would perform uniformly in all the indicators. Comparison of overall environmental performance of mining firms thus needs a single but multidimensional measure. ii) Opening up of the mining industry for private participation (both domestic and foreign) further creates an apprehension that it will aggravate the environmental damage. In this context this paper seeks to provide a better methodology to compare the overall environmental performance of pollution generating firms and provide the empirical findings in the context of Indian chromite mining industry.

The rest of the paper is organised as follows. Section II reviews the literature on firm ownership and environmental compliance. Section III provides the theoretical framework for explaining the differential environmental performance of public and private firms. Section IV explains the methodology and data used for analysis. Section V provides the results and section VI concludes.

II

2. Review of Literature

The relationship between firm ownership and environmental compliance remains highly contested. It is argued that private firms stress more on maximising their private benefits and ignore the social cost owed to environmental degradation. On the other hand, realising the social responsibility, public firms act judiciously to mitigate the environmental damages. However, this has been highly suspected while probing the association between technical efficiency and environmental performance. It has been pointed out that technically efficient firms perform better in environmental dimension. This section does a survey of economic literature to highlight the factors that influence the environmental performance of pollution generating firms.

Production Efficiency

A number of studies have attempted to explain the environmental effects of production inefficiencies (Pearce et al., 1990; O'Connor, 1991; Warhurst, 1999; Loayza, 1999). These studies point out that low investment capacity constrains the firms to accumulate non-resource capital, develop organisational capabilities and skilled human resources. Loayza (1999) argues that a mining firm's dynamic efficiency significantly affects its internalization of environmental costs. Dynamic efficiency – a firm's ability to innovate and gain economies of scale – is not only a significant influence on its ability to compete but also a principal determinant of its environmental performance. Increased competitiveness encourages investment in technological capability and production capacity, and this in turn reduces pollution per unit of output, whereas decreased competitiveness increases pollution per unit of output. Warhurst (1999) points out that the firms that pollute the most are mismanaging the environment precisely because of their inability to innovate. Environmental degradation is greatest in operations with low levels of productivity, obsolete technology, limited capital, and poor human-resource management. The most efficient firms are generally better environmental managers because they are innovators. They are able to harness both technological and organizational change to reduce the production and environmental costs of their operations. Furthermore, where the costs of complying with environmental regulations threaten competitiveness, the dynamic firm can offset these costs by improving production efficiency. In the minerals industry, regulatory costs cannot be passed on to consumers because international metal prices are determined in terminal auction markets and cannot be controlled by the producers. The policy of requiring firms to reduce pollution at source, which necessarily involves changing their production technology and organization, overlooks the possibility that firms might already be searching for new ways to improve metal recovery, reagent use, energy efficiency, water conservation, and so on as part of their corporate strategies to increase competitiveness.

O'Connor (1991) points out that in the mining industry, low educational and skill levels of workers can negatively affect productivity and the maintenance of equipment. This reduces profit and constrains a company's capacity to invest. As a result, companies are unable to renew capital equipment or acquire state-of-the-art equipment that pollutes less per unit of output. Similarly, a principal characteristic of the many artisanal mining operations that prevail in developing countries is their under-exploitation of ore deposits and overexploitation of the environment's capacity to receive waste. This situation is a result of high rates of time preference and a shortage of capital and technical knowledge.

Hilson (2000) highlights three constraints faced by the polluting firms to adopt clean production technology (CPT). (i) *Economic Barrier*: Even though there are highly efficient waste minimization technologies available on the market lack of available funds prevents widespread adoption of these in the mining industry. (ii) *Technological Barrier*: In many instances, structural barriers exist that prevent the adoption of cleaner technologies and strategies. Some of the pollution control systems at sites represent billion dollar investments, and the people employed have skills and knowledge specific to the system. Changes to conventional technologies could make workers and managers obsolete, and would require investment by companies in training programs, an added difficulty for a firm with a limited budget. In many parts of the world, another major technological barrier preventing the adoption of cleaner technology in mining operations is the lack of available systems. A significant portion of global mineral production originates from grassroots operations, which lack the appropriate technologies to avoid environmental problems. (iii) *Legislative Barrier*: In most of the developed nations environmental legislation is amended so often that systems that are recognized as being effective pollution prevention apparatuses one year could very well be obsolete in the years to follow.

Firm Size

Does firm size matter over the environmental performance? Empirical findings reveal that due to capital and technological constraints small and medium size firms fail to comply with the environmental norms. McMahon et al. (1999) in a study of artisanal, small and medium in Bolivia, Chile and Peru point out that on average although artisanal and small mine sector (ASM) is significantly dirtier per unit of output than other types of mining, this is not always the case. Contrary to common believe that the internalization of environmental cost into their production cost might make the ASM's operation of unviable, the study points out that ASM is often economically viable, even when environmental costs are taken into consideration, suggesting that many of the solutions lie in the areas of environmental and economic policy. On the comparison of environmental performance of medium and large scale mines environmental performance the study does not find any clear distinction between medium and large mines as important as the distinction between old and new mines. In Chile, although the state owned company, Empresa Nacional de Mineria (ENAMI), is entrusted with smelting all of the output of small and medium producers its smelters are heavy polluters and there have been a number of lawsuits against them. It implies that ownership does not make any significant difference to the environmental compliance. MacMahon et al, (2000) in the context of mining in Indonesia demonstrate that the environmental performance of medium-scale mines is considered to be poor to very poor. Artisanal and small-scale mining (ASM) in Indonesia is undertaken with little or no environmental care. Large scale mines in Indonesia seemed to be using the state of the art technologies and practices and had relatively limited impact on the environment in Indonesia. Most of the large scale mines had shown an improvement in the environmental performance.

Chakravorty (2001) points out that Small-Scale Mines in India, particularly the very small ones, normally do not bother about eco-friendly operations. They not only destroy inadvertently (and at times deliberately for extra income) the vegetation and the trees, particularly at and near the area of mining operation, but they also do not take any step to regenerate environmental status or create greeneries. Ghose, (2003) points out that approximately 90% of India's mines are operating on a small-scale basis. Of them only a few operation are semi-mechanized, whereas others are predominantly manual. Improper exploration techniques, lack of planning and low-to-intermediate technology results in the poor recovery of mineable deposits. Environmental protection in these mines is seldom more than rudimentary.

