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The Compliance Ceiling: Observable Inputs, Unobservable Knowledge and the Economics of Occupational Safety Regulation in India's Fertilizer Material-Handling Sector

[1]Subrota Ghosh, [2]Dr. Preeti Kulshrestha

[1]Research Scholar, United world Institute of Management, Karnavati University, Gandhinagar, India

[2]Professor, United world Institute of Management, Karnavati University, Gandhinagar, India

Abstract:

Conventionally, the stock of protective inputs a firm can document is used to evaluate occupational safety regulation. This paper proposes that this evaluation is incomplete economically, since statutory compliance arises from two inputs whose verification costs differ significantly: capital-embodied provisions can be observed by the regulator at low verification cost, whereas knowledge transferred to the worker can be observed only at high verification cost. If the first input is the basis of enforcement, firms make rational decisions about how much to spend on compliance with the first input, and the second input becomes a hard constraint on the realized safety. Evidence from a survey of 262 workers and safety officers involved in material-handling construction at four fertilizer plants in southern and western India is examined to support the proposition. Sixteen seven-point items pertaining to hazard control, statutory welfare and regulatory compliance were analysed using rank-based inference, one-sample tests against the 50% point on the scale, Kruskal-Wallis comparisons between plants and multiple regression procedures on worker attributes. The endorsement of capital-embodied provisions was nearly maximized: seven out of sixteen items had no variance; the hazard-control and welfare composites had 97.5% and 96.8% of scale maximum. It achieved only a 77.5% regulatory-compliance composite, with its two lowest items being those related to what the worker knows, not what the firm has installed: communication of statutory regulations (M = 4.27) and awareness of statutory equipment inspection (M = 4.73). The knowledge margin varied systematically and significantly between plant levels, but not among workers (R-squared = .115). The results highlight an information-transfer gap as the economically relevant gap in compliance and suggest that the marginal cost of enforcement is higher when directed at checking workers' knowledge than when directed at re-auditing physical compliance at the ceiling level.

Keywords: Occupational Safety Economics; Regulatory Compliance; Multitask Agency; Human Capital; Fertilizer Industry; India

1. Introduction

The fertilizer industry has a structurally protected status in India’s economic policy because it is at the top end of the food security chain. Its material-handling infrastructure – silos, conveyor galleries, bagging stations and rail-loading platforms, is continuously built and rebuilt alongside live plant operations, and this construction activity concentrates a disproportionate share of the sector's occupational risk. This economic risk is shared among firms through injury compensation, lost time, and insurance loading, and among workers and households due to reduced capacity to earn income. There is a regulation to address the external effect, so the regulation's effectiveness is an economic rather than a purely technical matter.

Empirical studies of the economics of safety regulation have found that regulation can lower injury rates without generating any observable loss of output or employment (Levine et al., 2012). That literature has not been quick to identify the specific element of the compliance bundle responsible for the reduction. There is no one to blame for a lack of compliance. It is created from two or more separable inputs. The first of these is capital-embodied and tangible: provision of protective equipment, first-aid facilities, sanitation facilities, audit files, and incident registers. The second is knowledge-embodied – does the worker who operates a conveyor drive know what the statutory regime is for its inspection, and has the regime been communicated to him in a way that enables him to

act upon it? There is a significant difference in the cost of verifying the two inputs. The first can be confirmed by a visiting inspector in the afternoon. The second cannot.

This imbalance inevitably has a predictable consequence. A high payoff for an easily measured dimension of effort leads the agent to shift effort resources away from the other, unmeasured dimension (Holmstrom & Milgrom, 1991; Kerr, 1975). In the context of a safety regulatory regime based on inspection, the prediction is that the volume of observed provisions will be saturated while missing provisions will remain undersupplied, and that the volume of observed provisions will overestimate realized safety by precisely the amount of missing provisions.

This paper examines that hypothesis from original data on four fertilizer plants from the southern and western regions of India. There are three questions that are answered. First, do there exist systematic differences in endorsement for capital-embodied safety provisions in relation to endorsement for knowledge-embodied provisions in the same workforce in the same instrument? Second, is the identified gap at the worker level, or at the establishment level? Thirdly, what implications does the location of that gap have for the allocation of enforcement and firm expenditure? The contribution is to create an industrial site with a clearly high level of compliance with a specific, identifiable, and cheap-to-correct input deficit.

2. Theoretical Framework and Related Literature

2.1 Compliance as A Multitask Production Problem

The multi-task principal-agent model suggests that if the principal can observe some activities more closely than others and the agent can undertake several activities, the optimal contract will cause the agent to invest more in the activity the principal can observe more closely (Holmstrom & Milgrom, 1991). The organizational version of this had been described earlier by Kerr (1975). The role of the principal (in safety regulation) is to oversee transposition; the role of the agent (in safety regulation) is the plant; and the measurable task in safety regulation is maintaining documentary and physical evidence of compliance. No other explicit artefact of investment in understanding the worker can be seen, and no other investment yields a similar 'return on the investment'. There is no similar 'return on the investment' in the sense of an evidentiary artefact in the investment of understanding of the worker. The forecast is neither about “bad behaviour” by firms, but about “optimal behaviour” in the face of the enforcement technology available to them.