Public Vs. Private

Private firms may have higher level of production efficiency hence it may cause less pollution with the same resources. Therefore, better environmental quality could be achieved with greater private sector participation (Kikeri et. al., 1992; Schmid and Rubin, 1995). Although private firms may have higher efficiency in resource utilisation, they may not seek to internalise environmental cost (Baumol and Oates, 1988). In other words, the private sector may compromise the environment to avoid the potential cost of environmental investments and expenditures. However, public firms would seek to internalise the environmental costs for their objective is to maximise social welfare. Environmental performance would also vary a great deal owing to different level of 'Environmental Bargaining Power' of firms. Wang and Jin (2002) define Environmental bargaining power as 'an enterpriser's capacity to negotiate with the local or national environmental agencies pertaining to the enforcement of pollution control regulations such as pollution charges, fines, etc'. The managers of public firms and private firms will have different bargaining strength with the pollution control authorities. It would result in differentiated environmental performance (ibid). Similarly, firms with different ownership may receive different levels of informal regulations, or community pressure on pollution abatement. The effect of the community pressure on emissions has been confirmed in several empirical studies (Pargal and Wheeler, 1996; Wang, 2000). They find that proxies for direct community pressures (community income and education levels) have significant effects on plant level emissions. But whether a community takes environmental action or at what level the informal regulation and community pressure are effective to pollution control, possibly depend on the impacts of a certain enterprise on the regional economy. There is an inherent trade-off by local residents in choosing an optimal pressure level to impose on a certain enterprise taking into consideration the potential economic benefits from their job opportunities, income expectations, and the environmental and social costs of production externalities.

In a cross country study Talukdar and Meisner (2001) point out that higher the degree of private sector participation in a developing economy, the lower is its environmental degradation. Moreover, they have argued that through increased participation of developed economies in its private sector development environmental degradation can be reduced further. Nunez-Barriga and Castaneda-Hurtado (1999) in the context of Peru point out that environmental behaviour is unrelated to ownership structure (that is, foreign, state, or domestic private) or the size (that is, large or medium) of firms. However, longevity of production capacities has significant bearing on the same.

In sum, the literature on firm ownership and environmental performance lacks consensus on any singular relationship and remains an empirical issue. Next section explicates the theoretical framework of the study.

III

3. Theoretical Framework

Each firm attempts to minimise its total cost subject to an output target (constraint). Total cost of a firm has three components: (i) input cost, including the expenditure on pollution abatement; (ii) penalty paid to the regulatory authorities and (iii) social cost accrued due to pollution. Private firms, however, account for only first two cost components and treat the third component as zero. On the other hand, public firms are presumed to account for the social cost. The decision of a firm to abate environmental damage is analysed with a simple optimisation model in Wang and Jin (2002). Keeping in view these three costs of production the differential environmental performance of public and private firms would emanate from three channels. ***i) Regulation Effect***: If only government environmental regulations are considered, the environmental performance of private firms would be better than that of the public firms. The primary reason being the bargaining powers with government authorities are the strongest for public firms and weakest for private firms. However, rent seeking activities by private firms would reverse the scenario. Managers of public firms are left with little scope for bribing the regulatory agencies and get rid of the punitive actions. Managers of private firms however could bribe the regulatory agencies to escape from the paws of regulatory agencies. In such a context, private firms would be more polluting than their public counterparts. ***ii) Internalisation Effect:*** Assume the strength of environmental regulation is the same for all companies, and the only difference in the marginal prices inputs are caused by the internalisation of the pollution externality. For private firms do not pay heed to the environmental cost they would use more pollution generating inputs as compared to the State owned firms due to the latter's social responsibility. Therefore, public firms would be the best performer, while private firms would be the worst performers. ***iii) Efficiency Effects:*** Similarly, production efficiency would also cause immense difference in environmental performance. For an input x positively contributing to pollution discharge, a higher efficiency means a lower marginal discharge of such an input. For an input negatively contributing to pollution discharge, higher efficiency means a higher marginal pollution reduction. Therefore, higher efficiency means less pollution generation and a higher pollution reduction, and finally better environmental performance. If private have higher efficiencies than public firms, the environmental performance of former would be the better than the latter.

The overall environmental performance of a firm will be the sum of three effects discussed above. Therefore, it is difficult to predict theoretically and remains an empirical issue.

IV

4. Methodology and Data

4.1 Methodology

For comparing the environmental performances of public and private firms the study focuses on the Indian Chromite mining Industry[2]. First, a comparison is made, separately, on four indicators namely i) quality of mine drainage water, ii) management of overburden, iii) ambient air quality and iv) quality of drinking water. In the second step an aggregate environmental performance measure named Multidimensional Environmental Defiance Index (MEDI) has been constructed and in the end comparison is made between the environmental performance of public and private firms through permutation test. Before venturing into the comparison of environmental performance of public and private firms I explain the MEDI in details and its computation process.

Most of the studies compare the environmental performance of firms in one indicator or other – such as pollution of air, water, noise. Unidimensional measures of this nature, however, might not be able to reveal the overall environmental performance of a firm for two reasons. Firstly, a firm might be polluting through more than one channels. Secondly, the intensity of pollution might be different in different indicators. For example, a firm might have fully complied in controlling air pollution (keeping the emission within permissible limit) but have failed in checking water pollution or noise pollution. The intensity of defiance (excess from the permissible limit) might also be different in these two indicators. In such a context, unidimensional measures of environmental performance would not reflect the true picture. Therefore, we need an aggregate measure which can reflect upon the performance in each indicator and more importantly the measure should satisfy the property of monotonicity with respect to dimensions and degree of defiance. For practical purposes such a measure assumes enormous significance. For example, while imposing penalty on a polluting firm it is crucial to measure the dimensional failures and degree of defiance. Use of unidimensional measures would leave the firm with either nill or full penalty. In this context a new measure called *Multidimensional Environmental Defiance Index* (MEDI), is proposed[3], which satisfies the property of monotonicity with respect to the dimensions and intensity of defiance.

In a very simplistic framework the multidimensional environmental performance can be measured by aggregating all the indicators. For the indicators would be in different units, we need to normalise them by converting into indices. Next we compute the average of all the indices and arrive at a single indicator for the overall environmental performance of firms. However, this simple averaging of indices suffers from several limitations. From a regulator's perspective it is crucial to oversee whether a firm has complied with the environmental standard or not. If not, to what extent has it exceeded from the permissible limit. In order to target the polluting firms it is therefore more important to identify the defying firms and measure their

[2] Chromite mining is one of the most polluting industries. For more discussion on the environmental effects of chromite mining see Appendix-A2. Also see Appendix –A1 for a brief description on the Regulatory Framework in India for Environmental Protection in Mining Areas.

[3] For a multidimensional index in poverty literature see Alkire and Foster (2008)

degree of defiance than measuring the degree of compliance of complied firms[4]. The simple indices (e.g. Indices of Human Development Index class) however, fail to perform on this line. In the process of simple averaging, the extra level of achievements gets automatically compensated for the extra level of defiance. Although the merits of extra level of achievements in compliance cannot be undermined, it would be unwise to compensate it for the extra level of defiance. This can be justified with the fact that firms' extra level of achievement within the permissible limit does not make much difference. Instead, if a firm exceeds the permissible limit it causes serious environmental and health damages. With increasing level of defiance, therefore level of damage goes up. Moreover, extra level of compliance in one indicator cannot compensate for the violation in other indicator. For example, a firm might have kept the level of Suspended Particulate Matter (SPM) in air by ten points below the permissible limit, but have exceeded by ten points in controlling the level of hexavalent chromium in drinking water. Here it would be irrational to say that ten points extra achievements in controlling air compensates for the ten point extra defiance in controlling hexavalent chromium in drinking water. Therefore, while measuring the environmental performance of pollution generating firms, first firms should be classified into compliant and defiant and next their degree of defiance should be gauged. In the following section I explain the method in details.

Measurement of multidimensional environmental defiance is carried out in two stages. First stage involves 'identification', which is done through setting the criteria for distinguishing the defying firms from the complying firms. Second stage involves 'aggregation' where we combine the firms' performance in different indicators. In identification exercise we take the permissible limit set by the pollution control board as first cutoff following which we categorise all firms into compliant (keep emission below permissible limit) and defiant firms (emission exceeds the permissible limit) in each indicator. However, to arrive at a single indicator, or conclude whether a firm is defiant or compliant we have to set a dimensional cutoff. For this purpose, we count the number of indicators a firm has failed to reach the standard. Then depending upon the dimensional cutoff we can categorise them into compliant and defiant. In a strict regulatory environment a firm will be considered to be a defiant it defies at least in one indicator and in a full liberal regime if it violates in all the indicators. However, we can set the cutoff in between these two polar extremes. After identifying the defiant firms we measure their degree of violation. In second stage i.e. 'aggregation' we bring dimensional failures and degree of defiance in a single indicator to measure the overall defiance.

Terminology, Notations and Settings:

Before proceeding further, let us familiarise with the terminologies and notations that will be used for computing MEDI.

[4] This is called as focus axiom.

Let N represent the number of firms in the industry and $d \geq 2$ be the number of (environmental) indicators/dimensions under consideration. Let $a = [a_{ij}]$ denote the $n \times d$ matrix of achievements where the typical entry $a_{ij}$is the achievement of firm $i = 1,2..,n$ in dimension $j = 1,2,\ldots,d$. Each row vector a_i lists firm i's achievement, while each column vector a_j gives the distribution of dimension j achievements across the set of firms. Let $l_j$denote the cutoff/permissible level above which a firm is considered to be defiant in dimension j and let l be the row vector of dimension specific cutoffs.

Following Bourguignon and Chakravarty (2003) the identification method is defined by using an identification function $\rho(a_i; l)$, of the individual achievement vector a_i and the cutoff vector l that takes two values: $\rho(a_i; l) = 1$ to indicate that firm 'i'is defiant and $\rho(a_i; l) = 0$ to indicate that firm is not. Applying ρ to each firm's achievement vector in 'a' yields the set $L \subseteq \{1, \ldots n\}$ of firms who have defied in 'a' given the 'l'.

In order to define this methodology, it will be useful to express the data in terms of defiance rather than achievements. For any given a, let $g^0 = [g^0_{ij}]$ denote the 0-1 matrix of defiances associated with a, whose typical element g^0_{ij} is defined by $g^0_{ij} = 1$ when $a_{ij} > l_j$, while $g^0_{ij} = 0$ otherwise. Clearly, g^0 is an $n \times d$ matrix whose ij^{th} entry is 1 when firm i defies in the j^{th} dimension, and 0 when the firm does not. The i^{th} row vector of g^0, denoted g^0_i, is firm i's defiance vector. From the matrix g^0 we can construct a column vector 'c' of *defiance counts,* whose i^{th} entry $c_i = |g^0_i|$ represents the number of defiances by the firm i. The vector c will be especially helpful in describing our method of identification. It is noteworthy that even when the variables in 'a' are only ordinally significant, g^0 and c are still well defined.

If the variables in 'a' are cardinal, the associated matrix of (normalised) excesses can provide additional information for environmental defiance measurement. For any 'a', let g^1 be the matrix of normalised excesses, where the typical element is defined by $g^1_{ij} = \frac{a_{ij} - a_{min}}{a_{max} - a_{min}}$ whenever $a_{ij} > l_j$, while $g^1_{ij} = 0$ otherwise. Clearly, g^1 is an $n \times d$ matrix whose entries are nonnegative numbers less than or equal to 1, with g^1_{ij} being a measure of the extent to which that firm i has defied in dimension j.

Identifying the Defiant Firms

Who is a defiant firm? A reasonable starting point for the identification would be to compare the performance of each firm in each indicator against the permissible limit. However, dimension specific cutoffs do not suffice to identify who is defiant; we must consider additional criteria that look across the dimensions as well as to derive at a complete specification of identification method.

One simple method is to aggregate all achievements into one single cardinal variable and use an aggregate cutoff to determine who is defiant. However, this form of identification involves a host of simplifying assumptions and restricts its applicability in practice and its desirability in principle[5]. Another major drawback of viewing multidimensional defiance through a unidimensional lens is the loss of information on dimension specific violations (excesses). If dimensions are independently valuable and necessary and accordingly individual excesses are inherently undesirable then there are good reasons to look beyond unidimensional approach.

A commonplace measure of this nature is called *union method* of identification. In this approach a firm 'i' is said to be multidimensionally defiant if at least in one dimension the firm has defied (i.e. $\rho(a_i; l) = 1$ if and only if $c_i \geq 1$). If compliance in every indicator were truly essential to be considered as fully complied firm, this approach would be quite intuitive and straightforward to apply. However, a union based environmental defiance measurement may not be effective for distinguishing and targeting the most polluting firms, especially when the number of dimensions is large.

A second identification approach is the *intersection* method, which identifies firm i as being defiant only if the firm flouts in all dimensions. (i.e., $\rho(a_i; l) = 1$ if and only if $c_i = d$). This criterion would accurately identify the defiant firms if compliance in any single indicator were enough to prevent it from being red listed; indeed, it successfully identifies the defiant firms as a group of most polluting firms. However, it misses many firms who defy in a few indicators but not all. Thus, it detects only a few firms that even shrinks further as the number of dimensions increases – and disregards the rest.