This is related to the literature on signalling (Spence, 1973), in which agents invest in observable attributes primarily because they are observable, and to the market-for-lemons problem (Akerlof, 1970), in which unobservable quality is underprovided. A safety file is a way of signalling. The quality the signal is supposed to represent is worker competence. There is no certainty that the two will travel side by side.

2.2 Safety Knowledge as Human Capital

Understanding the regulatory environment is a form of human capital specific to a company, helping to explain the persistence of the deficit (Becker, 1993). The private returns to the firm remain uncertain even when there is a high social return from knowledge of a statutory inspection regime, because knowledge is not transferable across employers and declines with turnover. The appropriability problem is particularly acute in construction projects with a large number of contractors that have fluctuating workforces between their respective employers. This is supported by the findings that mandatory safety training in the construction industry has been shown to only contribute very slightly to the increase in risk knowledge (as stated) and could have minimal impact on affective commitment to safety (Loosemore & Malouf, 2019), suggesting that training volume is not the same as training transfer.

2.3 Human Resource Practices and Organizational Outcomes

The strategic human resource management literature provides the mechanism for delivering the knowledge input. The findings of the meta-analytical evidence suggest that the effects of HRM systems on organizational outcomes are primarily mediated by employee capability and motivation, not simply through the structural provision of HRM systems (Jiang et al., 2012), and high-performance work systems have been found to enhance occupational safety, with effects being mediated by trust in management and perceived safety climate (Zacharatos et al., 2005).

A recent study of institutional settings in India (Sehgal & Kumar, 2025a), using data from higher education institutions in the NCR, found that training and development were the most important single factor driving motivation, satisfaction and retention, and a complementary study of institutional performance (Sehgal & Kumar, 2025b) found the top two predictive factors, performance management and leadership development, to explain 54% of the variance in outcomes. While these studies focus on academia, the finding of structure also transfers to workplace settings, where the developmental and communicative elements of an HRM bundle are more explanatory than the provisioning elements. Does an industrial safety system, which is based mostly on provisioning, display the deficiency that this literature argues?

2.4 Measurement of Compliance and the Self-Report Problem

The importance of the concept of safety climate has been well established in safety research, as the reporting of safety and accident rates are not necessarily congruent, and the reporting of accidents is endogenous: The more severe the consequences of reporting, the lower the rate of reporting (Zohar, 1980; Cooper & Phillips, 2004; Christian et al., 2009; Neal & Griffin, 2006; Probst et al., 2008; Probst & Estrada, 2010). The general result is the same for sensitive-topic survey research (Tourangeau & Yan, 2007). Any compliance action based on a respondent endorsement of the employer's provisions is thus likely to be upwardly biased. In this paper, this bias is not considered a nuisance but rather informative, as it leaves a pattern of unevenness in the location of the underlying constraint.

3. Data and Method

Primary data were gathered from 262 workers and safety officers working in material handling construction projects in four fertilizer plants from the southern and western parts of India (Table 1). The on-site survey was conducted with all respondents' written authorization from plant authorities, and with anonymity and voluntary answers. It consisted of 16 items grouped into three sections: hazard identification and personal protective equipment controls (seven items), working conditions and statutory welfare (five items), and compliance with the guidelines of the Directorate of Industrial Safety and Health (four items). The internal consistency for each domain was acceptable (alpha = .842, .798, .811, and .876 overall), and criterion standards for internal consistency (Nunnally & Bernstein, 1994) were met.

In each of the three blocks (19.84, 27.04, and 27.04, respectively, with both $p < .001$), the composite scores deviated significantly from normality; therefore, rank-based procedures were primarily used to infer the results; parametric results are also reported for comparison purposes (Norman, 2010). One-sample tests were used to compare each item and the composite with the scale centre. Gender and plant location were compared using Mann-Whitney tests and Kruskal-Wallis tests with epsilon-squared effect sizes; Levene's test was used to test variance homogeneity, and Welch corrections were applied to the tests where Levene's test showed variance heterogeneity. For each composite, all composites were regressed on age, experience, and gender to quantify the variation in the observed composites explained by worker attributes. Effect sizes are based on Cohen (1988). All data are single-source and self-reported, and the analytical approach below aims to mitigate common-method and social-desirability risks.