A natural alternative is to use an intermediate cutoff for c_i that lies somewhere between the two extremes of 1 and *d*. For $k = 1, \dots, d$, let$\rho_k$be the identification method defined by $\rho_k(a_i; l) = 1$ whenever $c_i \geq k$ and $\rho_k(a_i; l) = 0$ whenever $c_i < k$. In other words, $\rho_k$identifies firm i as defiant when the number of dimensions in which i has flouted in at least k; otherwise, if the number of defiance dimensions falls below the cutoff k, then i is not defiant according to ρ_k. Since ρ_k is dependent on both the *within dimension* cutoffs l_j and the *across dimension* cutoff k, we will refer to ρ_k as the *dual cutoff* method of identification. It is noteworthy that $\rho_k$includes the union and intersection methods as special cases where $k = 1$ and $k = d$.

In the next section we'll introduce the multidimensional environmental defiance index (MEDI) measures that use the ρ_k identification method and its associated set $L_k = \{i: \rho_k(a_i; l) = 1\}$ of defiant firms. Accordingly, we shall make use of some additional notation that censors the data of non-defiant firms. Let $g^0(k)$ be the matrix obtained from g^0 by replacing the i^{th} column with

[5] Aggregating across dimensions for the purpose of identification entails strong assumptions regarding cardinality, which are impractical when data are ordinal (Sen, 1997)

a vector of zeros whenever $\rho_k(\ a_i; l) = 0,$ and define $g^{\propto}(k)$ analogously for $\propto > 0$. The typical entry of $g^{\propto}(k)$ is thus given by $g_{ij}^{\propto}(k) = \ g_{ij}^{\propto}$ for i satisfying $c_i\ \geq k$, while $g_{ij}^{\propto} = 0$ for i with $c_i < k$. As the cutoff k rises from 1 to d, the number of non-zero entries in the associated matrix $g^k(k)$falls, reflecting the progressive censoring of data from firms those are not meeting the dimensional defiance requirement presented by ρ_k. It is clear that the union specification $k = 1$ does not alter the original matrix at all; consequently, $g^{\propto}(1) = \ g^{\propto}$. The intersection specification $k = d$ removes the data of any firms who has not defied in all d dimensions; in other words, when the matrix $g^{\propto}(d)$ is used, a firm defied in just a single dimension is indistinguishable from a firm deprived in $d-1$ dimensions. When $k = 2, \ldots, d-1$ the dual cutoff approach provides an intermediate option between the union and intersection methods as reflected in the matrix $g^{\propto}(k)$.

Measuring Defiance

Categorisation of firms into defiant(1) and compliant(0) however does not reflect the breadth (failure in number of indicators) and intensity of defiance (excess from the permissible limit). If a defiant firm flouts in an indicator in which it had previously not defied, the categorisation remains unchanged. This violates the property of 'dimensional monotonicity'. In an ideal case if a defiant firm i defies in an additional dimension, then overall non-compliance measure should rise.

In order to incorporate this aspect, we have to include the breadth of defiance committed by firms. Let $c(k)$ be the censored vector of defiance counts defined as follows: If $c_i(k) \geq \ c_i$, then $c_i(k) = \ c_i$, or firm i's defiance count; if $c_i\ < k$, then $c_i(k) = 0$. The share of possible defiance committed by a firm i , S_i, is $c_i(k)/d$. This partial index conveys relevant information about multidimensional defiance, namely, the fraction of possible dimensions d in which the firm defies. Thus, the multidimensional defiance ratio, which combines information on the prevalence of defiance and breadth of defiance, can be defined as follows:

Definition: The Multidimensional defiance ratio is defined by $S_i = c_i(k)/d$.

In simple words, the *Multidimensional defiance ratio* is the total number of indicators in which the firm has exceeded the permissible limit, or $|c(k)| = |g^0(k)|$, divided by the maximum number of defiance that could possibly be committed by the firm, or d. The value of $S_i$ranges from 0 to 1. This measure satisfies the dimensional monotonicity, since if a firm defies in an additional dimension, then values of S_i rises.

The *Multidimensional defiance ratio* however, does not reveal the dimension specific information on the intensity of defiance. Consequently, it will not satisfy the traditional monotonicity requirement that violation should increase as a firm exceeds off the permissible limit in any given dimension. Hence we need an alternative measure. The censored matrix is defined as $g^1(k)$ by $g^1_{ij}(k) = 0$ if $c_i < k$ and $g^1_{ij}(k) = g^1_{ij}$ if $c_i \geq k$, so that $g^1(k)$ only includes the defiance of firms. Let 'G' be the *excess of defiance* across all instances in which firms have defied given by $G = |g^1(k)|/|g^0(k)|$. Thus, the multidimensional defiance measure $M_1(a; l)$which combines information on the prevalence of defiance, breadth of defiance and the intensity of defiance, can be noted as follows:

Definition: The Multidimensional Environmental Defiance Index M_1 is defined by $M_1 = SG$.

The Multidimensional Environmental Defiance Index (MEDI) is thus the product of *Multidimensional defiance ratio 'S_i'* and the excess of defiance 'G' and its values range between 0 and 1. If a firm defies in excess in any dimension, then the respective $g^1_{ij}(k)$will rise and hence will M_1.

Ordinal and Cardinal Data

The merit of this multidimensional environmental defiance index is that it allows us to use both cardinal and ordinal data together. The mixed case poses no problems for the dual cutoff identification method $\rho_k$nor for the multidimensional defiance ratio S_i, which dichotomises all variables before aggregating. However, for M_1, a tension arises across dimensions: they cannot be applied to ordinal dimensions and yet dichotomisation of cardinal dimensions loses valuable information. In such situations, there may be grounds for creating a hybrid defiance matrix in which entries are normalised excesses for the cardinal dimensions and 0-1 defiances for the rest. The monotonic M_1 measure can then be computed from this matrix to obtain measures that reflect the intensity of defiance in each cardinal dimensions, but follow the ordinal measurement restriction for the remaining dimension. Even in case of ordinal variables with more than two rankings we can still compute the normalised excess where values lie between 0 and 1and we can incorporate this into the M_1 computation excercise. This process may seem to increase the effective weight on ordinal dimensions since all defiant firms will appear to have the most severe degree of defiance possible. As a correction, differential weights across dimensions could be assigned.

4.2 Data

For examining the relationship between firm ownership and environmental performance the study focuses on the chromites mines in Orissa, a state located in the eastern part of India[6]. Data

[6] Orissa accounts for about 98% of the total proved chromite (chromium ore) reserves of the country, of which about 97% occur in Sukinda Valley, over an area covering approximately 200 sq. km., in the Jajpur district.

pertaining to annual production of chromite, year of commencement of the mine, and environmental compliance on four environmental indicators have been gathered from the State Pollution Control Board, (SPCB) Bhubaneswar, Orissa. The four environmental indicators on which data are collected are: (i) quality of mine drainage water which shows the content of Cr.(VI), in milligram per litre, in the water drained out from the Effluent Treatment Plant (ETP) outlet,(collected between 2005 and 2007 at various points of time for different firms) (ii) management of overburden by the mining firms, (iii) Ambient air quality in Industrial areas (April 2004 to April 2005) which measures the level of Suspended Particulate Matter (SPM) in micrograms/cubic meter and (iv) quality of drinking water which shows the concentration of Cr(VI) in drinking water found in the nearby bore-wells during the period from April 2004 to April, 2005). Management of overburden by firms are classified into three categories: satisfactory, partial and poor with ranks one two and three. For other three indicators, maximum values of pollutive content have been taken from the sample.

V

5. Results

In this section results are presented in two parts. In first part, performance of public and private firms is compared on the basis of single indicators. In the second part, comparison is made on the basis of multidimensional environmental defiance index.

5.1 Unidimensional Environmental Performance

Table – 1 Environmental Performance of Chromites Mining Firms in Orissa

Firm Code	Owner	Drainage water	OBM	Air Quality	Drinking Water
1	Private	0.22	2	289	0.006
2	Private	1.025	3	171	0.022
3	Public	0.69	2	247	0.025
4	Private	0.444	3	260	0.004
5	Private	1.02	2	280	0.033
6	Private	0.119	1	272	0.035
7	Public	0.2	3	316	0.001
8	Public	0.108	1	208	0.004
9	Public	0.444	2	161	0.028
10	Private	0.169	1	600	0.04
Permissible Limits		0.100		500	0.05

Notes:

1. Quality of drainage water is measured in micrograms of Cr(VI) in a litre of water flowing out after treatment.
2. Overburden management (OBM) has been categorised

into 1=Satisfactory, 2=Partial, 3= Poor
3. Air quality has been measured in SPM counts in cubic meter of air.
4. Quality of drinking water is measured in micrograms of Cr(VI) in a litre of water.
5. Values exceeding the permissible limit are considered to be harmful.

Table-1 presents the Environmental performance of 10 chromites mining firms in four indicators namely quality of drainage water, management of overburden, air quality in industrial area and quality of drinking water in mining areas. In case of treatment of drainage water which is polluted with Cr(VI), all mining firms have exceeded the permissible limit. In overburden management only three firms show satisfactory performance, while four firms show partial and rest three poor performances. Most of the mining firms, except one, have been successful in controlling the air pollution by keeping the SPM counts within permissible limit. Similarly, all firms have succeeded in checking ground water pollution. Samples of drinking water from nearby bore-well shows that Cr(VI) has remained within permissible limit.

On the basis of firms' performance in each indicator and respective permissible limits all firms have been categorised into compliant and defiant. In the indicator overburden management firms showing satisfactory performance have been categorised as compliant and rest as defiant. (See Table-2). Last column in Table-3 presents the number of indicators the firm has defied in. Comparison of public and private firms in each indicator does not show any significant difference between the two groups. Similarly, comparison of defiance counts does not demonstrate any divide between the two groups. For a pictorial comparison between public and private firms in each indicator see Figure-1, 2, 3 and 4 in Appendix-A.3. Simple classification of firms into compliant and defiant firms, however, does not reflect the intensity of defiance. Therefore, in the second part I present the results of MEDI, which is monotonic in dimension and degree, to compare the performance of public and private firms.

Table–2 Identification of Defiant Mining Firms

Firm Code	Owner	Drainage water	OBM	Air Quality	Drinking water	Defiance Counts
1	Private	1	1	0	0	2
2	Private	1	1	0	0	2
3	Public	1	1	0	0	2
4	Private	1	1	0	0	2
5	Private	1	1	0	0	2
6	Private	1	0	0	0	1
7	Public	1	1	0	0	2
8	Public	1	0	0	0	1
9	Public	1	1	0	0	2
10	Private	1	0	1	0	2

Note:1 = Defiant, 0= Compliant

5.2 Multidimensional Environmental Performance

In this section, at the very outset, all mining firms have been categorised into compliant and defiant by following the dual-cutoff approach. Three measures in Table-3 namely S1, S2 and S3 categorise the firms into defiant if it exceeds the permissible limit at least in one, two and three indicators respectively. The last column computes the multidimensional defiance ratio (defiance count divided by total number of dimensions) of all firms. Comparison of performance between public and private firms from these indicators does not show any significant difference. However, till now we have only categorised the firms into complaint and defiant without measuring their degree of defiance. This has been addressed in the MEDI. The values of MEDI are presented in Table-4.

Table – 3 Identification of Defiant Firms on Dual-cutoff Criterion

Firm Code	Owner	S1	S2	S3	S_i
1	Private	1	1	0	0.50
2	Private	1	1	0	0.50
3	Public	1	1	0	0.50
4	Private	1	1	0	0.50
5	Private	1	1	0	0.50
6	Private	1	0	0	0.25
7	Public	1	1	0	0.50
8	Public	1	0	0	0.25
9	Public	1	1	0	0.50
10	Private	1	1	0	0.50

1 = Defiant, 0= Compliant

Table – 4: Multidimensional Environmental Defiance Index

CCode	Owner	M11	M12	M13
1	Private	0.078	0.078	0.0
2	Private	0.250	0.250	0.0
3	Public	0.142	0.142	0.0
4	Private	0.171	0.171	0.0
5	Private	0.187	0.187	0.0
6	Private	0.001	0.000	0.0
7	Public	0.138	0.138	0.0
8	Public	0.000	0.000	0.0
9	Public	0.108	0.108	0.0
10	Private	0.133	0.133	0.0

As mentioned earlier, MEDI is monotonic with respect to dimensions and degree of defiance. A firm flouting in more indicators and far off the permissible limit will score higher values in the index. As earlier indices, M11, M12 and M13 present the MEDI values with the cutoff of one, two and three dimensions respectively. The difference between three measures of MEDI on the basis of different cutoffs -M11, M12 and M13- is clearly witnessed from Table-4. With the rise in the number of dimensions in dual cutoff approach number of defiant firms declines. It is witnessed when we compare between M11and M12. As per M11, all firms are considered to be defiant whereas only eight firms are categorised as defiant as per M12. More interestingly, not a single firm is considered to be defiant firm as per M13.

Comparison of environmental performance of private and public firms from the MEDI values also does not show any significant difference. Out of ten chromite mining firms, six are private and four are public. As per M11 all public and private firms are defiant firms and the mean MEDI value for private firms is 0.136 whereas for public firms it is 0.097. For a pictorial comparison between public and private firms see Figure-5 in Appendix-A.3.