Table 1. Sample Composition by Plant Location and Gender

Plant location	n	% of sample	Male (n)	Female (n)
Jamnagar, Gujarat	118	45.0	88	30
Vadodara, Gujarat	83	31.7	62	21
Mangalore, Karnataka	40	15.3	30	10
Raigarh, Maharashtra	21	8.0	15	6

Plant location	n	% of sample	Male (n)	Female (n)
Total	262	100.0	195	67

Source: Authors' own

4. Results

4.1 The Variance Structure of Endorsement

Descriptive statistics on the item level for all 16 items are presented in Table 2. The most important characteristic of the data is that there is no variation across the seven items; all respondents indicated the same response. All of them by themselves are measures of provision - protective equipment provided and used, health and safety training carried out, drinking water available, sanitation made available, medical and welfare cover extended and statutory audits carried out. There were nine items that varied, and some were the most spread out when they asked what the worker knows rather than what the firm provides.

Table 2. Item-Level Descriptive Statistics and Variance Status

Item	M	SD	Range	Variance
A1 Mechanical aids inspected	6.24	0.43	6-7	Varies
A2 Unsafe practices prevalent	6.97	0.17	6-7	Varies
A3 Safety signage displayed	6.70	0.46	6-7	Varies
A4 Emergency procedures defined	6.95	0.21	6-7	Varies
A5 Emergency procedures followed	6.94	0.25	6-7	Varies
A6 PPE consistently used	7.00	0.00	7-7	Constant
A7 PPE used properly	7.00	0.00	7-7	Constant
B1 Health and safety training regular	7.00	0.00	7-7	Constant
B2 First-aid available	6.87	0.33	6-7	Varies
B3 Drinking water adequate	7.00	0.00	7-7	Constant
B4 Sanitation adequate	6.00	0.00	6-6	Constant
B5 Medical and welfare cover	7.00	0.00	7-7	Constant
C1 Statutory regulations communicated	4.27	0.54	4-6	Varies
C2 Regular statutory audits	6.00	0.00	6-6	Constant
C3 Equipment inspected under statute	4.73	0.80	4-6	Varies
C4 Incident reports maintained	6.68	0.47	6-7	Varies

Source: Authors' own

Table 3 aggregates the three domains. Endorsement of hazard controls stands at 97.5% of the scale maximum and endorsement of statutory welfare at 96.8%, both effectively at the ceiling. Regulatory compliance stands at 77.5% - twenty percentage points lower than within the same respondents, the same sitting and the same response format. Because the gap is internal to each respondent, it cannot be attributed to sampling, to acquiescence common to the instrument, or to differences in respondent disposition. It reflects a genuine difference between the two classes of items.

Table 3. Cross-Domain Comparison of Composite Endorsement

Domain	Items	Composite M (SD)	% of max	Location (KW) p	Regression R-sq.
A: Hazards and PPE controls	7 (2 constant)	47.79 (0.73)	97.5	= .001	.020 (ns)
B: Conditions and welfare	5 (4 constant)	33.87 (0.33)	96.8	< .001	.077
C: Regulatory compliance	4 (1 constant)	21.69 (1.23)	77.5	< .001	.115

Source: Authors' own

4.2 Locating the Deficit Within the Compliance Domain

The three domains are combined in Table 3. Hazard controls have a 97.5% endorsement rating, the maximum on the scale; statutory welfare is 96.8%, also at the maximum. Regulatory compliance is currently at 77.5%, 20% lower than the last sitting with the same respondents and the same response format. The gap is internal to each respondent and not due to sampling, differences in respondents' dispositions, or common acquiescence on the instrument. It attests to a real distinction between the two categories of items.

In the regulatory compliance area, the item is clearly distinguished by the cost of verification. The two items with the highest scores concern artefacts that a visiting inspector would examine, statutory audits conducted (M = 6.00, invariant) and incident reports kept (M = 6.68). The two lowest scores were for communication of statutory regulations (M = 4.27, SD = 0.54) and awareness that equipment is inspected under statutory requirements (M = 4.73, SD = 0.80). However, every item's median exceeded the scale midpoint at conventional significance (all $p < .001$), and the composite was at a very large level ($t(261) = 74.9$, $p < .001$, $d = 4.6$), indicating that compliance is not absent. It is precisely in line with the multitasking argument that compliance is not equally distributed across inputs.

There is only a modest association within the domain between statutory equipment inspection and incident reporting (rho = .37, $p < .001$), and between the two documentary-related items. Regulatory knowledge is unrelated, as it is provided idiosyncratically and not integrated into it.

4.3 Establishment Effects Versus Worker Effects

Deficit, if a worker-level phenomenon (lit, tenure or age) should be predictable from worker attributes. It is not. The compliance composite is not informed by age and experience, which are highly collinear and exclude the reliable predictor, gender (VIF > 86; $F(3, 256) = 11.14$, $p < .001$). This finding should be independently confirmed using the underlying personnel records. The variation in regulatory knowledge is thus explained by workers' attributes, accounting for about 11 per cent, with the majority of this variation being compositional (that is, not human-capital) in nature.