In order to test the statistical significance of difference between the mean MEDI values of public and private mining firm I use permutation test. A **permutation test** (also called a randomization test, re-randomization test, or an exact test) is a type of statistical significance test in which a reference distribution is obtained by calculating all possible values of the test statistic under rearrangements of the labels on the observed data points. To illustrate the basic idea of a permutation test, suppose we have two groups *A* and *B* whose sample means are $\bar{x}_A$and $\bar{x}_B$, and that we want to test, at 5% significance level, whether they come from the same distribution. Let n_A and n_B be the sample size corresponding to each group. The permutation test is designed to determine whether the observed difference between the sample means is large enough to reject the null hypothesis H_0 that the two groups have identical probability distribution.

The test proceeds as follows. First, the difference in means between the two samples is calculated: this is the observed value of the test statistic, T(obs). Then the observations of groups *A* and *B* are pooled. Next, the difference in sample means is calculated and recorded for every possible way of dividing these pooled values into two groups of size n_A and n_B (i.e., for every permutation of the group labels A and B). The set of these calculated differences is the exact distribution of possible differences under the null hypothesis that group label does not matter. The one-sided p-value of the test is calculated as the proportion of sampled permutations where the difference in means was greater than or equal to T(obs). The two-sided p-value of the test is calculated as the proportion of sampled permutations where the absolute difference was greater than or equal to T(obs)

Thus permutation test allows us to examine the statistical significance of the difference between two groups with small sample and without making any distributional assumption. It applies computing power to relax some of the conditions needed for traditional inference and to do inference in new settings. The big ideas of statistical inference remain the same.

For the present study permutation test with 100 repetitions shows that 29 of the 100 randomly permuted datasets yielded sums from the private group larger than or equal to the observed sum of 0.819 (see Table-5). Thus, the evidence is not strong enough, at the 5% level, to reject the null hypothesis that there is no difference between the mean MEDI values for public and private mining firms.

Table-5: Summary of MEDI Values for Public and Private Chromite Mining Firms

	Mean MEDI	N	SD
Public Firms	0.097	4	0.067
Private firms	0.136	6	0.088

Monte Carlo Permutation Results

Replications 100

	T(obs)	C	N	P=C/N	SE
Sum	0.819	29	100	0.290	0.045

Note: SD- Standard Deviation

Confidence interval is with respect to P=C/N.

C = #{|T| >= |T(obs)|}

VI

6. Conclusion

In fine, the paper probed into a highly debated question whether public and private firms comply with environmental regulations differently by undertaking an empirical exercise in the context of Indian chromite mining industry. It proposed a new methodology to measure environmental performance in a multidimensional framework. Merit of multidimensional measure over unidimensional measure for comparing the environmental performance of pollution generating firms is clearly revealed from the analysis. Comparison between the environmental performance of public and private mining firms in four indicators separately gives inconclusive results. However, MEDI, which is monotonic with respect to the dimensions and degree of violations, makes a better comparison for the same. From both unidimensional and multidimensional indicators the study fails to find any significant difference between the environmental performances of public and private mining firms.

Appendix

A1. Regulatory Framework in India for Environmental Protection in Mining Areas

For achieving sustainable development mining has to be done in a way that causes least damage to natural resources such as air, water, soil, and biomass. A slew of rules and regulation relating to the conservation of environment govern the mining activities. Those are: *Water (Prevention and Control of Pollution) Act, 1974*, Forest Conservation Act 1980, *Air (Prevention and Control of Pollution) Act 1981 and* Environment Protection Act 1986.

As per the Environmental Impact Assessment (EIA) Notification dated 27 January 1994 mining projects of major minerals of more than 5 hectares lease area require environmental clearance. After the Supreme Court judgment of 18th March 2004 [in the matter of Writ Petition (civil) 4677 of 1985 M. C. Mehta Vs. Union of India and Others] the said EIA notification was amended on 28 October 2004 to include all mining projects of more than 5 hectares that had until then not obtained environment clearance and they were required to obtain the same at the time of the renewal of the lease. Environmental clearance procedure has three components. First, an EIA study has to be submitted as part of the clearance procedure and there are special rules relating to the formulations and appraisal of the EIA. Second, a public hearing has to be conducted and the procedure for the same is laid down in detail. Third, an environmental management plan (EMP) has to be submitted and clearance for the same separately obtained. Under EIA, mining companies are expected to undertake a comprehensive assessment of the probable environmental impact accrue in the mining areas and it provides for ceasing mining operation in environmentally sensitive areas. In order to incorporate the views of local people on the mining projects the policy provides for holding public hearing in the mining regions. Environmental plans provide the strategy to be adopted by the mining companies in order to mitigate the environmental damage such as degradation of forest, air pollution, water pollution and noise pollution. Under this provision companies are supposed to undertake compensatory afforestation programme, check air pollution, water pollution, noise pollution in the mining regions by managing the overburden dumps and other wastes originating from mines.

A2. Environmental Impacts of Chromite Mining

Chromium is a metallic element with an atomic number of 24. It is a member of group VIB on the periodic table, along with molybdenum and tungsten. Chromium generally occurs in small quantities associated with other metals, particularly iron. The most common prevalence are +3 and +6. Chromium forms a number of salts, which are characterized by a variety of colours, solubilities and other properties. The name "chromium" is from the Greek word for colour. The most important chromium salts are sodium and potassium chromates and dichromates, and the potassium and ammonium chrome alums. The metal is usually produced by reducing the chromite ($FeCr_2O_4$) ore with aluminium. Chromium is used to harden steel, in the manufacture of stainless steel, and in the production of a number of industrially important alloys (Weast et al., 1988). Chromium is used in making of pigments, in leather tanning and for welding. Chromium plating produces a hard mirror-like surface on metal parts that resists corrosion and enhances appearance.

Cr(III), as found in chromite and other naturally occurring minerals, is an essential micro nutrient for maintenance of normal glucose metabolism. Chromium deficiency can lead to insulin circulation and cardiovascular problems. There are reports that even relatively large doses of Cr(III) do not induce any harmful effect, when fed in water or food to animals. The portion which is not absorbed in the gastrointestinal tract is excreted. It is believed that Cr(VI) is formed only by human activities, which is rapidly reduced to relatively harmless Cr(III) in acidic solutions ($pH < 4$) by organic matters or biomass. Cr(VI) beyond a certain concentration, is toxic, inducing such symptoms as skin ulcers, vomiting, diarrhoea, gastrointestinal bleeding leading to cardiovascular shock. It is cytotoxic, mutagenic and carcinogenic. For long, the chromite matrix was considered to be quite stable in the Cr(III) state. However, recent studies reveal that Cr(III) lodged in the chromite, can get oxidised to toxic Cr(VI), though various physico-chemical and biological processes. Chromite mineral can occur either in the lumpy or friable form. It has been observed that generally Cr(VI) problem is associated with the mining of the friable mineral

Presence of Cr(VI) in mine drainage water:

Opencast chromite mining generate huge volumes of seepage water. Even though chromium in chromite is in the trivalent state, some hexavalent Cr(VI) is always formed due to certain complex reactions. If Cr(VI) containing mine drainage water is released untreated, can severely contaminate the nearby water bodies. Many mines have chrome ore beneficiation (COB) plants, where chromium content in the ore is concentrated through washing and sorting. Washings from the COB plants can also be a source of Cr(VI).