The establishment effects are much more pronounced. The scores for compliance vary significantly between the four plants (Kruskal-Wallis $H(3) = 26.67$, $p < .001$, epsilon-squared = .10; Welch $F(3, 74.4) = 12.25$, $p < .001$), with the highest score at Raigarh (M = 22.24) and the lowest score at Jamnagar (M = 21.24). The three domains

are all affected by location effects; these effects occur only for variables with meaningful dispersion in the compliance domain. The establishment is then the unit of variation that is relevant to economic considerations, not the worker.

Table 4. Regulatory-Compliance Composite by Plant Location

Plant location	n	M (of 28)	SD	% of max
Jamnagar	118	21.24	1.03	75.9
Vadodara	83	22.01	1.33	78.6
Mangalore	40	22.07	1.31	78.8
Raigarh	21	22.24	0.87	79.4

Source: Authors' own

5. Discussion

There are three results that have an economic dimension. The first is the structure of the variance itself. Seven of the 16 items have received unanimous responses; all 7 concern the provisions the firm can refer to. Even if there is no signal, a low-verification-cost input will be considered "saturation" in the survey data. It is not reasonable to assume that each worker at each plant, on each shift, is using protective equipment properly; it is quite reasonable to assume that each worker knows the correct answer to the question of whether he is. The endorsement is based on observability of the input, not efficacy.

The second is the 20-point gap between the provision and knowledge in the same instrument. The difference in scores between the two classes is not due to the format or setting, since both classes have the same respondents, but rather because they represent different underlying constructs. What workers say is that the equipment is there and the audits are conducted, but there is no explanation of what the rules are or how they work. That is a description of an information-transfer failure, and it is certainly the least costly failure in the entire compliance bundle to fix: sharing an inspection schedule costs a fraction of installing the equipment being inspected.

The third is the structure of the deficit at the establishment level. The productive margin for intervention is managerial rather than individual because worker characteristics account for very little, whereas plant identity accounts for much more. This is consistent with the HRM evidence that developmental and communicative practices, as an organizational system, explain better the performance outcomes than provisioning (Jiang et al., 2012; Sehgal & Kumar, 2025a, 2025b; Zacharatos et al., 2005), and with the safety-specific research that links management practice and leadership to the occurrence of injuries, rather than the characteristics of the workers (Barling et al., 2002; Vredenburgh, 2002; Hofmann et al., 2017).

Together, the findings indicate a restatement of the sector's apparent good compliance position. The companies in this sample don't avoid regulation; they are following the verified part. The remaining risk is focused on the non-residual. When the amount of expenditure devoted to re-auditing physical provisions falls at the ceiling, the marginal product of that expenditure is very low. If you reallocated some of those dollars to either short unannounced knowledge assessments at the workface or document review in the plant office, you'll have enforcement at the edge of the envelope where the variation is, and so will the risk. This analysis is consistent with the finding by Levine et al. (2012) that inspection works – how much it works depends on what it inspects.

6. Policy Implications, Limitations and Conclusion

Four implications follow. The inspectorate should have a component of worker knowledge in its compliance verification as a reward for producing a document. The evidence presented here suggests that the most important constraint for plant management is cheap: it is the lack of communication of the statutory regime, which can be overcome through briefing plants in vernacular terms, specifically related to the type of equipment and specifically

linked to the inspection cycle, and which is likely to have limited attitudinal impact when provided through additional generic training volume (Loosemore & Malouf, 2019). In the case of principal employers who rely on contract workers, the issue of "appropriability of knowledge" in safety human capital suggests that regulatory knowledge be transferred through portable, transferable certificates of attainment rather than through employer induction. The establishment-level structure of the deficit means that, for sectoral policy, the reporting unit should be at the plant level, not the industry level.

Several restrictions were imposed on these results. The data are obtained from a single point in time and from a single source and are self-reported, meaning that common-method variance cannot be ruled out (Podsakoff et al., 2003), and the ceiling effect in the provisioning items is also partially due to this design. The four plants are not a random selection of plants from the Indian fertilizer industry. There was no observation of injuries/sustained harm, so the relationship between the identified knowledge deficit and the realized harm is inferential rather than estimated. Demographic results should not be trusted, given the high degree of age-experience collinearity in the personnel data, which must be addressed in the source records. Future research could include worker knowledge scores, along with establishment-level injury and near-miss data, and could leverage heterogeneity in inspection levels across establishments to directly measure the effect of enforcement.

The authors' conclusion is quite narrow, and we believe it is very strong. The remaining compliance shortfall is an information shortfall; it does not reside in the worker but in the establishment; it does not cost much to remedy compared with other inputs in the compliance package. Only measurable safety regulation would continue to demonstrate success on a part of the input that is already at the ceiling.

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