Overburden generation:

Opencast chromite mining generates enormous quantities of overburden (OB). The stripping ratio varies from 1:5 to 1:10. Unless managed properly, run offs from the OB dumps have the dual potential of polluting the water bodies by siltation and leaching of Cr(VI).

Appendix-A.3

Figure-1

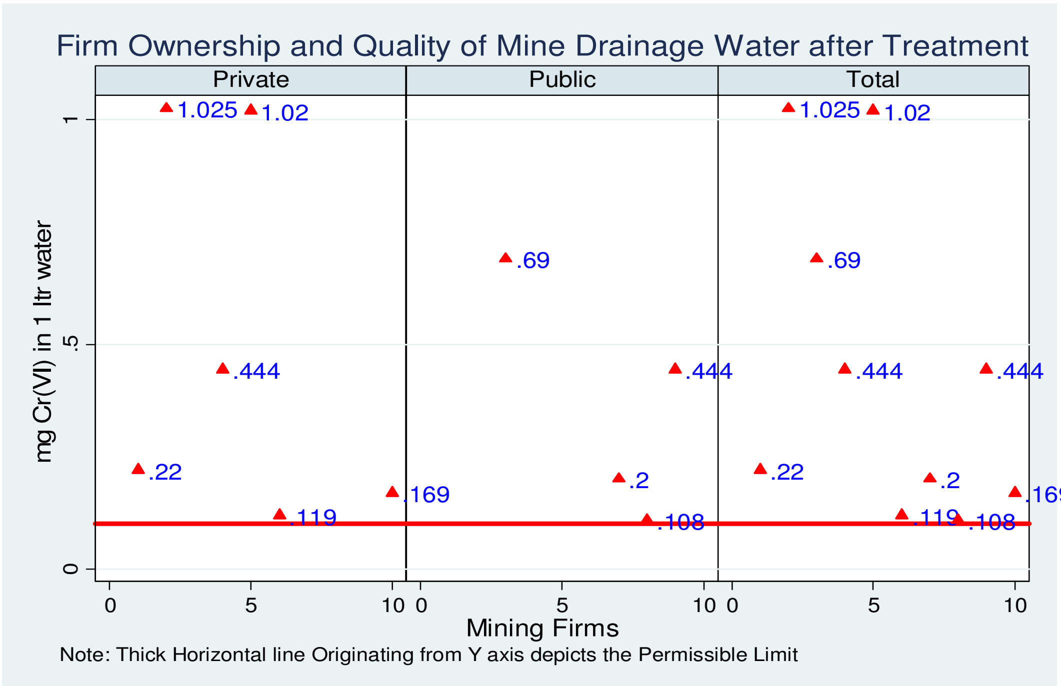


Figure-2

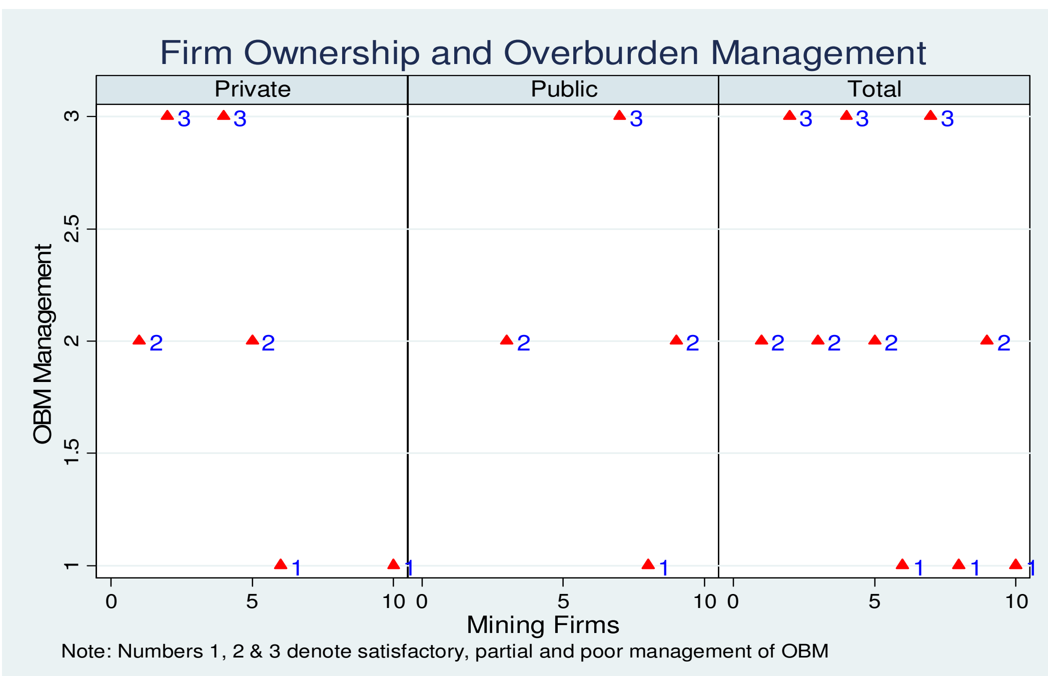


Figure-3

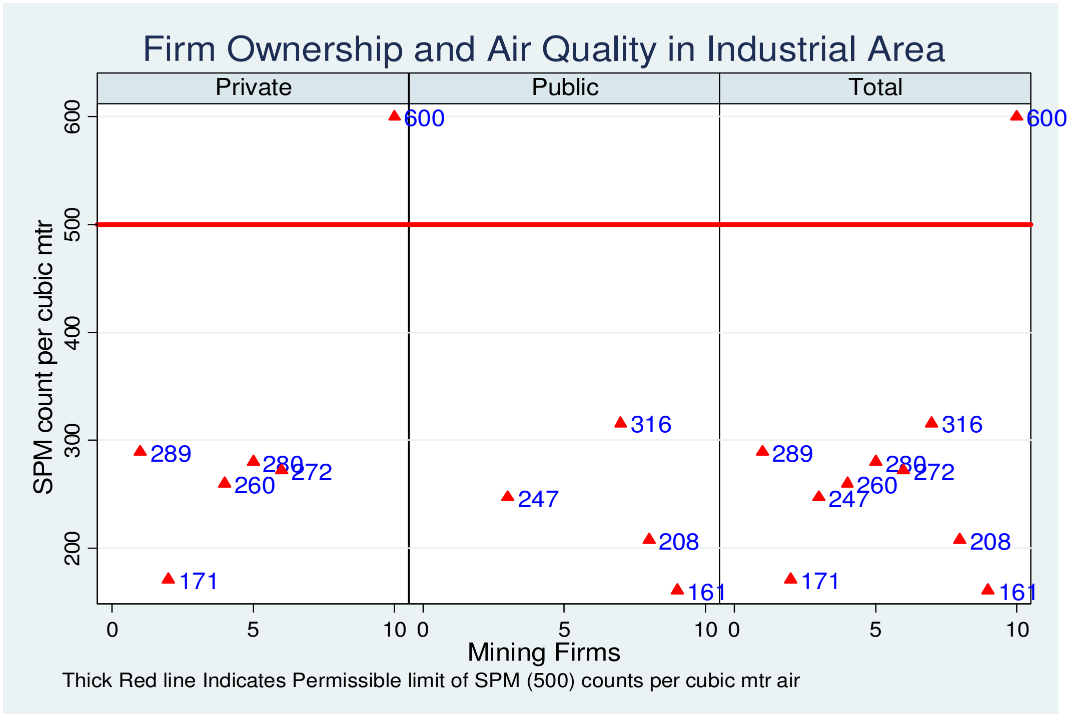


Figure-4

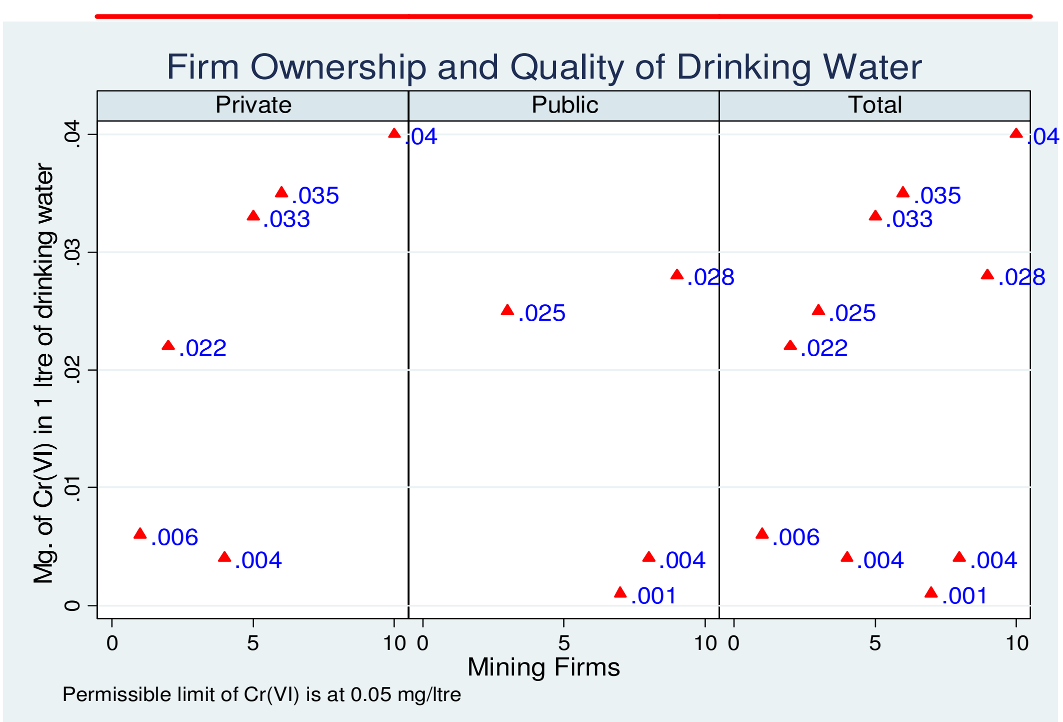
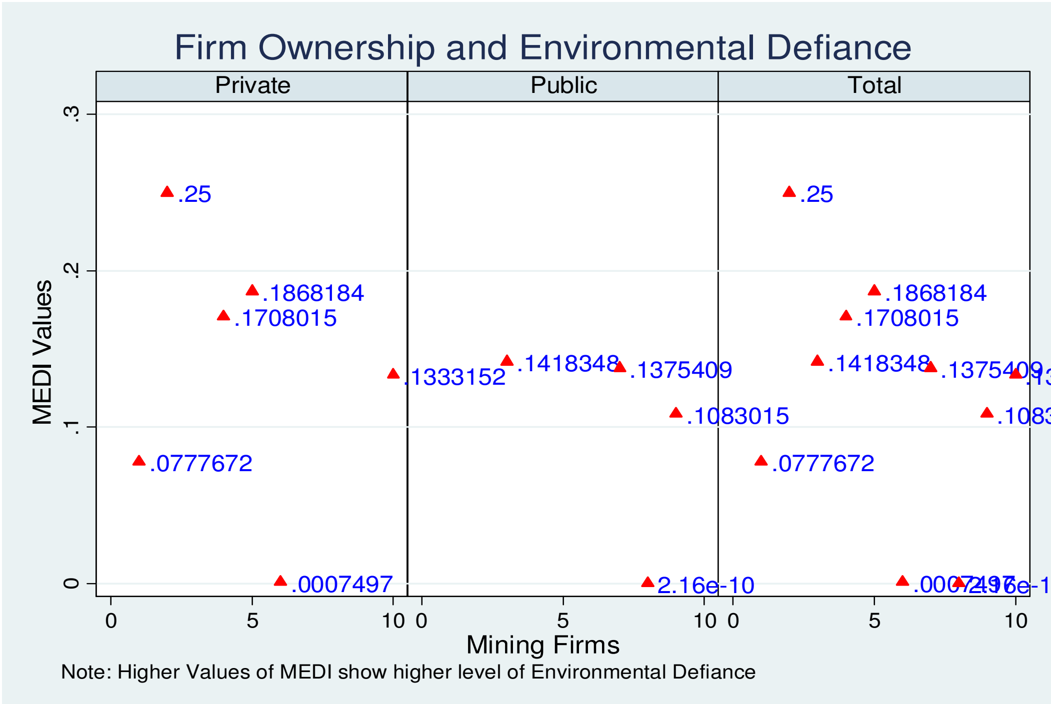


Figure-5


Firm Ownership and Environmental Defiance
Private
Public
Total
MEDI Values
0
.1
.2
.3
.25
.1868184
.1708015
.1333152
.0777672
.0007497
.1418348
.1375409
.1083015
2.16e-10
.25
.1868184
.1708015
.1418348
.1375409
.1333152
.1083015
.0777672
.0007497
2.16e-10
0
5
10
Mining Firms
Note: Higher Values of MEDI show higher level of Environmental Defiance

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